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Promouvoir l'activité physique chez les personnes atteintes de maladies chroniques : le rôle des mécanismes affectifs

Promoting physical activity in people with chronic diseases: the role of affective mechanisms

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« *Toutes les grandes personnes ont d'abord été des enfants.*

(Mais peu d'entre-elles s'en souviennent.) »

Antoine de Saint-Exupéry, Le Petit Prince, 1943

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Introduction

« As miracle cures are hard to come by, any claims that a treatment is 100% safe and effective must always be viewed with intense scepticism. There is perhaps one exception. » Godlee (2019, p.1)

Au cours de ces dernières décennies, l'espérance de vie humaine a considérablement augmenté, notamment dans les pays à revenus élevés (Kirkwood, 2017). Toutefois, l'espérance de vie en bonne santé n'a pas suivi le même rythme (Salomon et al., 2012). Les progrès en matière de vaccination, de nutrition, d'assainissement et d'autres réussites dans le domaine de la santé publique, conjugués à l'évolution des modes de vie, et en particulier la mécanisation du travail et des transports et la digitalisation des loisirs, ont contribué à une transition épidémiologique des maladies infectieuses aux maladies non transmissibles, ou maladies chroniques (Adogu et al., 2015 ; Hacker, 2024). Ces dernières constituent la première cause de mortalité dans le monde, responsables de 75 % des décès, soit 41 millions de morts en 2019 (World Health Organization, 2023b). Parmi celles-ci, les maladies cardiovasculaires, les cancers, les maladies respiratoires chroniques et les différents types de diabète représentent plus de 80 % des décès (World Health Organization, 2023a). Le coût des maladies chroniques pour la société est considérable. Entre 2011 et 2030, le coût cumulé de celles-ci à l'échelle mondiale est estimé à 47 000 milliards de dollars (Bloom et al., 2012 ; Hacker, 2024), représentant environ 75 % du PIB mondial en 2010 (Bloom et al., 2012). Les principales causes des maladies chroniques sont étroitement liées à des comportements de santé modifiables, notamment le tabagisme, une alimentation riche en sodium et en acide gras trans, la consommation excessive d'alcool et l'inactivité physique (World Health Organization, 2023a, 2024b). Face à ce constat, l'Organisation Mondiale de la Santé (OMS) a élaboré des recommandations visant à améliorer la prévention et le contrôle des maladies chroniques.

L'OMS recommande aux adultes, aux personnes âgées et aux personnes atteintes de maladies chroniques de pratiquer des activités physiques[1] aérobies d'intensité modérée pendant 150 à 300 minutes par semaine, ou d'intensité vigoureuse pendant 75 à 150 minutes par semaine, ou une combinaison des deux (Bull et al., 2020 ; World Health Organization, 2024a). Elle préconise également de consacrer au moins deux jours par semaine au renforcement musculaire, ainsi que de limiter le temps passé en position sédentaire (Bull et al., 2020). L'objectif de l'OMS est de réduire l'inactivité physique mondiale de 10 à 15 % d'ici 2030 (World Health Organization, 2018, 2024a), permettant ainsi une baisse de 25 % du taux de mortalité prématurée liée aux maladies chroniques (World Health Organization, 2023a, 2024a).

Dans les centres de réadaptation ou les associations spécialisées, les programmes d'activité physique adaptée (APA) constituent une composante essentielle de la prise en charge des individus souffrant de maladies chroniques (Bierbauer et al., 2020 ; Richardson et al., 2019). Pour ces personnes, la pratique régulière d'une activité physique joue un rôle clé dans la prévention secondaire et tertiaire de leur maladie (Bierbauer et al., 2020 ; Bracewell et al., 2022 ; Kanaley et al., 2022 ; Spence et al., 2020). Par exemple, les patient·es atteint·es de cancer ou de maladies cardiovasculaires qui s'engagent dans les niveaux d'activité physique recommandés peuvent connaître une atténuation des effets secondaires des traitements, une amélioration de leur qualité de vie et de leur santé physique ainsi qu'une diminution des risques de mortalité (Bracewell et al., 2022 ; Spence et al., 2020). De plus, comme le démontre notre récente étude portant sur une cohorte de 121 875 adultes issus de 29 pays, les bénéfices d'une activité physique régulière sur la santé physique et mentale sont particulièrement prononcés chez les personnes souffrant de deux maladies chroniques ou plus (Fessler et al., 2023).

[1] Dans ce manuscrit, nous parlerons d'activité physique comme « un terme générique qui comprend à la fois des activités structurées et non structurées de loisirs, de déplacement, d'activités domestiques et professionnelles [et est] souvent caractérisée en termes d'intensité légère, modérée et vigoureuse », et d'exercice comme « un sous-ensemble d'activités physiques structurées qui sont plus spécifiquement conçues pour améliorer la condition cardiorespiratoire, la fonction cognitive, la souplesse, l'équilibre, la force et/ou la puissance » (Bangsbo et al., 2019).

Compte tenu de tous les bienfaits attachés à l'activité physique, certain·es auteur·es n'ont pas hésité à qualifier l'activité physique de « remède miracle » (Godlee, 2019 ; Haseler et al., 2019 ; McNally, 2015).

Bien que la majorité des individus semblent convaincus des bénéfices de l'activité physique pour leur santé (Canadian Fitness and Lifestyle Research Institute, 2018 ; Fredriksson et al., 2018), 40 % des personnes présentant des facteurs de risque pour leur santé (e.g., hypertension, obésité, diabète) ne parviennent pas à transformer leurs intentions d'être physiquement actives en actions concrètes (Feil, Fritsch, & Rhodes, 2023). De plus, Tang et al. (2013) ont montré qu'au sein d'un panel de 10 158 Américain·es atteint·es de maladies coronariennes, seul·es 17 % atteignaient les recommandations en matière d'activité physique. Plus récemment, les niveaux d'activité physique de 7 998 patient·es coronarien·nes de 24 pays européens ont été collectés par la Société européenne de cardiologie (Kotseva et al., 2016). Seul·es 38 % des patient·es parviendraient à atteindre les recommandations, et ce, malgré les conseils des professionnel·les de santé (e.g., médecins, masseurs·euses-kinésithérapeutes) ou de l'activité physique (e.g., enseignant·es en APA).

Cette observation soulève une question importante : pourquoi ces personnes éprouvent-elles autant de difficultés à s'engager dans des activités physiques malgré leur connaissance des bienfaits de celles-ci pour leur santé ? Les recherches antérieures visant à comprendre ce phénomène ont principalement exploré les <u>variables socio-cognitives</u> qui régulent le comportement d'activité physique telles que les <u>attentes de résultat</u>, les <u>intentions</u> ou le <u>sentiment d'efficacité personnelle</u>. Ces études ont notamment tenté de modifier ces cognitions en mettant l'accent sur les avantages pour la santé des comportements d'activité physique (Rhodes, McEwan, et al., 2019). Cependant, il apparaît que ces approches n'ont produit que des effets limités sur le changement de comportement à long terme (Gourlan et al., 2016 ; Rhodes, McEwan, et al., 2019). Elles ont été plus efficaces pour améliorer les intentions d'être actif·ve physiquement, que pour modifier le comportement en tant que tel (Rhodes et al., 2022 ; Rhodes & Dickau, 2013). Dans un récent article d'opinion, nous avons démontré que la valeur motivationnelle des bienfaits pour la santé de l'activité physique n'est pas suffisante pour favoriser l'engagement et le maintien dans des comportements d'activité physique, en raison du caractère différé ou retardé des bénéfices (i.e., *delay-discounting*), de l'effort substantiel requis pour les atteindre (i.e., *effort-discounting*), ainsi que de la présence de biais cognitifs qui amènent l'individu à ne pas considérer l'activité physique comme quelque chose d'urgent à mettre en œuvre (i.e., *belief distorsion*) (Maltagliati et al., 2022). Il semblerait que lorsque les bénéfices pour la santé constituent les seules raisons de pratiquer une activité physique, l'engagement dans celle-ci soit assez fragile. Pour faire avancer la recherche dans ce domaine, il est impératif d'identifier de nouvelles cibles pour les interventions visant à modifier plus durablement le comportement d'activité physique.

Un facteur qui a été assez négligé dans les recherches concerne les affects que véhicule l'activité physique. En effet, une activité physique peut être agréable pour certaines personnes, mais peut constituer une expérience extrêmement désagréable pour d'autres, en particulier chez celles qui ont une mauvaise condition physique, des problèmes respiratoires ou un surpoids marqué (Ekkekakis et al., 2020 ; Ekkekakis et al., 2010 ; Ekkekakis et al., 2016). En accord avec le courant émergent dit de « l'affectivisme » (Dukes et al., 2021), nous avons émis l'hypothèse générale selon laquelle les variables affectives (e.g., réponses affectives, affect remémoré, tendances d'approche-évitement) pourraient constituer une voie prometteuse pour compléter et enrichir les modèles socio-cognitifs dominants dans la compréhension des processus qui régulent l'engagement et le maintien des comportements d'activité physique. Notamment, nous avons récemment proposé qu'une évaluation affective positive de l'activité physique (e.g., « Je trouve que l'activité physique est un comportement plaisant et agréable ») pourrait diminuer notre tendance naturelle à minimiser les efforts physiques, et ainsi jouer un rôle clé pour combler l'écart entre nos intentions et nos actions (Cheval et al., 2024 ; Maltagliati, Fessler, et al., 2024). Ces mécanismes affectifs pourraient être particulièrement pertinents chez les personnes atteintes de maladies chroniques, en raison de la douleur, de l'inconfort ou de la peur de s'engager qui accompagnent leurs expériences en matière d'activité physique (Aydemir et al., 2022 ; Cheval et al., 2021 ; Goubran et al., 2024 ; Hoffmann et al., 2018). Par exemple, une récente méta-analyse a mis en évidence que les personnes atteintes de maladies chroniques, notamment celles souffrant de maladies cardiovasculaires, sont particulièrement touchées par la kinésiophobie. Cette peur excessive et irrationnelle du mouvement pourrait résulter du développement d'évaluations affectives négatives envers l'activité physique (Gourban et al., 2024). Les résultats de cette méta-analyse ont montré que des niveaux élevés de kinésiophobie étaient modérément associés à des niveaux inférieurs d'activité physique autodéclarée. En outre, le développement d'états affectifs négatifs envers l'activité physique peut dépendre non seulement de cette peur du mouvement, mais aussi des conditions physiologiques objectives associées à la maladie, telles que la douleur associée à la claudication intermittente (i.e., douleur du membre inférieur pendant la marche ; Abaraogu et al., 2018). Par conséquent, il est essentiel de comprendre le rôle des mécanismes affectifs dans la promotion de l'activité physique chez les personnes atteintes de maladies chroniques.

Bien que quelques études aient examiné la relation entre des mécanismes affectifs et l'activité physique (e.g., Liao et al., 2017 ; Rhodes, Gray, et al., 2019 ; Rhodes & Kates, 2015 ; Stevens et al., 2020 ; Teixeira et al., 2024 ; Williams et al., 2016), l'examen de cette relation chez des personnes atteintes de maladies chroniques reste marginal. De plus, l'efficacité des interventions ciblant des variables affectives pour augmenter l'activité physique chez cette population n'a pas été clairement établie.

Par conséquent, ce travail doctoral vise à répondre à trois questions principales :

1. La prise en compte des mécanismes affectifs, en plus des variables socio-cognitives, améliore-t-elle la prédiction de l'activité physique chez les personnes atteintes de maladies chroniques ? Si oui, quelles sont les variables qui prédisent le plus l'activité physique ?

2. Quelles sont les stratégies d'intervention qui permettent de manipuler des variables affectives ?

3. Est-il possible d'améliorer l'activité physique des personnes atteintes de maladies chroniques en ciblant des variables affectives ?

Pour structurer la réponse à ces questions, ce travail doctoral s'appuiera sur l'approche de la médecine expérimentale appliquée au changement de comportement de santé développée par

Sheeran et al. (2017). Cette approche comporte quatre étapes : (1) l'identification des variables « putatives » (i.e., des variables affectives potentiellement modifiables et reliées à l'activité physique ; étape A, Figure 1), (2) l'évaluation de la relation entre ces variables et le comportement ciblé (i.e., examiner l'influence de variables affectifs sur le changement de comportement d'activité physique, en termes d'intensité, de temporalité et de mécanismes ; étape B, Figure 1), (3) l'évaluation de l'effet des interventions sur les variables putatives (i.e., identifier des stratégies efficaces pour modifier les variables affectives présumées ; étape C, Figure 1) et (4) La mise en œuvre d'une étude interventionnelle (i.e., tester l'efficacité de stratégies d'intervention sur le comportement d'activité physique via la modification du médiateur présumé, à savoir, la variable affective identifiée ; étape D, Figure 1).

Selon Sheeran et al. (2017), l'approche de la médecine expérimentale se différencie des essais d'efficacité traditionnels *(standard efficacy trials)* qui se concentrent principalement sur le « si » les interventions favorisent le changement de comportement en matière de santé, sans explorer le « comment » (étape X, Figure 1). Ces essais traditionnels omettent souvent de mesurer les variables putatives ou, lorsqu'elles sont incluses, ne procèdent pas à des tests de médiation formels pour valider leur rôle dans le changement de comportement.

En résumé, l'approche de la médecine expérimentale applique les principes fondamentaux des sciences du comportement pour découvrir et influencer les mécanismes qui sous-tendent le changement de comportement et qui peuvent servir de cibles pour de futures interventions (Dunton et al., 2023 ; Sheeran et al., 2017).

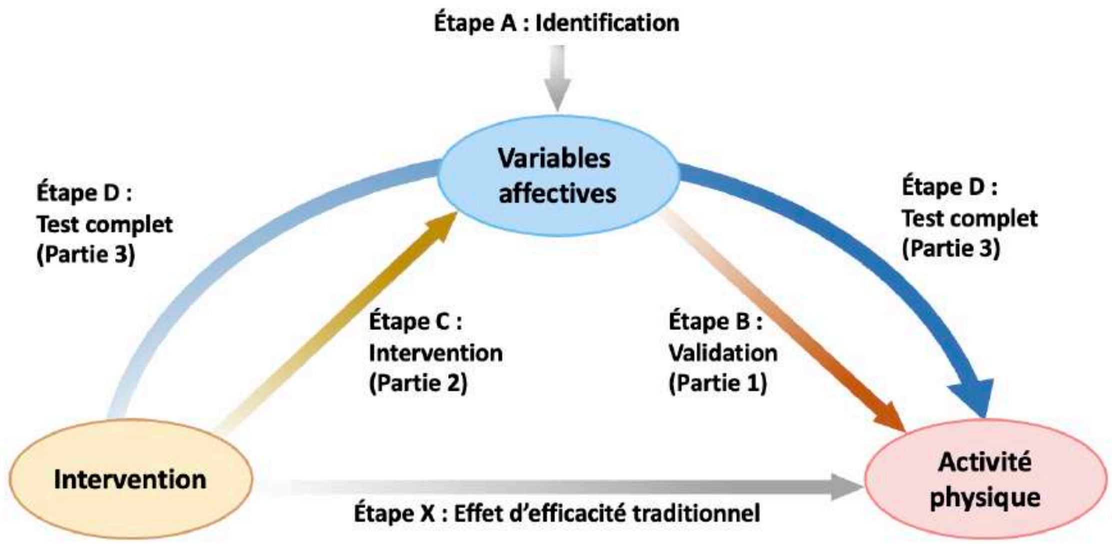
Sur la base de cette approche, ce travail doctoral sera structuré en trois parties, chacune visant à répondre à un objectif spécifique (Figure 1) :

1. La **première partie** se concentrera sur l'identification des liens entre des variables affectives reliées à l'activité physique et l'activité physique quotidienne des personnes atteintes de maladies chroniques (**Contributions n°1 et 2, étape B**).

2. La **seconde partie** visera à déterminer et tester des stratégies d'intervention permettant l'amélioration de ces variables affectives (**Contributions n°3 et 4, étape C**).
3. La **troisième partie** s'attachera à identifier, concevoir, mettre en œuvre et évaluer l'efficacité d'interventions ciblant certaines variables affectives liées à l'activité physique pour augmenter le niveau quotidien d'activité physique des personnes atteintes de maladies chroniques (**Contributions n°5, 6 et 7, étape D**).

Figure 1

Projet de recherche calqué sur l'approche de la médecine expérimentale appliquée au changement de comportement de santé proposée par Sheeran et al. (2017)



Chacune de ces parties sera composée de plusieurs chapitres.

La **première partie** sera constituée de cinq chapitres. Dans le **Chapitre 1**, nous soulignerons l'importance et la difficulté de définir les différents mécanismes affectifs, en abordant notamment la notion du « sophisme du *jingle-jangle* » *(jingle-jangle fallacy).* Nous y définirons les concepts d'émotion, d'humeur, d'affect et d'affect fondamental. Dans le **Chapitre 2**, nous examinerons l'apport des variables affectives dans la compréhension des comportements humains, en particulier les comportements d'activité physique. Après une brève présentation des théories socio-cognitives traditionnelles visant à identifier les déterminants de l'engagement dans une activité physique (e.g., Ajzen, 1991), nous verrons comment les théories affectives peuvent compléter et enrichir ces modèles (e.g., Brand & Ekkekakis, 2018 ; Cheval & Boisgontier, 2021). Le **Chapitre 3** présentera différents déterminants affectifs de l'activité physique, à partir du cadre conceptuel des Affects et des Comportements de Santé *(Affect and Health Behavior Framework)* adapté à l'activité physique (Stevens et al., 2020 ; Williams & Evans, 2014), nous montrerons que certaines variables affectives sont liées aux ressentis pendant et/ou immédiatement après une expérience d'activité physique particulière (e.g., réponse affective, affect remémoré), tandis que d'autres sont associées au traitement cognitif résultant de l'accumulation d'expériences affectives antérieures (e.g., attitudes affectives, tendances d'approche-évitement). Après avoir exposé la problématique générale de ce projet doctoral dans le **Chapitre 4**, nous présenterons deux contributions empiriques dans le **Chapitre 5**. La première étude explorera les associations entre des variables affectives liées au concept général d'activité physique (i.e., attitudes affectives, tendances d'approche-évitement) et l'activité physique quotidienne chez des patient·es sortant d'un programme de réadaptation cardiovasculaire (**Contribution empirique n°1**). La seconde analysera les associations entre des variables affectives rapportées durant une séance d'APA (i.e., réponse affective, affect remémoré, réponse affective anticipée) et l'activité physique quotidienne subséquente chez des personnes atteintes de maladies chroniques (**Contribution empirique n°2**).

La **seconde partie** sera constituée d'un unique chapitre, le **Chapitre 6**, qui visera à identifier et tester des stratégies pour modifier certaines variables affectives. Ce chapitre débutera par une revue narrative des stratégies endogènes et exogènes principales utilisées dans les interventions visant à maximiser les expériences affectives lors de la pratique d'une activité physique (**Contribution n°3**). Ensuite, le chapitre se poursuivra par la présentation d'un protocole dont l'objectif est de tester l'efficacité de la musique comme stratégie exogène pour améliorer l'expérience affective des patient·es en réadaptation cardiovasculaire stationnaire. Il s'agit plus précisément de tester l'impact de la musique jouée à des moments clés (e.g., au début ou à la fin) d'une séance d'APA d'intensité modérée sur vélo stationnaire, sur les affects fondamentaux *(core affect)*, l'affect remémoré et la réponse affective anticipée (**Contribution empirique n°4**). Le chapitre se terminera par une exploration des stratégies d'interventions digitales ciblant la réponse automatique (e.g., tendances d'approche-évitement), sans nécessiter d'expérience physique directe avec l'activité physique.

La **troisième partie**, constituée de deux chapitres, s'ouvrira avec le **Chapitre 7** qui proposera une revue systématique des études interventionnelles ciblant des variables affectives pour augmenter l'activité physique chez des personnes atteintes de maladies chroniques (**Contribution n°5**). Cette revue cherchera en particulier à déterminer si certaines variables affectives peuvent être manipulées et si cela entraine des modifications significatives dans les niveaux d'activité physique. Le **Chapitre 8** présentera deux études interventionnelles distinctes. La première sera un essai contrôlé randomisé en triple aveugle destiné à tester l'efficacité d'une intervention digitale visant à accroitre l'activité physique de patient·es en réadaptation cardiovasculaire. Cette intervention cible les tendances automatiques d'approche de l'activité physique, une variable située en aval du processus affectif. Cependant, en raison de difficultés de recrutement et d'adhésion, les analyses statistiques nécessaires à l'évaluation de son efficacité n'ont pu être réalisées. Par conséquent, la contribution associée à cette étude prendra la forme d'un article d'opinion, qui discutera des défis spécifiques liés à ce type d'intervention, ainsi que des solutions potentielles pour y remédier (**Contribution n°6**). La seconde, préliminaire, examinera si la manipulation de l'intensité de l'effort en fin de séances d'APA améliore l'affect remémoré, les attitudes affectives à l'égard de l'activité physique, et le temps d'activité physique quotidien chez des patient·es atteint·es de la maladie de Parkinson (**Contribution empirique n°7**).

Enfin, le **Chapitre 9** proposera une discussion générale et une conclusion, apportant des éléments de réponse aux objectifs de ce projet doctoral. Nous y aborderons également les implications théoriques et pratiques, les points forts et les limites de cette thèse, et proposerons des pistes pour des recherches futures.

PARTIE 1

Identification des liens entre les variables affectives et l'activité physique chez les personnes atteintes de maladies chroniques

Chapitre 1 Émotion, humeur et affect : de quoi parle-t-on ?

« *Everyone knows what an emotion is, until asked to give a definition.* » Fehr and Russell (1984, p. 464).

Comme nous allons le voir dans ce chapitre, définir et conceptualiser les mécanismes affectifs n'est pas une chose aisée. De plus, comme dans de nombreux autres domaines de la psychologie, il existe une profusion de termes pour qualifier ces mécanismes, et les chercheur·euses qui travaillent sur ce thème peuvent être amené·ess à utiliser des termes différents pour désigner des construits identiques, ou inversement, à utiliser des termes identiques pour désigner des construits différents. Ce constat peut exposer les lecteur·trices peu attentif·ves à un raisonnement erroné appelé sophisme du *jingle-jangle* *(i.e., jingle-jangle fallacy).* Le sophisme du *jingle* consiste à supposer à tort que deux concepts sont identiques parce qu'ils portent le même nom, alors que le sophisme du *jangle* se produit lorsque le même phénomène psychologique est désigné par des termes différents, ce qui peut amener à considérer à tort qu'ils sont distincts (Kelley, 1927 ; Thorndike, 1904). Dans son chapitre intitulé « *Dénouer le Nœud Gordien Terminologique* » *(Untangling the Terminological Gordian Knot)*, Panteleimon Ekkekakis (2013) souligne l'importance de définir précisément les différentes variables affectives, trop souvent utilisées de manière interchangeable. Dans ce chapitre, nous allons tenter de définir et de distinguer les variables affectives les plus courantes mobilisées dans les modèles psychologiques des comportements de santé, à savoir l'émotion, l'humeur, l'affect et l'affect fondamental (Ekkekakis, 2013).

1.1 Émotion et humeur, des états affectifs souvent confondus

A. L'émotion : un processus rapide en deux étapes

Bien que plus de 92 définitions aient été proposées (Kleinginna & Kleinginna, 1981), aucune taxonomie exhaustive de l'émotion n'a recueilli pleine satisfaction dans la communauté scientifique

(Sander, 2016). Cependant, un consensus minimal existe sur sa définition (Ekkekakis, 2013 ; Sander, 2016 ; Sander et al., 2018 ; Sander & Scherer, 2019). L'émotion serait à considérer selon au moins quatre critères clés. Tout d'abord, 1) l'émotion est un processus dynamique complexe résultant de la coordination de cinq composantes : une évaluation cognitive (e.g., interpréter une phrase comme un compliment) ; une réponse périphérique (e.g., une augmentation de la fréquence cardiaque) ; une tendance à l'action (e.g., vouloir s'approcher de la personne qui nous complimente) ; une expression motrice (e.g., sourire) ; et un sentiment subjectif (e.g., ressentir de la joie). Ensuite, 2) l'émotion est un processus en deux étapes, impliquant un déclencheur et une réponse (Figure 2). Parmi ces déclencheurs, on retrouve la composante d'évaluation cognitive, tandis que les autres composantes constituent la réponse (Sander et al., 2018). Par exemple, pour une personne en situation d'obésité qui réalise une séance d'exercice à haute intensité, la douleur et l'essoufflement induits par cet évènement pourraient déclencher une réponse émotionnelle négative, telle que la peur ou le dégoût. D'autre part, 3) une émotion est déclenchée par un objet spécifique et pertinent pour l'individu. Cette pertinence se traduit à travers la nouveauté de l'objet, son plaisir intrinsèque, et sa proximité aux buts et besoins de l'individu (Sander et al., 2005). Par exemple, l'odeur d'un gâteau au chocolat pendant une période de perte de poids. Enfin, 4) les épisodes émotionnels sont de courte durée (quelques secondes à quelques minutes ; Ekkekakis, 2013).

En conclusion, sur la base des éléments mentionnés ci-dessus, une définition consensuelle a été récemment proposée : « l'émotion est un processus rapide, focalisé sur un événement et constitué de deux étapes. La première est un mécanisme de déclenchement fondé sur la pertinence de l'événement qui façonne la seconde étape. Cette seconde étape est une réponse constituée de plusieurs composantes (les tendances à l'action, les réactions du système nerveux autonome, l'expression et le sentiment). » (Sander, 2016, p. 4).

B. L'humeur : un état de faible intensité et diffus

Bien que les émotions et les humeurs partagent des caractéristiques communes, il est possible de les distinguer. Tout d'abord, les humeurs se différencient des émotions par des réponses moins marquées et plus diffuses, qu'il s'agisse des réponses physiologiques, des expressions faciales ou des tendances à l'action (Ekkekakis, 2013). Par ailleurs, les humeurs peuvent parfois être déclenchées par un objet pertinent pour l'individu, mais ces déclencheurs sont souvent plus généraux que ceux des émotions (Ekkekakis, 2013). Par exemple, lorsqu'une personne est d'humeur tendue, l'objet peut être quelque chose d'aussi général qu'une pensée sur la situation climatique actuelle ou d'aussi lointain qu'une réflexion sur son avenir (Ekkekakis, 2013). Finalement, les humeurs se distinguent des émotions par leur durée. Contrairement aux émotions, qui sont généralement de courte durée, les humeurs peuvent persister pendant plusieurs heures, jours, voire plusieurs mois dans le cas de troubles cliniques tels que des épisodes dépressifs (Ekkekakis, 2013).

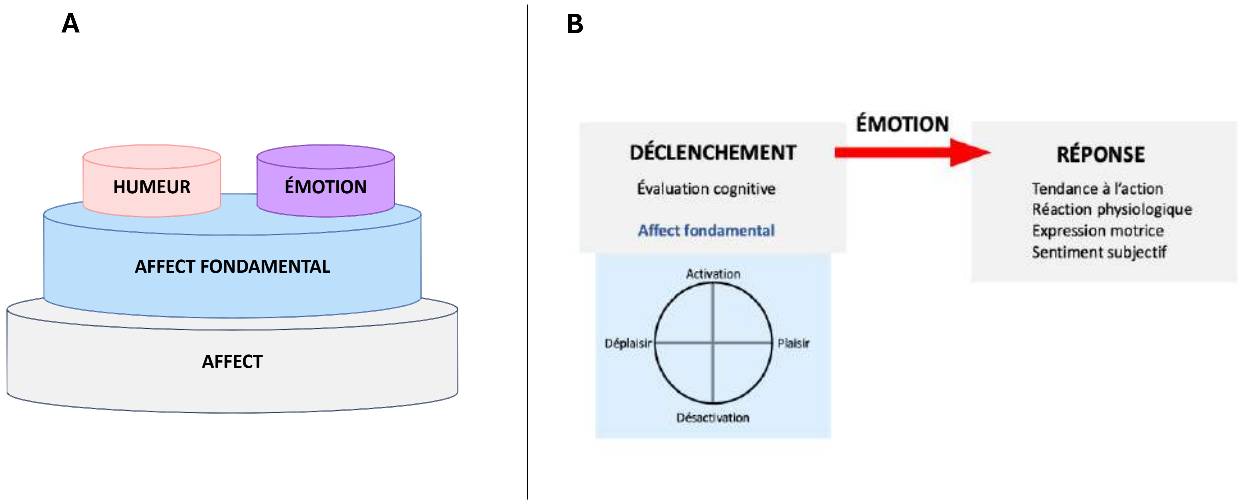
En conclusion, l'humeur peut être définie comme « un état affectif de longue durée, de faible intensité et qui présente un caractère diffus. » (Frijda, 2009b, p. 383 ; traduction libre).

1.2 L'affect fondamental : entre valence et activation

Pour certain·es, l'affect est un terme générique qui englobe l'ensemble des états affectifs, tels que les émotions et les humeurs (Niven, 2020). Pour d'autres, les affects désignent une partie du processus émotionnel ; c'est le cas de l'affect dit « fondamental » (ou *core affect*). Ce construit a été défini comme « un état neuro-physiologique accessible à la conscience en tant que simple sentiment primitif non réfléchi […]. » (Russell & Feldman Barrett, 2009a, p. 142 ; traduction libre). Selon le modèle circulaire bidimensionnel — ou circumplex — de Russell et Feldman Barrett (1999), il est constitué de deux dimensions orthogonales et distinctes : la valence (i.e., plaisir-déplaisir) et l'activation (ou *arousal* ; tension-relaxation). Contrairement à l'émotion, l'évaluation de l'affect fondamental ne fait pas nécessairement allusion à un objet particulier (e.g., « Comment vous sentez-vous à ce moment précis ? » ; Hardy & Rejeski, 1989 ; Russell & Feldman Barrett, 2009a). Finalement, dans certains modèles des émotions, l'affect fondamental est considéré comme l'un des déclencheurs du processus émotionnel (Figure 2 ; Sander, 2013 ; Sander et al., 2018).

Figure 2

Affect, affect fondamental, humeur et émotion



Note. La figure A est adaptée de Ekkekakis (2013). L'affect fondamental est un concept plus large que l'humeur et l'émotion. Il représente l'ensemble des états affectifs de base qui sous-tendent et influencent la variété des humeurs et des émotions ressenties par une personne. La figure B est adaptée de Sander et al. (2018). Elle présente le processus émotionnel en deux étapes : le déclenchement et la réponse. L'affect fondamental y est intégré en tant que déclencheur de la réponse émotionnelle.

Ainsi, la mise en évidence des spécificités de l'émotions, de l'humeurs et de l'affect fondamental constitue une base sémantique essentielle pour comprendre les mécanismes par lesquels les mécanismes affectifs influencent divers aspects de notre vie quotidienne. Dans le Chapitre 2, nous allons examiner plus spécifiquement comment certains mécanismes affectifs contribuent à la compréhension des comportements humains, et plus particulièrement, des comportements liés à l'activité physique.

Résumé du Chapitre 1

Les concepts d'**émotion**, d'**humeur**, d'**affect** et **d'affect fondamental** sont souvent **confondus** et utilisés de manière interchangeable. Il convient néanmoins de les différencier car ils ne désignent pas exactement le même construit affectif. L'**émotion** est définie comme un processus rapide, focalisé sur un événement et constitué de deux étapes. La première est un mécanisme de déclenchement fondé sur la pertinence de l'événement qui façonne la seconde étape. Cette seconde étape est une réponse constituée de plusieurs composantes (les tendances à l'action, les réactions du système nerveux autonome, l'expression et le sentiment). En revanche, l'**humeur** est définie comme un état affectif de longue durée, de faible intensité et qui présente un caractère diffus. Le terme « **affect** » englobe quant à lui ces états affectifs ; mais l'**affect fondamental** *(core affect)* est défini comme étant un état neurophysiologique accessible à la conscience en tant que simple sentiment primitif non réfléchi, caractérisé par deux dimensions principales : la valence (plaisant ou déplaisant) et l'activation (tension ou relaxation). Il peut servir de déclencheur dans les épisodes émotionnels. Ces mécanismes affectifs interagissent continuellement avec notre environnement et nos expériences, jouant un rôle crucial dans la compréhension des comportements humains, en particulier ceux liés à l'**activité physique**.

Chapitre 2 **L’essor de l’affectivisme**

« *Research over the past decades has demonstrated the explanatory power of emotions, feelings, motivations, moods, and other affective processes when trying to understand and predict how we think and behave. In this consensus article, we ask: has the increasingly recognized impact of affective phenomena ushered in a new era, the era of affectivism?* » Dukes et al. (2021, p. 816)

Dans un article de consensus publié en 2021 dans la revue Nature Human Behaviour, Daniel Dukes et 63 chercheur·euses renommé·es dans le domaine des sciences affectives se demandent si, après les époques du béhaviorisme et du cognitivisme, nous ne serions pas entrés dans une nouvelle ère : celle de l’affectivisme. En effet, l’influence grandissante des sciences affectives dans les travaux sur l’esprit et le comportement humain est visible dans l’évolution des financements et des publications scientifiques consacrés à ces mécanismes (Dukes et al., 2021). Comme le démontrent les auteur·es, de plus en plus de disciplines scientifiques accordent une attention croissante aux mécanismes affectifs, que ce soit la psychologie, les neurosciences, le domaine clinique, l’informatique, les sciences humaines, les sciences sociales, les sciences politiques, la communication, la littérature et les arts. L’objectif de ce chapitre est de présenter l’apport des mécanismes affectifs, à côté des modèles théoriques plus « cognitifs », dans la compréhension des comportements de santé, en particulier les comportements d’activité physique.

2.1 Des théories socio-cognitives aux modèles duaux

A. Les modèles socio-cognitifs

Dans l'étude des comportements d'activité physique, l'approche dite « socio-cognitive » constitue le cadre dominant (Rhodes, McEwan, et al., 2019). Selon celle-ci, les choix individuels sont influencés par une évaluation consciente et rationnelle des avantages et des inconvénients potentiels des actions envisagées, tout comme des chances d’obtenir ces avantages (Rhodes, McEwan, et al., 2019). Parmi ces modèles, la majorité des études visant à prédire les niveaux d'activité physique ont mobilisé la théorie du comportement planifié (*Theory of Planned Behavior* ; Ajzen, 1991) et la théorie sociale cognitive (*Social Cognitive Theory* ; Bandura, 1986) (Beauchamp et al., 2019 ; Downs & Hausenblas, 2005 ; Feltz et al., 2008 ; Hagger et al., 2002 ; Hagger et al., 2022 ; McEachan et al., 2011 ; Rhodes, McEwan, et al., 2019). Par exemple, la théorie du comportement planifié propose que l'*intention* de réaliser un comportement – identifiée comme la variable la plus proximale du comportement – est déterminée par trois facteurs principaux : (1) l'*attitude* envers le comportement, c'est-à-dire jusqu’à quel point la réalisation du comportement est valorisée positivement ou négativement, (2) la *norme subjective*, qui fait référence à la pression sociale perçue de s’engager ou de ne pas s’engager dans le comportement, et (3) le *contrôle comportemental perçu*, qui renvoie à la perception qu'a l'individu de sa capacité à accomplir ce comportement (Ajzen, 1991). La théorie sociale cognitive (Bandura, 1986), quant à elle, propose que le comportement humain est le résultat d'une interaction réciproque entre les facteurs personnels (notamment la cognition), les comportements et l'environnement. Un élément central de cette théorie est le *sentiment d'efficacité personnelle*, défini comme la croyance d'une personne en ses capacités à organiser et à réaliser les actions nécessaires pour obtenir des résultats spécifiques (Bandura, 1997). Ce sentiment est considéré comme un déterminant crucial du comportement (Bandura, 2004). Le·la lecteur·trice attentif·ve aura alors observé un fort recouvrement entre le contrôle comportemental perçu de la théorie du comportement planifié (Ajzen, 1991) et le sentiment d’efficacité personnelle de la théorie sociale cognitive (Bandura, 1986), tous deux renvoyant à la capacité perçue de mettre en œuvre un comportement. Comme nous l’avons évoqué dans le chapitre précédent, l'utilisation de terminologies variées pour décrire des concepts similaires complique l'identification des variables explicatives d’un comportement et leurs mécanismes d'action (Sheeran et al., 2017).

B. Limites des modèles socio-cognitifs

Bien que les interventions fondées sur les modèles socio-cognitifs aient montré une certaine efficacité pour influencer le comportement d'activité physique (Gourlan et al., 2016), les méta-analyses indiquent qu’elles impactent davantage les intentions d’être physiquement actif·ve, que le comportement réel (Rhodes et al., 2021 ; Rhodes & Dickau, 2012). Cette observation a conduit les chercheur·euses à explorer les modulateurs du lien entre intention – action, tels que les attitudes affectives, le sentiment d'efficacité personnelle, les habitudes ou les tendances d'approche-évitement (Cheval et al., 2015 ; Maltagliati, Raichlen, et al., 2024 ; Rhodes, 2024 ; Rhodes et al., 2022). Parmi ces modulateurs, un intérêt croissant s'est porté sur les processus psychologiques « automatiques » mis en évidence par les théories dites « duales » (Brand & Ekkekakis, 2018 ; Cheval & Boisgontier, 2021 ; Conroy & Berry, 2017 ; Hofmann et al., 2008 ; Strack & Deutsch, 2004). En effet, ces théories, qui complètent les modèles socio-cognitifs traditionnels, proposent une distinction entre deux types d'influences comportementales : les processus psychologiques réfléchis et les processus psychologiques automatiques (Hofmann et al., 2008 ; Melnikoff & Bargh, 2018b ; Strack & Deutsch, 2004). Les premiers se caractérisent par leur nature intentionnelle, contrôlable et consciente, et une mobilisation importante des ressources cognitives (Chaiken & Trope, 1999 ; Evans & Frankish, 2009 ; Melnikoff & Bargh, 2018a, 2018b ; Strack & Deutsch, 2004). En revanche, les processus automatiques, sont considérés comme involontaires, incontrôlables et souvent inconscients, et se distinguent par une faible demande en ressources cognitives (Chaiken & Trope, 1999 ; Evans & Frankish, 2009 ; Melnikoff & Bargh, 2018a, 2018b ; Strack & Deutsch, 2004). Il est toutefois important de noter que certaines variables peuvent combiner des caractéristiques des deux types de processus (Melnikoff & Bargh, 2018b). Par exemple, l'affect fondamental *(core affect)* peut être déclenché de manière automatique tout en restant accessible à la conscience, ce qui révèle sa dimension réfléchie (Russell & Feldman Barrett, 2009b).

2.2 Intégration des variables affectives dans les modèles à double processus

Depuis près d'une décennie, plusieurs modèles duaux ont intégré les mécanismes affectifs au centre de leur cadre conceptuel (Brand & Ekkekakis, 2018 ; Cheval & Boisgontier, 2021 ; Cheval et al., 2024 ; Conroy & Berry, 2017 ; Stevens et al., 2020 ; Williams & Evans, 2014). Par exemple, le modèle de l'évaluation affective automatique de l'activité physique (Conroy & Berry, 2017) ou la Théorie Affective-Réflexive de l'inactivité physique et de l'exercice (*Affective-Reflective Theory of physical inactivity and exercise*, ART) de Brand et Ekkekakis (2018) soulignent le rôle clé des processus affectifs automatiques dans l’adoption de comportements d’activité physique. Ainsi, à côté des processus réfléchis (e.g., intention), ces modèles proposent que, face à la perception d’une opportunité d'activité physique (e.g., voir un sentier dans un parc boisé), la valence associée à ce comportement soit automatiquement déclenchée. Cette évaluation affective automatique, basée sur les expériences affectives antérieures, colore à son tour l'évaluation affective réfléchie (ou attitude affective) vis-à-vis de l'activité physique.

Ainsi, une expérience plaisante liée à une activité physique (e.g., « J’ai pris beaucoup de plaisir à courir au bord du lac ») pourra renforcer tant l'évaluation automatique (i.e., l’association spontanée de l’activité physique à des attributs positifs) que réfléchie (i.e., la perception de l’activité physique comme plaisante). Ces modèles pourraient par exemple permettre d'expliquer pourquoi certaines personnes atteintes de maladies chroniques, éprouvant des expériences de déplaisir lors de la pratique de l'activité physique (Ekkekakis et al., 2010 ; Ekkekakis et al., 2016 ; Goubran et al., 2024 ; Hoffmann et al., 2018), peuvent rencontrer des difficultés à maintenir une pratique physique régulière, même en étant conscientes des bienfaits pour leur santé.

Pour approfondir cette perspective, Cheval et Boisgontier (Cheval & Boisgontier, 2024 ; 2021) ont développé la Théorie de la Minimisation de l'Effort en Activité Physique (*The Theory of Effort Minimization in Physical Activity*, TEMPA). Selon celle-ci, il existerait une tendance naturelle, héritée de notre évolution, à minimiser l’effort physique afin de conserver les ressources énergétiques de l’individu. Cette propension à minimiser l'effort constitue un incitateur automatique qui peut prendre le pas sur l’intention d'être physiquement actif·ve (Cheval & Boisgontier, 2021). Selon ce modèle, des expériences affectives positives liées à l'activité physique pourraient aider à réduire la perception de l'effort, facilitant ainsi l'engagement et le maintien de cette pratique (Cheval et al., 2024 ; Maltagliati, Fessler, et al., 2024).

Résumé du Chapitre 2

Dans l'étude des comportements d'activité physique, les **modèles socio-cognitifs** occupent une place importante. Ils postulent que les comportements sont principalement déterminés par une évaluation consciente des avantages et des inconvénients associés aux actions envisagées, ainsi que par la perception de ses capacités perçues à les mettre en œuvre. La théorie du comportement planifié et la théorie sociale cognitive font figure d’exemples. Cependant, ces modèles présentent certaines limites, notamment en ce qui concerne leur **efficacité à transformer durablement les comportements**. Dans le but de compléter ces modèles, les **théories duales** ont émergé, intégrant à la fois des déterminants **réfléchis** et **automatiques** des comportements. Certains modèles, comme la **Théorie Affective-Réflexive de l'inactivité physique et de l'exercice** ou la **Théorie de la Minimisation de l'Effort en Activité Physique**, placent les variables affectives au cœur de leur cadre conceptuel. Ces théories postulent que, face à une opportunité d'activité physique, les **expériences affectives antérieures** activent simultanément des **évaluations automatiques** et **réfléchies**, qui influencent à leur tour (a) les **tendances automatiques** à approcher ou éviter cette opportunité, (b) **l'effort perçu**, et (c) **l'intention** de s'engager dans l'activité. Par exemple, l'accumulation d'expériences négatives dans le cadre de l’activité physique peut entraîner une évaluation affective négative de l'activité physique (e.g., « Courir va me faire mal aux genoux »), une tendance automatique à éviter ce comportement, une perception d'effort élevée et une faible intention de s'y engager. Ces modèles contribuent à expliquer pourquoi certaines personnes atteintes de **maladies chroniques**, bien qu’elles reconnaissent les bienfaits de l’activité physique pour leur santé, éprouvent des difficultés à maintenir une pratique régulière.

Chapitre 3 **Déterminants affectifs de l'activité physique**

En 2014, Williams et Evans ont proposé un cadre conceptuel, le cadre des Affects et des Comportements de Santé (*Affect and Heath Behavior Framework* [AHBF]), pour intégrer les construits affectifs des comportements de santé présents dans la littérature en psychologie de la santé. L'AHBF s'inscrit dans la perspective des modèles à double processus, en suggérant deux voies possibles pour le traitement de l'affect : une voie automatique et une voie réfléchie[2]. Il convient de noter que l'AHBF n'est pas une théorie au sens strict, mais plutôt un cadre organisateur qui n'entre pas en concurrence avec d'autres théories. Il facilite la recherche et la théorisation des effets des variables affectives sur le comportement (Williams & Rhodes, 2023). Par ailleurs, ce cadre est conçu pour rester ouvert à des modifications, permettant l'intégration de nouveaux construits, pistes causales ou ajustement de terminologie (Williams & Rhodes, 2023). Une version plus récente de ce modèle a été proposée, pour s'ajuster plus spécifiquement aux comportements d'activité physique (Stevens et al., 2020). L'AHBF se distingue des théories affectives présentées dans le Chapitre 2 par son approche exhaustive : il intègre une large diversité de construits affectifs et socio-cognitifs, tandis que les théories précédentes privilégient une approche plus parcimonieuse en se concentrant sur un nombre restreint de variables clés.

Dans le cadre de ce travail doctoral, nous nous appuyons sur l'AHBF, tout en mobilisant les théories affectives les plus contemporaines (e.g., Brand & Ekkekakis, 2018 ; Cheval & Boisgontier, 2021 ; Conroy & Berry, 2017) pour compléter et préciser nos questions de recherche.

L'AHBF distingue quatre catégories distinctes : (1) les réponses affectives, (2) les affects incidents (ou *incidental affect* en anglais), (3) le traitement de l'affect (ou *affect processing* en anglais), et (4) la

[2] Contrairement à d'autres modèles, tel que l'ART (Brand & Ekkekakis, 2018), les auteurs n'ont pas assimilé les mécanismes affectifs à la voie automatique et les mécanismes cognitifs à la voie réfléchie. Selon ces auteurs, il existe des mécanismes affectifs dans les deux voies.

motivation chargée affectivement (Figure 3). Dans ce chapitre, nous définirons ces catégories avant de présenter l’AHBF dans le contexte de l’activité physique, offrant ainsi un cadre analytique pour notre travail doctoral. Le lien entre les variables affectives et les comportements d’activité physique sera approfondi dans le Chapitre 5, ainsi que dans les Contributions.

3.1 Les réponses affectives

Dans l’AHBF, les *réponses affectives* font référence aux affects fondamentaux ressentis pendant (e.g., réponse affective d’une personne à l’instant où elle effectue un exercice) ou juste après (e.g., réponse affective d’une personne à l’instant où elle termine sa séance) l’exécution d’un comportement de santé. Ces réponses incluent les dimensions de *valence* et d’*activation*, bien que certain·es auteur·es les limitent parfois à l'expérience de plaisir-déplaisir, se focalisant ainsi uniquement sur la valence (e.g., Ekkekakis et al., 2020 ; Williams & Evans, 2014). Dans ce manuscrit, nous utiliserons le terme « réponses affectives » pour désigner cette dimension de valence (plaisir-déplaisir) et le terme « affect fondamental » pour inclure à la fois les dimensions de valence et d’activation *(core affect)*. Pour illustrer ces concepts, considérons une séance de course à pied d'intensité élevée. Une personne pourrait ressentir une forte sensation d'énergie (activation) tout en éprouvant un déplaisir modéré (valence) en raison des ressources physiques et mentales mobilisées à ce moment précis. Dans ce cas, son affect fondamental est caractérisé par cette combinaison d'une énergie élevée et d'un déplaisir modéré, tandis que la réponse affective renvoie uniquement à sa sensation de déplaisir.

Différencier la réponse affective *pendant* le comportement de celle mesurée *après* celui-ci est important car, pour de nombreux comportements de santé (e.g., sevrage tabagique ou alcoolique, consommation de drogue, comportements sexuels illicites), l’état affectif ressenti pendant le comportement peut être nettement différent (parfois même opposé) de celui ressenti immédiatement après le comportement (Hladik et al., 2002 ; Hofmann & Fisher, 2012 ; Ulijaszek, 2007 ; Williams & Evans, 2014). Concernant l’activité physique, des travaux ont révélé de grande variation d’une personne à une autre dans les réponses affectives éprouvées pendant la pratique (Ekkekakis et al., 2020). En revanche, la réponse affective ressentie après la pratique d'une activité physique semble s'améliorer généralement de façon quasi-universelle, un phénomène dénommé « effet de rebond affectif » (Beaumont et al., 2020 ; Box et al., 2020 ; Ekkekakis, 2003 ; Ekkekakis et al., 2020).

3.2 Les affects incidents *(incidental affect)*

Les *affects incidents* résultent de facteurs situationnels externes au comportement en question (Lerner et al., 2015). Il s'agit d'états affectifs quotidiens, qualifiés d'« incidents », car indépendants d'un comportement de santé particulier (Stevens et al., 2020). Ces affects influencent néanmoins l'évaluation de la situation et la prise de décision qui en découle (Lerner et al., 2015). Par exemple, l'état de tristesse dans lequel se trouve une personne après une altercation avec un collègue dans le domaine professionnel peut sensiblement altérer le projet qu'elle avait de faire une séance d'activité physique.

3.3 Le traitement de l'affect *(affect processing)*

Le traitement de l'affect désigne les processus qui modifient l'évaluation d'un comportement en fonction d'expériences affectives répétées (Brand & Ekkekakis, 2018 ; Cheval & Boisgontier, 2021 ; Cheval et al., 2024 ; Conroy & Berry, 2017 ; Stevens et al., 2020 ; Williams & Evans, 2014). Par exemple, une personne qui éprouve régulièrement du plaisir à pratiquer des activités physiques pourrait progressivement développer une évaluation positive et durable de celles-ci. Contrairement aux réponses affectives, le traitement de l'affect peut se déclencher à tout moment en dehors du contexte d'un comportement de santé particulier (Stevens et al., 2020). Conformément aux modèles duaux, selon lesquels l'information sur une cible peut être traitée de manière automatique ou réfléchie, les différents construits qui sont liés au traitement de l'affect peuvent relever soit de processus automatiques soit de processus réfléchis.

Parmi les processus automatiques, le modèle AFHB met en avant les concepts d'*associations affectives* et d'*attitudes implicites*. Les associations affectives décrivent des liens mémorisés entre un comportement cible et les réponses affectives éprouvées lors d'expériences antérieures de ce comportement (Kiviniemi et al., 2007). Par exemple, éprouver de la fatigue, de l'ennui, voire de la douleur lors de séances d'activité physique peut amener une personne à associer automatiquement l'idée de faire de l'activité physique à quelque chose de désagréable. Les attitudes implicites, quant à elles, sont définies comme des « actions ou jugements qui sont sous le contrôle d'une évaluation activée automatiquement, sans que l'exécutant·e soit conscient·e de cette causalité » (Greenwald et al., 1998, p. 1464, traduction libre). Bien qu'elles soient conceptuellement proches des associations affectives (Stevens et al., 2020), les attitudes implicites peuvent être de nature affective (e.g., l'activité physique est associée de manière automatique à des adjectifs plaisants comme « agréable ») ou instrumentale (e.g., l'activité physique est associée de manière automatique à des adjectifs comme « bénéfique », « utile ») (Phipps et al., 2022 ; Stevens et al., 2020). Ces deux concepts se distinguent également par leurs méthodes d'évaluation. Les associations affectives sont généralement mesurées à l'aide de questionnaires auto-rapportés (e.g., « Quand je pense à l'activité physique, je me sens... » ; Stevens et al., 2020). En revanche, les attitudes implicites sont souvent évaluées par l'intermédiaire des tâches de temps de réaction, où les participant·es doivent réagir à des mots ou des images liés à l'activité physique, en même temps qu'à des adjectifs affectifs tels que « bon » ou « mauvais » (Cheval, Sarrazin, & Radel, 2016 ; Conroy et al., 2010 ; Greenwald et al., 1998 ; Karpinski & Steinman, 2006). Autrement dit, la distinction entre les associations affectives et les attitudes affectives implicites s'opère principalement à travers la méthode de mesure utilisée (i.e., questionnaire vs. tâche de temps de réaction).

Les attitudes implicites occupent une place importante dans plusieurs théories affectives de l'activité physique, notamment dans l'ART (Brand & Ekkekakis, 2018) et le modèle de Conroy et Berry (2017). Ces théories utilisent toutefois le terme « évaluations affectives automatiques » (*automatic affective (e)valuations*) pour décrire ces processus. Dans la mesure où les « attitudes implicites » ne sont pas exclusivement de nature affective (Phipps et al., 2022 ; Stevens et al., 2020) et que des auteurs (e.g., Corneille & Hütter, 2020) suggèrent d'abandonner le terme « implicite » au profit de « automatique » jugé plus précis pour décrire les processus par lesquels ces associations se forment et influencent le comportement, nous utiliserons nous aussi le terme « évaluations affectives automatiques » à la place d'attitudes implicites, tout au long de ce manuscrit.

Parmi les processus affectifs réfléchis, l'AHBF inclut les *jugements affectifs,* qui englobent les *attitudes affectives* et le *plaisir (enjoyment)*. Stevens et al. (2020) définissent les attitudes affectives envers l'activité physique comme « des évaluations de l'activité physique basées sur l'agrégation de la probabilité et de l'évaluation des résultats affectifs de l'activité physique [...]. » (p. 9, traduction libre). Autrement dit, elles reflètent à la fois la probabilité que l'activité physique soit perçue comme agréable et l'importance accordée à cette perception pour la personne interrogée. Ces attitudes affectives diffèrent des attitudes instrumentales, qui portent sur une évaluation plus utilitaire du comportement (e.g., « L'activité physique est bénéfique pour ma santé ») (Ajzen, 1991). Les attitudes affectives sont mesurées via des questionnaires auto-rapportés, permettant aux répondant·es d'évaluer dans quelle mesure elles et ils perçoivent l'activité physique comme plaisante, amusante, déplaisante, ou ennuyeuse (Stevens et al., 2020). Ces évaluations sont également proches de celle utilisée pour évaluer le plaisir *(enjoyment)*, un construit généralement mesuré à l'aide de la *Physical Activity Enjoyment Scale* (Kendzierski & DeCarlo, 1991), qui évalue à quel point l'activité physique est perçue comme agréable, amusante, revigorante ou gratifiante. Du fait de cette proximité conceptuelle, plusieurs méta-analyses ont associé le plaisir et les attitudes affectives sous le terme global de « jugements affectifs » (Nasuti & Rhodes, 2013 ; Rhodes et al., 2009 ; Rhodes, Gray, et al., 2019). C'est également pour cette raison que l'AHBF regroupe ces deux construits sous la variable « jugements affectifs » (Stevens et al., 2020).

Dans l'AHBF, le traitement de l'affect comprend également l'*affect remémoré* et la *réponse affective anticipée,* des variables affectives réfléchies. L'affect remémoré est défini comme « le souvenir de la réponse affective lors d'une activité physique précédente. » (Stevens et al., 2020, p. 10 ; traduction libre). Contrairement aux jugements affectifs, influencés par l'agrégation de réponses affectives multiples, l'affect remémoré fait référence à une expérience d'activité physique spécifique. Daniel Kahneman, lauréat du Prix Nobel d'économie en 2002, a suggéré que l'affect remémoré, appelé *utilité remémorée (remembered utility)*, ne reflète pas toujours fidèlement les réponses affectives ressenties au cours d'une expérience. Notre mémoire affective de l'événement pourrait être biaisée par les états affectifs éprouvés à certains moments de l'expérience (e.g., Fredrickson & Kahneman, 1993 ; Kahneman et al., 1993 ; Kahneman et al., 1997 ; Redelmeier & Kahneman, 1996). Plus précisément, selon le principe du « pic et de la fin », l’affect remémoré n’est pas la somme ou la moyenne des états affectifs ressentis au cours d’un événement particulier, mais dépend des moments affectifs les plus intenses (« pic ») et finaux (« fin ») de l’expérience (Alaybek et al., 2022 ; Fredrickson, 2000). Par exemple, si une personne éprouve principalement des réponses affectives légèrement positives tout au long d’une séance d'activité physique, mais que la fin de celle-ci est particulièrement éprouvante, induisant des réponses affectives négatives, l'affect remémoré de cette séance pourrait être coloré négativement.

La réponse affective anticipée fait référence, quant à elle, à « l'attente de ce qu’une personne ressentira en s'engageant ou en ne s'engageant pas dans une activité physique. » (Stevens et al., 2020, p. 10 ; traduction libre). Ce concept est proche de celui de la « croyance comportementale », dans la théorie du comportement planifié d’Ajzen (1991), qui lie un comportement (e.g., l’activité physique) à un résultat attendu (e.g., le plaisir). L’AHBF, comme la théorie du comportement planifié, considère la réponse affective anticipée comme un antécédent des attitudes affectives (Stevens et al., 2020 ; Figure 3).

3.4 La motivation chargée affectivement

D’après l’AHBF, la *motivation chargée affectivement* regroupe les états motivationnels fondés sur les affects fondamentaux liés à l'activité physique. Cette catégorie inclut notamment la motivation hédonique, telle l’*envie (craving)*, le *désir (desire)*, l’*appréhension (dread)*, la *peur (fear),* la *sensibilité à l’anxiété (anxiety sensitivity)* et la *motivation intrinsèque* (Williams & Evans, 2014 ; Stevens et al., 2020). Contrairement aux motivations réfléchies, qui reposent sur des processus de décision et de calcul des résultats (e.g., les intentions ou les buts), ces construits relèvent d’une motivation plus automatique.

La motivation hédonique repose sur le principe hédonique, selon lequel les individus cherchent naturellement à maximiser le plaisir et à éviter le déplaisir (Cabanac, 1992 ; Higgins, 1997 ; Williams, 2008, 2018). Dans ce cadre, les comportements associés à des réponses affectives positives suscitent le désir et l'envie, tandis que ceux qui génèrent des réponses négatives engendrent l’appréhension (Williams, 2018). L’envie/le désir hédonique *(hedonic craving/desire)* et l’appréhension représentent les deux extrêmes de cette motivation hédonique. Si cette motivation peut être vécue consciemment, Stevens et al. (2020) insistent sur le fait que la motivation hédonique est produite automatiquement, c’est-à-dire, sans traitement réfléchi. Dans le contexte de l’activité physique, où le problème principal réside dans le manque d’engagement plutôt que dans l’excès (à l’inverse d’autres comportements de santé comme l’alimentation, le tabac, l’alcool ou la drogue) (Hacker, 2024 ; Strain et al., 2024), l’appréhension hédonique semble plus pertinente que l’envie ou le désir hédonique[3] (Stevens et al., 2020). Celle-ci fait référence à une réticence automatique à s'engager dans une activité, induite par des expériences affectives négatives antérieures (e.g., déplaisir, inconfort) (Stevens et al., 2020). Par exemple, une personne souffrant d'artériopathie oblitérante des membres inférieurs – une pathologie provoquant une douleur aiguë après seulement 10 minutes de marche – pourrait développer une forte aversion pour l'activité physique, par crainte de revivre cette douleur.

La *peur* agit comme un moteur motivationnel en incitant les individus à éviter des comportements ou des objets associés à des expériences affectives négatives passées ou perçus comme potentiellement menaçants (LeDoux, 2012). Pour saisir pleinement son impact sur les comportements, il est important de considérer l’évaluation cognitive de cette réponse émotionnelle (de Hoog et al., 2007 ; Ruiter et al., 2001 ; Witte & Allen, 2000). Par exemple, la majorité des études sur l'impact des campagnes anti-tabac sur la consommation de cigarettes se sont concentrées sur les réactions émotionnelles induites par la peur, telles que l'évitement, plutôt que sur la peur en tant que telle (Hammond, 2011 ; Williams & Evans, 2014). Dans le domaine de l’activité physique, la peur est principalement examinée à travers le concept de « sensibilité à l'anxiété », défini comme l’appréhension de ressentir des symptômes d’anxiété somatique, comme l’augmentation de la fréquence cardiaque ou de la respiration, la tension musculaire et la transpiration (Reiss & McNally, 1985). Cette sensibilité accrue est négativement corrélée à la pratique de l'activité physique, en particulier chez les personnes ayant un indice de masse corporelle (IMC) élevé et lors d’exercices de haute intensité (Moshier et al., 2013 ; Moshier et al., 2016 ; Smits et al., 2010). Un

[3] Stevens et al. (2020) précisent que l’envie/le désir hédonique serait plus pertinent pour la recherche sur la dépendance pathologique à l’activité physique, telle que la dépendance à l’exercice physique.

mécanisme proposé pour expliquer cette association est la tendance de certains individus à surestimer l'effort perçu lors d'exercices physiques (Stevens et al., 2020). Par exemple, des participant·es souffrant de trouble panique perçoivent un effort plus élevé lors d’un test d’effort sur tapis roulant, par rapport à des participant·es en bonne santé, bien que leur fréquence cardiaque soit inférieure (Muotri et al., 2017). Les auteurs ont suggéré que l’anticipation de l’anxiété induite par l’exercice pourrait expliquer cette différence. Cette surestimation de l'effort perçu pourrait ensuite réduire la probabilité de s'engager dans des comportements d'activité physique ultérieurs (Cheval & Boisgontier, 2021 ; Cheval et al., 2024).

Finalement, l’AHBF intègre la *motivation intrinsèque* parmi les motivations chargées affectivement. Selon la théorie de l'auto-détermination (Ryan & Deci, 2000), on parle de motivation intrinsèque quand une personne fait une activité pour le plaisir et la satisfaction qui sont directement liés à celle-ci, et non pour d’éventuelles « récompenses » auxquelles elle pourrait conduire (i.e., motivation extrinsèque). Autrement dit, l’activité est gratifiante en elle-même parce qu’elle est nouvelle, comporte un défi, permet d’apprendre des choses, éveille la curiosité, entre autres. La majorité des recherches sur l'activité physique souligne l'importance de la motivation intrinsèque dans l'engagement et le maintien durable de ce comportement (Sarrazin et al., 2011 ; Teixeira et al., 2012 ; Vallerand, 2007).

Bien qu’elles ne soient pas explicitement intégrées dans l’AHBF, les *tendances d’approche-évitement* constituent des variables centrales dans les théories affectives les plus récentes appliquées à l’activité physique (Brand & Ekkekakis, 2018 ; Cheval & Boisgontier, 2021 ; Conroy & Berry, 2017). Ces tendances représentent une composante motivationnelle automatique du processus émotionnel (e.g., Cheval, Sarrazin, & Radel, 2016), supposées faciliter l’adoption ou l’évitement de comportements pour répondre à des buts et des besoins particuliers (Frijda, 2009a ; Sander et al., 2018). Elles se manifestent par des états motivationnels internes qui définissent l'urgence d'une réponse, son orientation (approche ou évitement) et l’importance accordée à cette urgence (Frijda, 2009a ; Sander et al., 2018). Autrement dit, les tendances d’approche-évitement sont souvent considérées comme des variables affectives proximales influençant directement le comportement (Cheval & Boisgontier, 2021 ; Conroy & Berry, 2017

; Friese et al., 2011). Par exemple, évaluer un objet comme une menace peut automatiquement déclencher une tendance à l'éviter, préparant ainsi l'organisme à fuir.

Si les tendances d'approche sont généralement associées à une valence affective positive et celles d'évitement à une valence négative (Ekkekakis, 2009), il est important de distinguer ces deux mécanismes, car ils ne se confondent pas systématiquement (Sander, 2016). Par exemple, bien que la colère ait une valence négative, elle peut déclencher une tendance d'approche ; en effet, l'hostilité peut inciter à se rapprocher de la personne envers laquelle cette émotion est dirigée (Sander, 2016).

Étant donné que l'AHBF est un cadre évolutif, dans lequel tous les construits pertinents peuvent être ajoutés (Williams & Rhodes, 2023), nous proposons d'y inclure les tendances automatiques d'approche-évitement parmi les éléments de la motivation chargée affectivement (Figure 3).

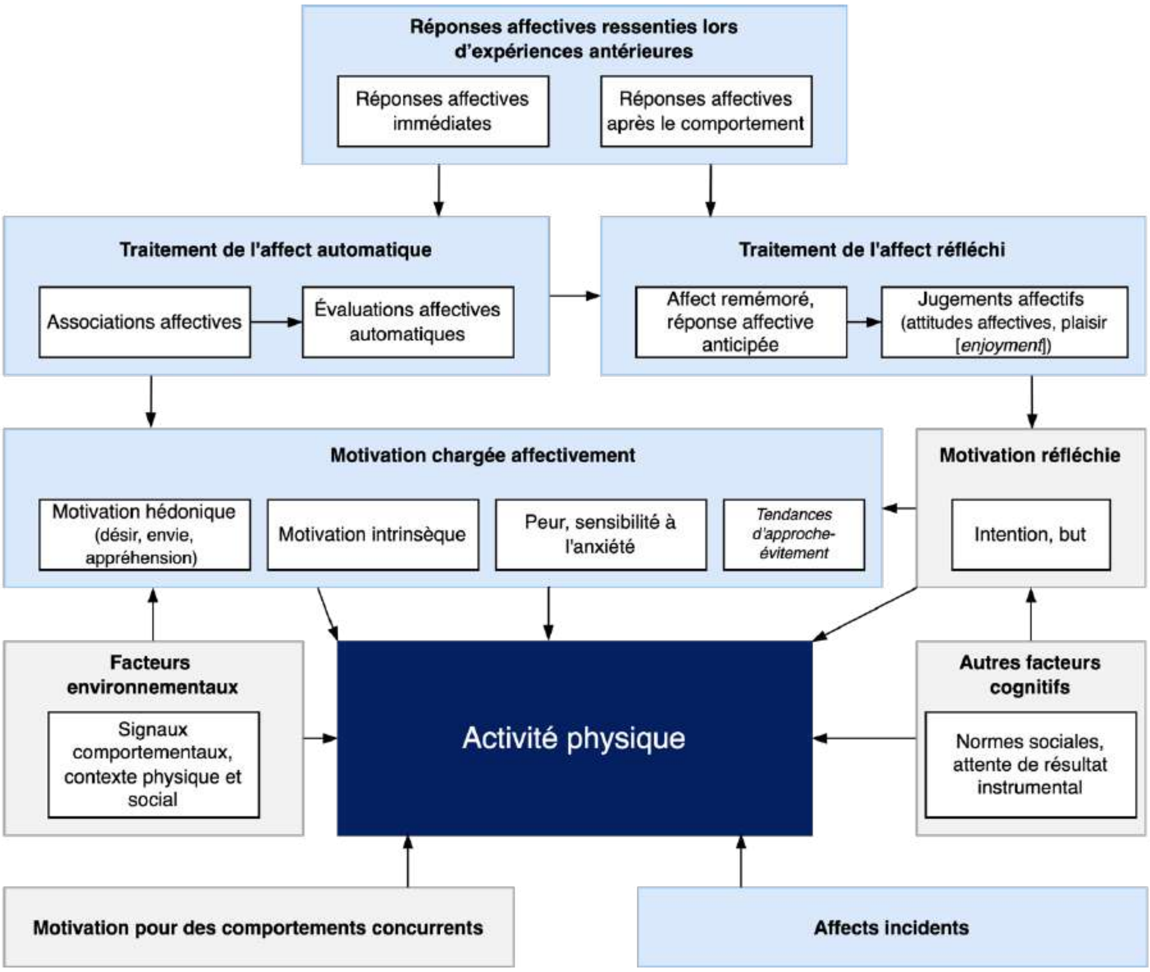
3.5 L'AHBF dans le contexte de l'activité physique

L'AHBF organise les construits affectifs, identifiés comme déterminants de l'activité physique, en quatre catégories : les réponses affectives, les affects incidents, le traitement de l'affect automatique et réfléchi, et la motivation chargée affectivement (Stevens et al., 2020 ; Williams & Evans, 2014). Ce modèle tient également compte d'autres facteurs influençant l'engagement et le maintien dans des activités physiques : les *facteurs environnementaux*, tels que les signaux comportementaux ou l'environnement physique et social, les *facteurs cognitifs non affectifs*, comme les normes sociales ou les attentes de résultat instrumental, ainsi que les *motivations pour des comportements concurrents*, telle que la motivation de regarder la télévision plutôt que de pratiquer une activité physique.

Pour illustrer les relations présumées entre les différentes catégories de l'AHBF, prenons l'exemple d'une personne en situation d'obésité à qui un·e médecin aurait recommandé une activité physique régulière pour améliorer sa santé. La force de son intention de commencer un programme d'exercice (i.e., sa motivation réfléchie) dépend, en partie, de son anticipation des conséquences affectives post-comportementales de l'exercice, comme la fierté, la satisfaction, ou encore le soulagement ressenti après avoir fini une séance d'entraînement (i.e., traitement de l'affect réfléchi). Toutefois, l'idée de faire une séance de course à pied planifiée le soir (i.e., un indice comportemental) peut déclencher une « appréhension » automatique liée à l'exercice (i.e., une motivation automatique) qui repose sur des associations affectives négatives (i.e., le traitement automatique de l'affect) avec des réponses affectives immédiates à l'exercice telles que l'inconfort et la douleur ressentis pendant l'exercice vigoureux. En cas de conflit entre cette appréhension automatique et l'intention de faire de l'exercice, la personne est susceptible d'éprouver une peur ou une anxiété consciente à l'égard de l'exercice (i.e., une motivation chargée affectivement). En plus de l'intention de faire de l'exercice, de l’appréhension automatique et de l'anxiété liées à l'exercice, d’autres facteurs peuvent également entrer en jeu comme les conditions météorologiques, la disponibilité d'un·e partenaire d'exercice (i.e., les facteurs environnementaux), l'humeur préalable de la personne (i.e., l'affect incident), d’autres priorités comme le désir de sortir pour aller dîner ce soir-là (i.e., la motivation pour les comportements concurrents), ou encore les encouragements reçus de son·sa partenaire (i.e., d'autres motifs cognitifs).

Figure 3

Déterminants affectifs de l'activité physique selon l'AHBF (adapté de Williams et Evans, 2014, et Stevens et al., 2020)



Note. Les variables affectives sont représentées dans les encadrés bleu clair. Les tendances d'approche-évitement ont été ajoutées au modèle original. Les attitudes implicites mentionnées dans l'AHBF ont été remplacées par les évaluations affectives automatiques.

Résumé du Chapitre 3

Le cadre conceptuel des **Affects et des Comportements de Santé** (AHBF), proposé par Williams et Evans (2014) et adapté à l’activité physique par Stevens et al. (2020), identifie quatre catégories de déterminants affectifs : (a) les **réponses affectives**, (b) les **affects incidents**, (c) le traitement de l’affect automatique et réfléchi, et (d) la **motivation chargée affectivement**. Les réponses affectives désignent les ressentis immédiats de **plaisir ou de déplaisir** éprouvés durant ou immédiatement après l’expérience du comportement, tandis que les affects incidents proviennent de facteurs **externes au comportement,** qui peuvent colorer l’expérience affective. Le traitement de l’affect regroupe les **associations et évaluations affectives**, qu’elles soient automatiques ou réfléchies, façonnées par la répétition d’expériences affectives. La motivation chargée affectivement englobe la **motivation hédonique**, la **peur**, la **sensibilité à l’anxiété** et la **motivation intrinsèque**, toutes influencées par les affects fondamentaux ressentis pendant l'activité physique. Dans ce travail doctoral, nous incluons également les **tendances d’approche-évitement** dans cette catégorie, les considérant comme une composante motivationnelle essentielle au processus émotionnel. En plus de ces déterminants affectifs, l’AHBF prend en compte d’autres facteurs comportementaux non affectifs, comme les **facteurs environnementaux** (e.g., contexte physique et social) et les **facteurs cognitifs non affectifs** (e.g., les normes sociales). Comme le décrivent Stevens et al. (2020, p. 2 ; traduction libre), « *Les réponses affectives antérieures à [l’activité physique] influencent à la fois le traitement automatique et réfléchi de l’affect, ce qui alimente la motivation chargée affectivement ainsi que la motivation réfléchie à réaliser (ou éviter) ce comportement. L'affect non lié au comportement cible, ressenti tout au long de la journée (affect incident), influence également le comportement, tout comme d'autres facteurs cognitifs, des facteurs environnementaux, ainsi que la motivation à réaliser d'autres comportements concurrents.* »

L’étude de ces variables affectives se révèle particulièrement pertinente dans le contexte de l’activité physique, un comportement fréquemment associé à des réponses affectives immédiates négatives, notamment chez les **personnes atteintes de maladies chroniques**.

Chapitre 4 **Problématique générale et questions de recherche**

« If we stop to consider just how much variance in the course of our lives is controlled by cognitive processes and how much by affect, and how much the one and the other influence the important outcomes in our lives, we cannot but agree that affective phenomena deserve far more attention than they have received from cognitive psychologists and a closer cognitive scrutiny from social psychologists. » Zajonc, R. B. (1980, p. 172)

Comme en témoigne cette citation, dès les années 1980, Robert Zajonc s'interrogeait déjà sur l'influence des affects sur nos actions quotidiennes, en questionnant notamment l'indépendance et la primauté des mécanismes affectifs par rapport aux processus cognitifs (e.g., Zajonc, 1980). Quarante-et-un ans plus tard, l'idée que les mécanismes affectifs jouent un rôle central dans les comportements humains semble avoir gagné en reconnaissance. Le courant de l'affectivisme propose que l'inclusion des variables affectives dans les modèles du comportement, de l'esprit et du cerveau « n'explique pas seulement les mécanismes affectifs, mais, de manière critique, renforce la capacité d'expliquer la cognition et le comportement » (Dukes et al., 2021, p. 816 ; traduction libre ; voir également Dukes & Sander, 2024).

Plus récemment, Ferrer et Gillman (2023) ont plaidé pour l'inclusion des variables affectives dans les modèles de changement des comportement de santé, qui se sont historiquement « concentrés sur les déterminants sociaux-cognitifs, en omettant les déterminants affectifs ou en les incluant de manière superficielle » (p. 586, traduction libre ; voir également Stussi et al., 2024). Ces autrices critiquent également les recherches actuelles dans le domaine des sciences affectives, soulignant qu'elles utilisent souvent des échantillons homogènes qui ne permettent pas de généraliser les résultats à l'ensemble de la population. Elles appellent à étudier les expériences uniques des populations spécifiques, notamment celles touchées par des disparités en matière de santé : les minorités raciales et ethniques, les minorités sexuelles et de genre, les communautés rurales mal desservies, et les personnes à faible statut socio-économique. Ces groupes peuvent en effet vivre des états affectifs particuliers qui influencent différemment leurs comportements (Halbert & Allen, 2021).

Dans le cas des personnes atteintes de maladies chroniques, il est possible que les états affectifs associés à certains facteurs de risque comme l'obésité (e.g., stress, anxiété, fatigue) aient un impact unique sur le comportement d'activité physique. Ainsi, « identifier les processus affectifs ayant le plus d'impact sur le changement de comportement dans des populations variées pourrait potentiellement réduire les disparités dans les contextes de maladies où le comportement est un facteur de risque. » (Ferrer & Gillman, 2023, p.588 ; traduction libre). Cela permettrait également de générer des connaissances importantes sur les processus affectifs parmi les populations spécifiques.

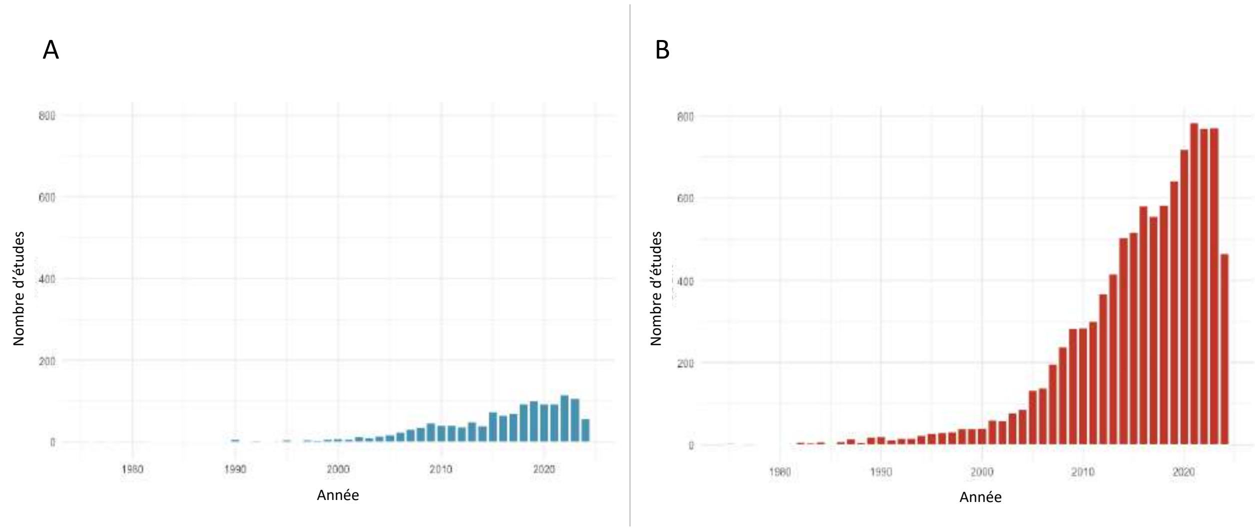
En d'autres termes, l'exploration des déterminants affectifs de l'activité physique chez les personnes atteintes de maladies chroniques ouvre de nouvelles perspectives pour lutter contre la pandémie d'inactivité physique (Kohl et al., 2012), contribuant ainsi à l'amélioration de leur qualité de vie (Haseler et al., 2019 ; Inserm, 2019). Pourtant, les études se concentrant sur les variables affectives auprès de cette population demeurent limitées, surtout par rapport aux recherches sur les variables socio-cognitives traditionnelles comme l'intention ou le sentiment d'efficacité personnelle, ces dernières étant près de huit fois plus fréquentes (Figure 4).

Ce constat soulève trois questions centrales pour ce projet doctoral :

1. La prise en compte des mécanismes affectifs, en plus des variables socio-cognitives, améliore-t-elle la prédiction de l'activité physique chez les personnes atteintes de maladies chroniques ?
   Si oui, quelles sont les variables qui prédisent le plus l'activité physique ?
2. Quelles sont les stratégies d'intervention qui permettent de manipuler des variables affectives ?
3. Est-il possible d'améliorer l'activité physique des personnes atteintes de maladies chroniques en ciblant des variables affectives ?

Figure 4

Nombre de publications scientifiques par année en lien avec l'activité physique, les réponses affectives et l'intention



Note. La figure A représente le nombre de résultats pour la recherche « *Physical activity and affective responses* » sur PubMed (*n* = 1 160). La figure B représente le nombre de résultats pour la recherche « *Physical activity and intention* » sur PubMed (*n* = 8 610). Les recherches ont été effectuées le 16 août 2024.

Répondre à la première question est essentiel pour renforcer le pouvoir explicatif et prédictif des modèles d'activité physique ciblant les personnes atteintes de maladies chroniques. L'intégration des variables affectives, en complément des variables socio-cognitives, permettrait d'identifier les mécanismes les plus prédictifs de l'activité physique dans cette population (étape B du modèle de la médecine expérimentale appliquée aux changements de comportements ; Sheeran et al., 2017 ; cf. Figure 1, p. 7). Répondre à la deuxième question permettrait d'identifier et de tester des stratégies ou « ingrédients actifs » susceptibles de faire évoluer les variables affectives dans le sens souhaité (étape C). Finalement, répondre à la troisième question permettrait de déterminer si ces stratégies facilitent l'adoption de l'activité physique en modifiant les variables affectives (étape D).

Les travaux de ce projet doctoral pourraient également servir à proposer des recommandations aux différentes parties prenantes. Par exemple, dans le Plan d'action mondial sur l'activité physique 2018–2030 de l'OMS, le terme « plaisir » n'est mentionné qu'une seule fois en plus de 100 pages, et les expériences affectives sont absentes des infographies correspondantes (Bull et al., 2020 ; World Health Organization, 2018). En France, des initiatives telles que la Grande Cause Nationale (https://www.grandecause-sport.fr/30-minutes-bouge) et le Programme National de Nutrition Santé « Manger Bouger » (https://www.mangerbouger.fr/bouger-plus), visent à encourager la population à pratiquer davantage d'activités physiques et sportives. Cependant, ces initiatives se concentrent principalement sur la quantité d'activité physique à réaliser quotidiennement (i.e., 30 minutes), plutôt que sur les conditions affectives et psychologiques nécessaires pour garantir un engagement durable dans ce comportement.

Ces observations nous conduisent à défendre la thèse suivante :

La manipulation de variables affectives telles que les réponses affectives, l'affect remémoré les tendances d'approche-évitement pourrait améliorer l'engagement dans les activités physiques chez les personnes atteintes de maladies chroniques.

Afin de tester cette thèse, ce projet doctoral s'articule autour de trois parties, basées sur l'approche de la médecine expérimentale appliquée au changement de comportement de santé (Sheeran et al., 2017 ; Figure 1).

La première partie vise à explorer les relations entre certaines variables affectives et l'activité physique quotidienne chez les personnes atteintes de maladies chroniques (étape B). Plus précisément, elle examine si des réponses affectives positives pendant une séance d'activité physique, et/ou des évaluations affectives (automatiques et réfléchies) positives envers l'activité physique, et/ou une tendance automatique à approcher ce comportement, favorisent la pratique régulière d'activités physiques chez cette population. Répondre à cette question constitue un premier pas pour identifier les variables d'intérêt à cibler afin de promouvoir l'activité physique chez les personnes atteintes de maladies chroniques, conformément au modèle de médicine expérimentale de Sheeran et collaborateurs (2017).

Deux études observationnelles ont été réalisées dans des contextes distincts pour répondre à cette question (Tableau 1). La première étude (**Contribution empirique n°1**) visait à analyser les niveaux d'activité physique et de sédentarité chez des patient·es ayant terminé un programme de réadaptation cardiovasculaire ambulatoire, et à examiner les corrélats motivationnels et affectifs. Les niveaux d'activité physique et de sédentarité, ainsi que les caractéristiques motivationnelles et affectives, ont été comparés à ceux de participant·es contrôles en bonne santé. Un total de 119 participant·es ont été recruté·es aux Hôpitaux Universitaires de Genève et dans la ville de Genève (68 patient·es et 51 contrôles). Les niveaux d'activité physique et de sédentarité ont été mesurés à l'aide d'accéléromètres sur une semaine. Les caractéristiques motivationnelles (capacités perçues, attitudes instrumentales, intention) et affectives (attitudes affectives, anxiété, symptômes dépressifs, fatigue, douleur) ont été évaluées à l'aide d'échelles validées, tandis qu'une tâche de temps de réaction a permis d'estimer les tendances d'approche-évitement envers l'activité physique. La seconde étude (**Contribution empirique n°2**) visait à évaluer l'influence des réponses affectives ressenties lors d'une séance d'APA sur les niveaux d'activité physique quotidiens subséquents, chez des personnes atteintes de maladies chroniques. Cette étude se distingue des travaux antérieurs par une mesure répétée des réponses affectives à différents moments de la séance. S'appuyant sur le principe du « pic et de la fin » (Fredrickson, 2000), ce protocole permet d'examiner si les réponses affectives éprouvées à certains moments, notamment à la fin de la séance, prédisent mieux que d'autres l'activité physique ultérieure. Elle a également investigué les mécanismes sous-jacents à cette association et a évalué sa robustesse en tenant compte des facteurs de confusion potentiels. Un total de 109 participant·es ont été recruté·es dans des associations en APA du bassin grenoblois. Les réponses affectives ont été mesurées à quatre moments différents pendant une séance d'APA habituelle, tandis que les niveaux d'activité physique quotidiens ont été enregistrés avec des accéléromètres pendant la semaine suivant la séance. Les variables affectives et motivationnelles réfléchies (réponses affectives, affect remémoré, réponse affective anticipée, motivations autonomes et contrôlées, attitudes affectives et instrumentales, intention) ont été évaluées à l'aide d'échelles validées, tandis que les variables affectives automatiques (évaluations affectives automatiques, tendances d'approche-évitement) ont été mesurées par des tâches de temps de réaction. Ces deux études ont permis de répondre à la première question de ce projet doctoral en examinant les liens entre les variables affectives, les construits cognitifs traditionnels, et les niveaux d'activité physique chez des personnes atteintes de maladies chroniques dans divers contextes (i.e., hospitalier et associatif).

La seconde partie de ce travail doctoral se concentre sur l'identification de stratégies d'intervention permettant d'améliorer les variables affectives liées à l'activité physique aussi bien chez la population générale que chez les personnes atteintes de maladies chroniques, répondant ainsi à l'étape C de l'approche de la médecine expérimentales appliquée au changement de comportement (Sheeran et al., 2017). Tout d'abord, une revue narrative sous forme de chapitre d'ouvrage a été réalisée pour présenter un éventail non exhaustif de stratégies endogènes et exogènes utilisées dans les interventions visant à maximiser les expériences affectives lors de la pratique d'une activité physique (**Contribution n°3**). Ensuite, un protocole a été élaboré pour tester l'efficacité d'une stratégie exogène proposée dans le chapitre précédent : l'utilisation de la musique pendant les séances d'activité physique pour des patient·es participant·es à un programme de réadaptation cardiovasculaire stationnaire aux Hôpitaux Universitaires de Genève (**Contribution empirique n°4**). En s'appuyant sur le principe du « pic et de la fin » – une stratégie endogène –, ce protocole visait à examiner l'effet de la musique jouée à différents moments de la séance sur les réponses affectives. Bien que cette étude n'ait pas pu être réalisée dans le cadre du projet doctoral, la Commission cantonale d'éthique de la recherche du canton de Genève a approuvé le protocole le 10 octobre 2024, permettant ainsi sa mise en œuvre dès 2025. Par ailleurs, une stratégie d'intervention endogène, centrée sur la répartition de l'effort au cours d'une séance d'APA, a également été explorée. Cependant, les résultats principaux étant liés à l'activité physique quotidienne, ils seront abordés dans la troisième partie de la thèse (**Contribution empirique n°7**). Enfin, nous cette seconde partie s'intéresse aux stratégies d'interventions digitales visant à modifier certaines variables affectives, comme les tendances d'approche-évitement, sans nécessiter d'expérience physique directe avec l'activité physique. A partir du cadre conceptuel de

Larsen et Holland (2022), trois stratégies d'interventions basées sur la « chronologie de la réponse automatique » sont explorées : (a) celles centrées sur les antécédents directs de la réponse (e.g., la situation), (b) celles axées sur les antécédents indirects (e.g., les ressources attentionnelles), et (c) celles ciblant directement la réponse automatique (e.g., les tendances d’approche-évitement). Dans le cadre de cette thèse, nous avons testé l’efficacité de cette dernière stratégie en nous concentrant sur la modification des tendances d'approche-évitement envers l’activité physique, sans qu’une expérience physique soit nécessaire (e.g., Cheval et al., 2021 ; Maltagliati, Sarrazin, et al., 2024). Cette étude sera développée dans le Chapitre 8. Ces contributions ont permis de répondre à la deuxième question du projet doctoral en identifiant et testant des stratégies d’intervention visant à manipuler les variables affectives chez des personnes atteintes de maladies chroniques.

La troisième partie de ce travail doctoral a pour objectif d’identifier, de concevoir, de mettre en œuvre et d’évaluer l’efficacité d’interventions ciblant des variables affectives spécifiques afin d’augmenter le niveau d’activité physique quotidien chez des personnes atteintes de maladies chroniques. Cette phase représente la dernière étape (étape D, Figure 1) du modèle de la médecine expérimentale (Sheeran et al., 2017), visant à approfondir notre compréhension des mécanismes qui sous-tendent l’efficacité des interventions destinées à promouvoir l’activité physique auprès de cette population.

Tout d’abord, une revue systématique des études interventionnelles a été réalisée dans le but (a) d’identifier les variables affectives qui ont été manipulées expérimentalement dans les travaux antérieurs, et (b) de vérifier si les changements éventuels opérés sur ces variables ont entrainé des modifications significatives dans les niveaux d’activité physique, chez les personnes atteintes de maladies chroniques (**Contribution n°5**). Comme nous le verrons dans le Chapitre 7, cette revue a mis en lumière le faible nombre d’études sur le sujet (*N* = 13), la qualité médiocre et la grande hétérogénéité tant au niveau des méthodes de mesure que des stratégies d’intervention qui les caractérisent. Ensuite, dans le cadre d’un essai contrôlé randomisé en triple aveugle mené auprès de patient·es inclu·es dans un programme de réadaptation cardiovasculaire ambulatoire des Hôpitaux Universitaire de Genève, nous avons évalué l'efficacité d'une intervention digitale visant à réentraîner les tendances automatiques d'approche-évitement à l'égard de l'activité physique, en dehors de l'expérience qu'elles et ils pouvaient avoir avec l'activité physique. Cependant, le faible nombre de participant·es ayant complété le protocole (moins de 5 % de l'échantillon prévu) a limité notre capacité à tirer des conclusions robustes sur l'efficacité de l'intervention. Une analyse a été réalisée pour explorer les raisons du manque d'engagement et d'adhésion au protocole expérimental. Elle sera présentée sous forme d'un article d'opinion discutant des défis inhérents à ce type d'intervention et proposant des stratégies pour améliorer l'engagement dans de futurs protocoles (**Contribution n°6**). Enfin, dans une étude interventionnelle préliminaire intra-sujet, nous avons testé l'efficacité d'une intervention visant à manipuler l'intensité de l'effort à la fin de séances d'APA sur l'affect remémoré de chaque séance, les attitudes affectives, les évaluations affectives automatiques envers l'activité physique, et le niveau d'activité physique quotidien de patient·es atteints de la maladie de Parkinson (N = 7) (**Contribution empirique n°7**). Les patient·es ont été recruté·es dans la clinique La Lignière (Suisse). Les variables affectives ont été mesurées à l'aide de questionnaires (affect remémoré et attitudes affectives) et d'une tâche de temps de réaction (évaluations affectives automatiques), tandis que le niveau d'activité physique quotidien a été mesuré à l'aide d'accéléromètres. Ces contributions ont permis de répondre à la troisième question du projet doctoral en identifiant et testant des stratégies d'intervention ciblant des variables affectives dans le but d'augmenter les niveaux d'activité physique quotidiens chez des personnes atteintes de maladies chroniques.

Au total, 235 participant·es ont été recruté·es dans ce travail doctoral, issus de structures variées telles que les Hôpitaux Universitaires de Genève (Suisse), la clinique de réadaptation La Lignière (Suisse), et des associations en APA issues du bassin grenoblois (France). Tous·tes les participant·es atteint·es de maladies chroniques étaient intégré·es dans des programmes de réadaptation cardiovasculaire ou membres d'associations en APA. Les procédures de recrutement, ainsi que les méthodes de mesure et les analyses statistiques, sont détaillées dans chaque étude.

Les variables affectives et socio-cognitives, ont été récoltées à l'aide de questionnaires (**Contributions empiriques n°1, 2, et 7**), de tâches de temps de réaction réalisées sur ordinateurs et tablettes tactiles via le logiciel Inquisit® (**Contributions empiriques n°1, 2, et 7**). Les niveaux d'activité physique et de sédentarité ont été récoltés à l'aide de questionnaires auto-rapportés et d'accéléromètres (**Contributions empiriques n°1, 2, et 7**). Ces données ont été analysées en utilisant divers modèles statistiques, notamment des régressions linéaires (**Contributions empiriques n°1 et 2**), des régressions logistiques (**Contribution empirique n°1**), ainsi que des modèles linéaires mixtes (**Contribution empirique n°7**). Des analyses de modulation (**Contributions empiriques n°1 et 2**) et de médiation (**Contribution empirique n°2**) ont également été appliquées. De plus, la technique de l'inférence à l'œil nu (*inference by eyes* ; Cumming & Finch, 2005) a été employée pour comparer certaines tailles d'effet (**Contribution empirique n°2**).

Les résultats des analyses statistiques, les données récoltées et les matériels associés ont été rendus publiquement accessibles sur des plateformes dédiées, telles que Zenodo ou OSF (**Contributions n°1, 2, 4, 5, 6 et 7**). Les **Contributions n°5** et **7** ont, quant à elles, été préenregistrées. À l'exception de la revue narrative (**Contribution n°3**), publiée en français sous la forme d'un chapitre d'ouvrage, les autres contributions empiriques ont été rédigées en anglais et présentées sous forme d'articles scientifiques. Certains de ces articles ont déjà été acceptés (**Contributions empiriques n°1, et 7**), tandis que d'autres sont en préparation pour soumission (**Contributions n°2, et 4, 5 et 6**). Étant conçus pour être lus indépendamment, ces manuscrits peuvent présenter certaines redondances entre eux, ainsi qu'avec le cadre théorique des chapitres précédents. Toutes les références utilisées dans ces travaux sont listées à la fin de chaque article.

Tableau 1

Présentation des Contributions

Contribution	Objectif principal	N_{total}	Contexte	Devis de recherche	Analyses statistiques
1	Identifier l'association entre des variables motivationnelles et affectives et les niveaux quotidiens d'activité physique	119 adultes (68 patient·es et 51 contrôles) en Suisse Maladies cardiovasculaires, obésité, asthme, pré-diabète, hypertension	Service de réadaptation cardiovasculaire ambulatoire	Observationnel	Modèles de régressions linéaires et logistiques ; analyses de modulation
2	Identifier les associations entre des réponses affectives à différents moments d'une séance d'APA et les niveaux quotidiens ultérieurs d'activité physique	109 adultes atteints de maladies chroniques en France Maladies cardiovasculaires, obésité, hypertension, hypercholestérolémie, AVC, diabète, BPCO, cancer, ulcère gastroduodénal, maladies de Parkinson et d'Alzheimer, démence, sénilité, troubles affectifs, cataracte, ostéoarthrite, arthrite rhumatoïde	Associations en APA	Observationnel	Modèles de régressions linéaires ; analyses de modulation et de médiation ; inférence à l'œil nu (*inference by eyes*)
3	Identifier des stratégies d'interventions endogènes et exogènes ciblant les variables affectives, telles que les réponses affectives, l'affect remémoré et la réponse affective anticipée, dans le contexte de l'activité physique chez la population générale	N.a.	Population générale	Revue narrative	N.a.
4	Construire un protocole visant à identifier l'effet d'une intervention basée sur la musique (stratégie exogène) et le principe du « pic et de la fin » (stratégie endogène) sur des variables affectives (i.e., affect fondamental, affect remémoré, réponse affective anticipée) durant des séances d'APA	72 patient·es en Suisse Maladies cardiovasculaires	Service de réadaptation cardiovasculaire stationnaire	Expérimental prospectif (protocole de recherche)	Modèles linéaires mixtes ; analyses de modulation et de médiation

Continue

Tableau 1 *(Continue)*

Contribution	Objectif principal	N_{total}	Contexte	Devis de recherche	Analyses statistiques
5	Identifier dans la littérature antérieure l'efficacité des interventions visant à promouvoir l'activité physique en ciblant des variables affectives	13 études incluant 904 adultes atteint·es de maladies chroniques en France, Suisse, USA, Suède, Norvège, Chine et Australie Obésité, maladies cardiovasculaires, asthme, BPCO, hyperlipidémie, hypertension, troubles mentaux mineurs, sclérose en plaques, douleurs musculo-squelettiques, troubles locomoteurs, maladie de Parkinson, syndrome des ovaires polykystiques, apnée du sommeil, cancer du sein, diabète	Service de réadaptation hospitalier et prise en charge dans la vie quotidienne	Revue systématique	Analyses de risque de biais et de qualité des preuves
6	***Objectif initial*** Tester l'effet d'une stratégie d'intervention digitale ciblant les tendances d'approche-évitement sur les niveaux d'activité physique quotidiens chez des patient·es ***Objectif final*** Rédaction d'une lettre d'opinion discutant des défis inhérents à ce type d'intervention et les solutions potentielles pour y faire face	68 patient·es en Suisse Maladies cardiovasculaires, obésité, asthme, pré-diabète, hypertension	Service de réadaptation cardiovasculaire ambulatoire	Essai contrôlé randomisé en triple aveugle	Analyses de puissance *post hoc*
7	Tester l'effet du principe du pic et de la fin (une stratégie endogène) lors de séances d'APA, sur les variables affectives réfléchies et automatiques, et les niveaux d'activité physique quotidien	7 patient·es atteints de la maladie de Parkinson, en Suisse	Clinique privée de réadaptation	Expérimental longitudinal (3 temps de mesure)	Modèles linéaires mixtes

Note. APA = activité physique adaptée ; AVC = accident vasculaire cérébral ; BPCO = bronchopneumopathie chronique obstructive.

Chapitre 5 **Variables affectives et activité physique chez les personnes atteintes de maladies chroniques**

« What if our patients were given a prescription bottle that required 30 minutes of twisting the cap, each day, just to get to the medicine? Although intention might be high, the arduous nature of the prescription could negatively affect subsequent behavior. » Faries (2016, p. 322).

5.1 Contribution empirique n°1

Cette citation tirée, de l'article « Why We Don't "Just Do It": Understanding the Intention-Behavior Gap in Lifestyle Medicine » de Mark Faries (2016) souligne la limite de l'intention dans l'engagement dans des activités physiques régulières chez les patient·es. Il est donc essentiel de déterminer les variables psychologiques associées à cet engagement chez cette population. La première Contribution empirique avait pour objectif d'analyser les niveaux quotidiens d'activité physique et de sédentarité, mesurés par accéléromètres sur une semaine, chez des patient·es ayant terminé un programme de réadaptation cardiovasculaire ambulatoire. Elle examinait également les corrélats motivationnels (capacités perçues, attitudes instrumentales, intention) et affectifs (attitudes affectives, tendances d'approche-évitement, anxiété, symptômes dépressifs, fatigue, intensité de la douleur) de ces comportements. Les résultats ont été comparés à ceux d'un groupe témoin (ou « contrôle ») ne présentant pas de maladie chronique. Un total de 119 participant·es (68 patient·es et 51 contrôles) ont été recruté·es dans le canton de Genève (Suisse). Les données ont été analysées à l'aide de modèles de régression linéaire et logistique. Il convient de noter que certaines terminologies mobilisées dans cette Contribution empirique diffèrent de celles utilisées dans ce travail doctoral. Notamment, la variable « capacités perçues » *(perceived capabilities)* mesurée dans cette Contribution renvoie à la capacité perçue de s'engager dans des activités physiques quotidiennes, concept similaire au sentiment d’efficacité personnelle (Bandura, 1977) ou au contrôle comportemental (Ajzen, 1991) (Rhodes et al., 2022 ; Williams & Rhodes, 2016). De plus, le terme « processus délibératifs » *(deliberative processes)* utilisé dans cette Contribution correspond aux « processus réfléchis » mentionnés dans ce travail doctoral. Enfin, cette Contribution regroupe les attitudes affectives et les tendances d'approche-évitement sous les corrélats « motivationnels » des comportements d’activités physiques et sédentaires ; et l'anxiété, les symptômes dépressifs, la fatigue, ainsi que l'intensité de la douleur sous les corrélats « émotionnels ». Cette distinction repose sur la nomenclature spécifique au questionnaire utilisé pour mesurer ces variables, le Système d'Information sur la Mesure des Résultats Rapportés par les Patient·es (PROMIS ; Ader, 2007).

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Motivational and emotional correlates of physical activity and sedentary behavior after cardiac rehabilitation: an observational study

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Abstract

Background The present study assessed physical activity (PA) and sedentary behavior (SB) levels and their motivational and emotional health-related correlates, in outpatients following a cardiovascular rehabilitation (CR) program, and compared these variables with those of a healthy control group.

Methods The study included 119 participants: 68 CR outpatients (M_{age} 57.76 ± 10.76; 86.76% males) and 51 control participants matched on age (M_{age} 57.35 ± 6.33 years; 45.10% males). PA and SB were assessed using accelerometers during the first week post-discharge for outpatients and during a typical week for controls. Motivational (i.e., perceived capabilities, affective and instrumental attitudes, intention, approach-avoidance tendencies) and emotional health-related variables (i.e., anxiety, depressive symptoms, fatigue, pain intensity) were measured using validated scales. PA and SB data from 17 outpatients and 42 controls were valid for analysis, resulting in a final sample of 59 participants.

Results CR outpatients engaged an average of 60.21 (± 34.79) min of moderate-to-vigorous PA (MVPA), and 548.69 (± 58.64) min of SB per day, with 18 more minutes of MVPA per day than controls (p = .038). Univariate and multivariate regressions indicated that positive affective attitudes were associated with higher MVPA (b = 10.32, R^2 = 0.07, p = .029), and that males spent more time in SB than females (b = 40.54, R^2 = 0.09, p = .045). Univariate and multivariate logistic regressions showed that meeting the World Health Organization's weekly guidelines for MVPA was associated with higher perceived capabilities toward PA and more positive affective attitudes (OR = 1.17, p = .030; OR = 1.26, p < .001, respectively). Interaction tests showed no significant differences in these results between outpatients and controls.

Conclusion The study highlights an association between higher perceived capabilities and positive affective attitudes toward PA with higher PA levels after outpatient CR. While these findings suggest that enhancing these motivational variables may be beneficial for increasing PA levels after CR, longitudinal and experimental studies are needed to further establish their role.

Keywords Exercise, Physical inactivity, Patients, Motivation, Health

Introduction

Physical activity (PA), defined as “any bodily movement produced by skeletal muscles that results in energy expenditure [1]”, is a cornerstone of cardiac rehabilitation (CR) programs [2, 3]. Exercise-based CR has demonstrated numerous benefits, including improved exercise capacity, enhanced quality of life, reduced cardiovascular mortality, and a lower risk of hospital readmission [3, 4]. In contrast, sedentary behavior (SB), defined as any waking behavior characterized by an energy expenditure ≤1.5 Metabolic Equivalent Tasks, such as sitting and lying down [5], has been associated with various adverse health outcomes. For instance, patients with coronary artery disease who engage in high levels of SB (4–8 hours per day) face a 62% higher mortality rate than those with less than 4 hours of SB per day [6]. While CR programs aim to increase PA and reduce SB, many patients continue to exhibit low PA and high SB levels after discharge [7-9]. For example, six months after discharge, only 20% of CR patients met the PA guidelines of 150–300 minutes of moderate-to-vigorous PA (MVPA) per week [7, 10]. Additionally, Bakker et al. [9] found that cardiovascular disease patients exhibited higher SB levels both before and up to 2 months after CR compared to healthy controls. Despite the independent health effects of PA and SB [11-13], few studies have examined these behaviors concurrently. Therefore, assessing PA and SB levels in patients after CR discharge and identifying their correlates is essential.

From a dual-process perspective, two types of psychological processes are thought to influence PA behavior [14-16]. The first, deliberative processes, are intentional, effortful, controllable, or conscious [17, 18]. The second, automatic processes, are typically unconscious, effortless, unintentional, or uncontrollable [18, 19]. Contemporary theoretical frameworks of PA behavior assert that both deliberative variables (e.g., intention, perceived capabilities, attitudes) and automatic variables (e.g., approach-avoidance tendencies), along with emotional variables (e.g., fear, anxiety), play a central role in shaping PA behavior [14-16, 20]. For example, the Affect and Health Behavior Framework (AHBF) [20, 21] posits that conflicts between motivational variables—such as between the intention to be physically active and automatic tendencies toward SB—can generate negative emotional states such as fear or anxiety, which may hinder regular PA engagement. In the context of CR, Bierbauer et al. [8] found that stronger PA intentions were associated with higher levels of PA after discharge. Similarly, Bermudez et al. [2] reported that CR patients with more positive affective attitudes toward PA (i.e., viewing PA as pleasant) had higher PA intention and engaged in more light-intensity PA after discharge. Recent research also suggests that automatic motivational variables may further explain PA engagement. For instance, Chevance et al. [22] showed that a positive automatic affective evaluation of PA was significantly associated with higher PA levels (β = .29) after pulmonary rehabilitation. More recently, Cheval et al. [23] proposed that approach-avoidance tendencies—the automatic preparation of the organism to execute a motor response toward a behavior [24]—may partly account for PA participation following CR programs.

In addition to motivational variables, the presence of depression, anxiety, or pain has also been linked to lower levels of PA following a CR program [7]. For patients with advanced cancer, chronic kidney disease, and chronic obstructive pulmonary disease, perceived fatigue is a significant barrier to PA [25-27]. However, the relationship between fatigue, PA, and SB in patients with cardiovascular disease after CR discharge remains unclear. Overall, these studies suggest that a comprehensive perspective on PA and SB levels after CR should include both deliberative and automatic motivational variables, as well as emotional health-related variables. Despite this, the role of automatic motivational processes in regulating PA and SB among cardiovascular patients has been largely overlooked. Furthermore, while previous research has shown that emotional health-related variables are associated with PA levels [7], the relationship between these variables and SB levels remains poorly understood.

The primary objective of this study was to assess accelerometer-based PA and SB levels during the first week following a 6-week outpatient CR program. In addition, the study aimed to examine psychological factors associated with PA and SB, including motivational variables (i.e., intention, perceived capability, attitudes, and approach-avoidance tendencies) and emotional health-related variables (i.e., depressive symptoms, anxiety, fatigue, and pain intensity). A secondary objective was to compare PA and SB levels, as well as associated motivational and emotional variables, between CR outpatients and a healthy control population to understand potential differences in these factors between the two populations [23, 28].

Methods

Study Design and Participants

The sample size was initially estimated to ensure adequate power for detecting effects in the Improving Physical Activity (IMPACT) trial, as detailed in the IMPACT trial protocol [23]. The IMPACT trial, carried out at Geneva University Hospitals (Switzerland), was a phase 3 single-center, placebo, triple-blind randomized controlled trial that enrolled participants from an outpatient CR program. The components of the CR program are described in Supplementary Material 1. The study was approved by the Ethics Committee of Geneva Canton, Switzerland (reference number: CCER2019-02257).

For the present study, a dataset comprising 68 CR outpatients was analyzed. Additionally, 51 community-dwelling control participants were recruited through snowball sampling. Community-dwelling participants were eligible if they were 40 years or older, matched the minimum age of the outpatients, had no contraindications to PA, and were not receiving medical care. PA and SB levels were measured using accelerometer (Actigraph GT3x+; Pensacola, USA) over seven consecutive days following discharge from the CR program for outpatients and during a similar period for control participants. Motivational and emotional health-related variables were assessed prior to measuring PA and SB for all participants.

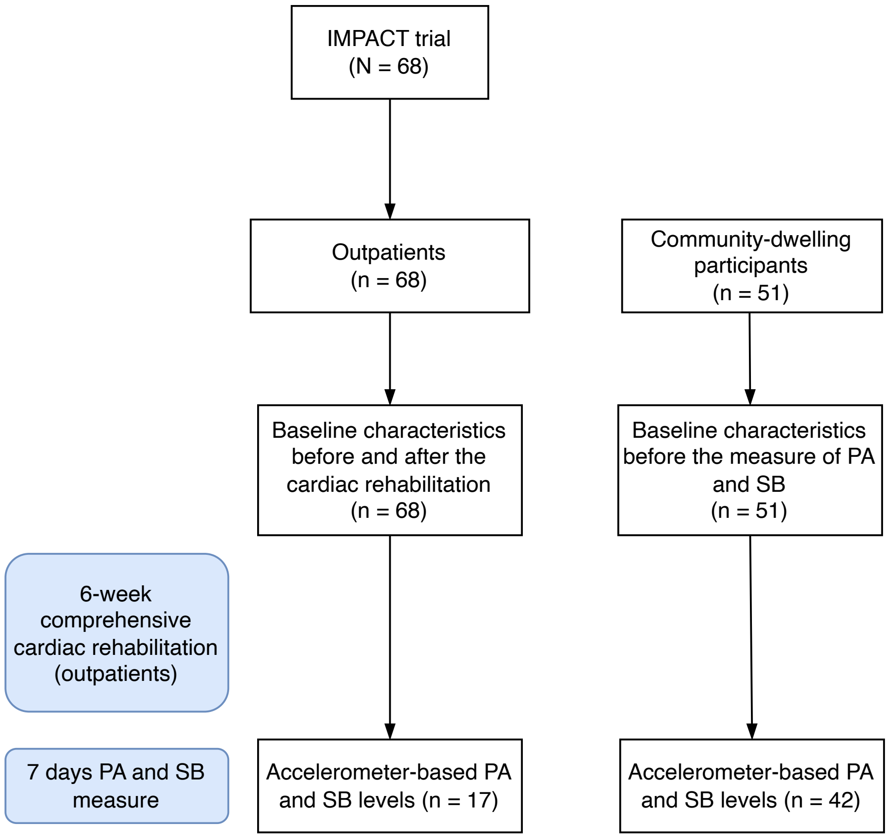
Measures

Physical Activity and Sedentary Behavior Outcomes

Usual levels of PA, defined as the amount of time spent being physically active during a typical week of free time, were assessed using the Saltin-Grimby PA Level Scale [29]. Outpatients reported their PA levels for a typical week before the onset of the health issue that necessitated the CR. Participants were categorized into one of four groups: (a) physically inactive, (b) engaging in some PA, (c) engaging in regular PA, or (d) engaging in regular high-intensity training.

Participants were instructed to wear the accelerometer only during waking hours. Data were included if the device was worn for at least 10 hours per day [30]. The Troiano (2007) algorithm, implemented in Actilife software (v. 6.13.3), was used to distinguish between wear and non-wear time. Self-reported diaries documenting the start and end times of wear were used to validate the algorithm's output. Data were included if at least four days met these criteria, including one weekend day [31]. Any participants who did not meet these criteria were excluded from the subsequent analyses. Additionally, daily PA and SB levels were self-reported using the short form of the International Physical Activity Questionnaire [32]. Accelerometer-based daily time spent engaging PA was categorized into light, moderate, vigorous, and moderate-to-vigorous intensity, with the number of steps also recorded. Accelerometer-based daily time spent in SB was used as an indicator of SB levels. The complete R script utilized for data management and analysis is accessible on Zenodo (https://doi.org/10.5281/zenodo.11064184).

Figure 1. Flow Diagram of the Study Protocol



Abbreviations: PA, physical activity; SB, sedentary behavior. The data for outpatients comes from the Improving Physical Activity (IMPACT) trial [23]. Outpatients followed a CR program that included exercise sessions every weekday for six weeks (see Supplementary Material 1 for further details). In addition, the program included 12 therapeutic patient education sessions addressing lifestyle modification, dietary advice, smoking cessation, stress management, and psychological support. Baseline characteristics included demographics and anthropometrics information, usual level of PA, number of limitations in activities of daily living, of limitations in instrumental activities of daily living), mobility, motivational and health-related variables, and health-related information.

Motivational Variables

Perceived capabilities to engage in PA was assessed using the following item from the Patients-Reported Outcomes Measurement Information System (PROMIS [33]): “To what extent are you able to perform daily physical activities such as walking, climbing stairs, or moving a chair?”. Participants answered on a scale from 1 (not at all) to 5 (completely).

Intention to be physically active was assessed using the following item: “I intend to do more PA in the near future [23].” Participants answered on a scale from 1 (totally disagree) to 10 (totally agree).

Instrumental and affective attitudes were assessed using the following two items “Would you say PA is something …”. Participants answered each item on a scale from 1 (useless) to 10 (useful) for instrumental attitudes, and from 1 (unpleasant) to 10 (pleasant) for affective attitudes [34, 35].

Automatic approach-avoidance tendencies toward PA and SB were assessed using the Visual-Approach/Avoidance-by-the-Self-Task (VAAST [36]). The VAAST protocol is explained in more detail in Supplementary Material 2.

Emotional Health-Related Variables

Anxiety, depression, fatigue, and pain intensity were assessed using PROMIS items. Anxiety was assessed using the following two items: “In the past 7 days, I felt scared” and “In the last 7 days, I found it hard to focus on anything other than my anxiety." Participants answered each item on a scale from 1 (never) to 10 (always). Items were averaged (Pearson correlation = 0.61).

Depression was assessed using the following four items: “In the past 7 days, I felt..." "useless," "powerless," "desperate," and "depressed." Participants answered each item on a scale from 1 (never) to 10 (always). The items were averaged (Cronbach's α = 0.81).

Fatigue was assessed using the following three items: “In the past 7 days, I felt tired," “In the last 7 days, I had a hard time starting things because I felt tired," and “In the past 7 days, how tired do you feel on average?”. Participants answered each item on a scale from 1 (not at all) to 5 (very much). The items were averaged (Cronbach's α = 0.90).

Pain intensity was assessed using the following item: "How would you rate your average pain level?". Participants answered on a scale from 1 (no pain) to 5 (worst pain imaginable).

Measures of additional health-related variables such as perceived mobility, limitations in activities of daily living, limitations in instrumental activities of daily living, global physical and mental health, life satisfaction, indication for enrollment in the outpatient CR, left ventricular ejection fraction (LVEF), maximal aerobic power (MAP), abdominal circumference, glycated hemoglobin (HbA1c), triglycerides, low-density lipoprotein (LDL)-cholesterol, blood pressure, smoking, and the presence of comorbidity are described in Supplementary Material 3.

Statistical Analyses

Descriptive Statistical Analyses

First, we conducted descriptive analyses of the participants' characteristics and compared them between the outpatient and control participants using independent t tests for numerical variables and chi-squared tests for categorical variables. Second, we compared outpatients' motivational and health-related characteristics measured at the beginning and end of the CR program using independent t tests. Third, we estimated the levels of PA and SB for seven consecutive days during the week following discharge from the CR program for the outpatients and for seven consecutive days for control participants. Fourth, we compared the levels of PA and SB in outpatients with those in control participants using independent t tests.

Univariate and Multivariate Regression Analyses

First, we conducted univariate and multivariate regression analyses to examine the associations of motivational (i.e., perceived capabilities to engage in PA, intention to engage in PA, instrumental and affective attitudes toward PA, and approach-avoidance tendencies) and emotional health-related variables (i.e., depressive symptoms, anxiety, fatigue, and pain intensity) with PA and SB levels. Outpatients' motivational and emotional health-related variables measured at the end of the CR were used in the univariate and multivariate analyses. In the univariate and multivariate regression analyses, interaction terms were tested between participant type (i.e., outpatient vs. control) and the motivational and emotional health-related variables to examine whether the associations of motivational and emotional health-related variables with the levels of PA and SB differed between outpatients and control participants. The independent variables were standardized. Finally, logistic regression analyses were conducted to determine the odds ratio associated with meeting the recommended level of PA (i.e., 150 min of MVPA per week [10]) based on the motivational and emotional health-related variables. Statistical assumptions, including normality of residuals, linearity, multicollinearity, and undue influence, were checked, and met for all models using the Performance R package [37].

Results

Descriptive results

Table 1 presents the results of the sample characteristics. A total of 119 participants (68 outpatients enrolled in an CR program [86.76% males; Mage = 57.76 ±10.76 years] and 51 community-dwelling control participants [45.10% males; Mage = 57.35 ±6.33 years]) were included in the study. The mean outpatients LVEF was 52.87% (±10.49), and most outpatients were enrolled in the CR program for acute coronary syndrome (40.30% non-ST elevation and 26.87% ST elevation). Before the cardiovascular event that led to CR, outpatients self-reported significantly lower PA levels than control participants. At the beginning of the CR program, outpatients also reported significantly higher perceived fatigue. Additionally, outpatients self-reported a significantly higher number of IADLs, greater difficulty with mobility, lower global physical and mental health, and life satisfaction compared to control participants. Regarding PA-related deliberative motivational variables, outpatients had significantly lower perceived capabilities and less positive affective attitudes toward PA at the start of the CR program compared to controls. However, no statistically significant differences were observed in automatic approach-avoidance tendencies toward PA and SB between outpatients and control participants.

Table 1. Descriptive Characteristics of the Outpatients at the Beginning of the Cardiac Rehabilitation Program and Before the Physical Activity Measures for the Community-Dwelling Participants

Characteristics N = 119	**Outpatients N = 68 (42.2%)**	**Controls N = 51 (31.7%)**	
	M (SD)	M (SD)	*P* value*
Demographics and anthropometrics			
Sex (*n*, %)			
Female	9 (13.24%)	28 (54.90%)	
Male	59 (86.74%)	23 (45.10%)	<.001
Age (years, *n*, %)			
<50	14 (20.90%)	5 (9.80%)	
50–59	25 (37.31%)	31 (60.78%)	
60–69	17 (25.37%)	12 (23.53%)	
70–79	10 (14.93%)	3 (5.88%)	
>80	1 (1.49%)	0 (0%)	.074
Body mass index (Kg/m^2; *n*, %)			
Underweight <18.5	0 (0%)	2 (3.92%)	
Normal 18.5–<25	19 (27.79%)	25 (49.01%)	
Overweight 25–<30	30 (45.45%)	19 (37.25%)	
Obese ≥ 30	17 (25.76%)	5 (9.80%)	.018
Usual level of PA (*n*, %)			
Physically inactive	18 (26.47%)	3 (6.38%)	
Some PA	28 (41.18%)	18 (38.30%)	
Regular PA	20 (29.41%)	23 (48.94%)	
High training	2 (2.94%)	3 (6.38%)	.020
Emotional health-related variables			
Anxiety [1–5]	1.79 (0.90)	1.60 (0.87)	.243
Depressive symptoms [1–5]	1.62 (0.76)	1.58 (0.74)	.722
Fatigue [1–5]	2.55 (1.06)	2.01 (0.85)	.003
Pain intensity [1–5]	2.10 (2.29)	1.62 (1.89)	.226
Additional health-related variables			
Number of ADL (*n*, %)			
No ADL	59 (86.76%)	44 (97.78%)	
>1 ADL	9 (13.24%)	1 (2.22%)	.094
Number of IADL (*n*, %)			
No IADL	49 (72.13%)	41 (83.67%)	
>1 IADL	18 (26.87%)	8 (16.32%)	.026
Mobility	3.70 (0.54)	3.95 (0.23)	.002
Global physical health [1–5]	2.88 (0.89)	3.69 (0.82)	<.001
Global mental health [1–5]	3.77 (0.98)	4.10 (0.76)	.046
Life satisfaction [1–7]	5.68 (1.26)	6.24 (0.66)	.005

Continued

Table 1. (*Continued*)

Characteristics N = 119	**Outpatients N = 68 (42.2%)**	**Controls N = 51 (31.7%)**	
	M (SD)	M (SD)	*P* value*
LVEF (%)	52.87 (10.49)	Na.	
MAP (Watt)	141.08 (45.08)	Na.	
Abdominal circumference (cm)	99.31 (12.02)	Na.	
HbA1c (%)	5.69 (0.74)	Na.	
Triglycerides (mmol/L)	1.59 (1.08)	Na.	
LDL (mmol/L)	2.94 (1.25)	Na.	
Systolic blood pressure (mmHg)	126.10 (14.64)	Na.	
Diastolic blood pressure (mmHg)	72.49 (8.29)	Na.	
Cigarette (pack/year)	10.82 (14.85)	Na.	
Comorbidity (*N* = 67, *n*, %)		Na.	
0	9 (13.43%)	Na.	
1	18 (26.87%)	Na.	
≥ 2	40 (59.70%)	Na.	
Indication for enrollment in the outpatient CR (*N* = 67, *n*; %)			
Acute coronary syndrome NSTEMI	27 (40.30)	Na.	
Acute coronary syndrome STEMI	18 (26.87)	Na.	
Acute coronary syndrome UA	4 (5.97)	Na.	
Coronary artery bypass graft surgery	7 (10.45)	Na.	
Coronary artery disease without ACS or surgery	8 (11.94)	Na.	
Heart failure	2 (2.99)	Na.	
Valvular surgery	1 (1.49)	Na.	
Motivational variables			
Perceived capabilities [1–5]	4.21 (0.97)	4.90 (0.36)	<.001
Intention [1–10]	5.51 (1.34)	4.99 (1.50)	.053
Instrumental attitudes [1–10]	9.09 (1.42)	9.36 (1.55)	.325
Affective attitudes [1–10]	8.16 (2.06)	8.96 (1.60)	.024
Approach toward PA	-34.22 (109.97)	-20.82 (63.82)	.461
Approach toward SB	8.98 (102.38)	-20.59 (77.78)	.111

Abbreviations: M, mean; SD, standard deviation; PA, physical activity; ADL, limitations in activities of daily living; IADL, limitations in instrumental activities of daily living; CR; cardiac rehabilitation; NSTEMI, non-ST elevation myocardial infarction; STEMI, ST elevation myocardial infarction; UA, unstable angina; ACS, acute coronary syndrome; LVEF, left ventricular ejection fraction; MAP, maximal aerobic power; HbA1c, fasting glycated hemoglobin; LDL, low-density lipoprotein-cholesterol; SB, sedentary behaviors. Usual level of PA was assessed with the Saltin-Grimby PA Level Scale. The LVEF is considered to fall within the normal range when it is between 50% and 70% [92]. A waist circumference greater than 95 cm for men and 80 cm for women is associated with an increased risk of all-cause mortality [93]. HbA1c levels are classified as normal, or within the non-diabetic range below 5.7% [94]. Triglycerides levels are considered normal if they are below 1.7 mmol/L [95]. LDL cholesterol levels are desirable if they are below 1.8 mmol/L for individuals with coronary artery disease or other forms of atherosclerosis, and below 2.6 mmol/L for healthy individuals [96]. Systolic blood pressure is considered high if it exceeds 129 mmHg, and diastolic blood pressure is considered high if it exceeds 79 mmHg [97]. A positive score in *Approach toward PA* suggests a tendency to approach PA, while a negative score suggests a tendency to avoid PA. A positive score in *Approach toward SB* suggests a tendency to approach PA, while a negative score suggests a tendency to avoid PA. **P*-value of the difference between the outpatients and control participants.

Physical Activity and Sedentary Behavior Levels One Week After the Cardiac Rehabilitation

Table 2 presents the PA and SB levels for the outpatients and control participants. Valid PA and SB accelerometer data were available for only 17 out of 68 outpatients and 42 out of 51 control participants (see Figure 1 for the flow diagram). Consequently, PA and SB levels were analyzed for 59 participants. The results showed that, on average, outpatients spent 548.69 minutes (±58.64) per day in SB, 211.16 minutes (±60.83) in light-intensity PA, 57.85 minutes (±34.68) in moderate-intensity PA, and 2.28 minutes (±3.67) in vigorous-intensity PA, during the week following CR. Thus, on average, outpatients spent 60.21 (±34.79) min per day in MVPA, with 88.2% of them meeting the recommended weekly level of 150 min of MVPA. Control participants displayed a similar overall pattern, although they spent slightly more time in light-intensity PA (253.77 ±69.11, p = .035) and slightly less time in moderate-intensity PA (37.46 ±25.03, p = .014). On average, control participants spent significantly less time (41.78 ±2.088, p = .038) per day in MVPA compared to outpatients, with 71.4% of them meeting the recommended 150 min per week of MVPA (p = .310). Finally, outpatients averaged 10,083.00 (±4,493) steps per day, while control participants averaged 8,785.02 (±3,424) steps per day. However, this difference was not statistically significant (p = .237).

Relationships of Motivational and Emotional Health-Related Variables with Physical Activity and Sedentary Behavior Levels

Accelerometer-based MVPA and sitting time (SB) were used in the primary analyses, while accelerometer-based steps per day, self-reported MVPA, and self-reported time spent sitting were included in the secondary analyses (see Supplementary Materials 4 and 5, Tables S1, S2, and S3). Table 3 presents the results from both univariate and multivariate regression analyses.

Table 2. Averaged Daily Physical Activity and Sedentary Behavior Levels During the First Week After the Cardiac Rehabilitation Program and During a Usual Week for the Community-Dwelling Participants

Levels (min/day)	**Outpatients (N = 17*)**	**Controls (N = 42*)**	
	M (SD)	M (SD)	*P* value**
Sedentary behavior	548.69 (58.64)	552.26 (78.25)	.866
Light activity	211.16 (60.83)	253.77 (69.11)	.035
Moderate activity	57.85 (34.68)	37.46 (25.03)	.014
Vigorous activity	2.28 (3.67)	3.66 (7.80)	.490
MVPA	60.21 (34.79)	41.78 (28.08)	.038
Number of steps	10083.00 (4493.27)	8785.02 (3424.07)	.237
Meeting the weekly recommended level (150 min MVPA); *n* (%)	15 (88.24%)	30 (71.43%)	.310

Abbreviations: M, mean; SD, standard deviation; MVPA, moderate-to-vigorous physical activity. *The sample size was reduced because some participants did not complete all the measures. ***P* value of the difference between the different participant types (outpatients vs. controls). Recommendation is of at least 150 min of MVPA per week [10].

Deliberative motivational variables. The univariate analyses (Table 3) showed that outpatients engaged in more daily MVPA compared to controls (b =18.43, 95% CI [1.10; 35.77], R^2 adjusted = 0.06, p = .038). Additionally, affective attitudes toward PA were positively associated with daily MVPA (b =10.32, 95% CI [1.09; 19.55], R^2 adjusted = 0.07, p = .029). No other significant associations with daily MVPA were found. Higher perceived capabilities to engage in PA (OR =1.17, 95% CI [1.02; 1.34], p = .030), stronger instrumental (OR =1.11, 95% CI [1.03; 1.19], p = .006), and affective attitudes toward PA (OR =1.26, 95% CI [1.12; 1.41], p <.001) increased the likelihood of meeting the recommended 150 min of weekly MVPA. No significant interactions were observed between PA or SB correlates and participant type (i.e., outpatient vs. control; ps >.05, see Supplementary Material 6, Table S4).

In the multivariate analyses, affective attitudes remained significantly associated with daily MVPA (b =10.15, 95% CI [1.21; 19.09], p = .049) after adjusting for participant type. This model explained 12% of the variance in daily MVPA. Finally, after controlling for instrumental attitudes and participant type, perceived capabilities (OR = 1.19, 95% CI [1.05; 1.35], p = .007) and affective attitudes toward PA (OR =

1.24, 95% CI [1.06; 1.45], p = .011) remained significantly associated with an increased likelihood of meeting the recommended 150 min of MVPA per week. However, instrumental attitudes were no longer significant (p = .804). No significant interactions were observed between PA or SB correlates and participant type (i.e., outpatient vs. control; ps >.05, see Supplementary Material 6, Table S4).

Automatic motivational variables. The univariate analyses (Table 3) showed no significant associations between automatic approach tendencies toward PA (b =2.60, 95% CI [-4.79; 9.99], p = .484) or SB (b =5.50, 95% CI [-1.59; 12.60], p = .0126) and daily MVPA. Similarly, no significant associations were observed between automatic approach tendencies toward PA (b =-4.73, 95% CI [-24.47; 15.02)], p = .633) or SB (b =-16.24, 95% CI [-35.05; 2.57], p = .089), and daily SB.

Emotional health-related variables. The univariate analyses (Table 3) showed that sex (ref. female; b = 47.54, 95% CI [11.41; 83.67], R^2 adjusted = 0.09, p = .011) and pain intensity (b = -20.44, 95% CI [-38.66; -2.22], R^2 adjusted = 0.07, p = .029) were associated with daily SB. In multivariate analyses, sex remained associated with daily SB (ref. female, b = 40.47, 95% CI [1.02; 79.92], p = .045) after controlling for pain intensity (b = -14.19, 95% CI [-33.13, 4.74], p = .139) and participant type (b = -17.49, 95% CI [-59.14; 24.17], p = .045). This model explained 10% of the variance in daily SB.

Table 3. Associations of Motivational and Emotional Health-Related Variables with Physical Activity and Sedentary Behavior Levels for One Week

Outcome: daily MVPA	**Univariate models (N =59)**		**Multivariate model (N =59)**	
	b (95% CI)	*P* value	b (95% CI)	*P* value
Intercept			40.66 (31.55; 49.77)	<.001
Participant type (ref. controls)				
Outpatients	18.43 (1.10; 35.77)	.038	18.81 (1.58; 36.05)	.047
R^2 adjusted	0.06			
Age	-0.32 (-10.76; 10.12)	.951		
Sex (ref. Female)				
Male	0.90 (-15.5; 17.2)	.917		
Body mass index	-4.47 (-14.23; 5.30)	.364		
Intention toward PA	3.94 (-3.96; 11.83)	.322		
Perceived capabilities toward PA	8.52 (-1.96, 18.99)	.109		
Instrumental attitudes	3.74 (-3.82; 11.30)	.326		
Affective attitudes	10.32 (1.09; 19.55)	.029	10.15 (1.21; 19.09)	.049
R^2 adjusted	0.07			
Approach toward PA	2.60 (-4.79; 9.99)	.484		
Approach toward SB	5.50 (-1.59, 12.60)	.126		
Depressive symptoms	1.02 (-7.77, 9.81)	.817		
Anxiety	-0.40 (-8.79; 7.99)	.924		
Fatigue	-3.18 (-13.64; 7.29)	.546		
Pain intensity	-4.02 (-12.10; 4.06)	.323		
R^2 adjusted for the multivariate model			0.12	

Continued

Table 3. (*Continued*)

Outcome: daily SB	**Univariate models (*N* = 59)**		**Multivariate models (*N* = 59)**	
	b (95% CI)	*P* value	b (95% CI)	*P* value
Intercept			534.90 (506.75; 563.03)	<.001
Participant type (ref. control)				
Outpatients	-3.57 (-45.75; 38.61)	.866	-17.49 (-59.14; 24.17)	.404
Age	-0.38 (-24.84; 24.07)	.975		
Sex (ref. Female)				
Male	47.54 (11.41; 83.67)	.011	40.47 (1.02; 79.92)	.045
R^2 adjusted	0.09			
Body mass index	0.14 (-22.90; 23.19)	.999		
Intention toward PA	-8.88 (-27.21; 9.46)	.336		
Perceived capabilities toward PA	11.17 (-13.68; 36.02)	.372		
Instrumental attitudes	-3.05 (-20.84; 14.74)	.732		
Affective attitudes	-15.07 (-37.20; 7.06)	.178		
Approach toward PA	-4.73 (-24.47; 15.02)	.633		
Approach toward SB	-16.24 (-35.05; 2.57)	.089		
Depressive symptoms	-0.56 (-21.08; 19.97)	.957		
Anxiety	-3.85 (-23.41; 15.70)	.695		
Fatigue	-11.45 (-35.77; 12.88)	.350		
Pain intensity	-20.44 (-38.66; -2.22)	.029	-14.19 (-33.13; 4.74)	.139
R^2 adjusted	0.07			
R^2 adjusted for the multivariate model			0.10	

Continued

Table 3. (*Continued*)

Outcome: meeting the recommended levels of MVPA	**Univariate models (N = 59)**		**Multivariate models (N = 59)**	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Intercept			1.90 (1.69; 2.13)	<.001
Participant type (ref. control)				
Outpatients	1.18 (0.93; 1.50)	.175	1.23 (0.99; 1.51)	.066
Age	1.02 (0.88; 1.17)	.809		
Sex (ref. Female)				
Male	1.10 (0.88; 1.37)	.415		
Body mass index	0.91 (0.80; 1.03)	.153		
Intention toward PA	1.10 (0.99; 1.22)	.090		
Perceived capabilities toward PA	1.17 (1.02; 1.34)	.030	1.19 (1.05; 1.35)	.007
Instrumental attitudes	1.11 (1.03; 1.19)	.006	1.02 (0.90; 1.15)	.804
Affective attitudes	1.26 (1.12; 1.41)	<.001	1.24 (1.06; 1.45)	.011
Approach toward PA	0.98 (0.87; 1.10)	.678		
Approach toward SB	1.07 (0.95; 1.19)	.278		
Depressive symptoms	1.01 (0.90; 1.14)	.836		
Anxiety	1.01 (0.91; 1.13)	.817		
Fatigue	1.06 (0.92; 1.22)	.430		
Pain intensity	1.00 (0.89; 1.11)	.957		

Abbreviations: PA, Physical activity; SB, sedentary behaviors; MVPA, Moderate-to-vigorous PA; 95% CI, Confidence interval at 95%; OR, odd ratio. The adjusted model includes only the significant predictors of the univariate models, with the exception of the participants type (i.e., patients versus control) which was adjusted for. The recommended levels of MVPA have been set at greater than or equal to 150 min of MVPA per week [10]. The R^2 adjusted was calculated only for statistically significant predictors.

Sensitivity Power Analyses

Following Lakens' recommendations [38], we plotted a sensitivity curve for a linear univariate regression with an alpha level of .05 and a sample size of 59 participants (i.e., those with complete accelerometer-based data). This curve allowed us to assess the effect sizes detectable across a range of desired power levels, from 33% (considered the lower threshold for insufficient power) [38, 39] to 90%. For univariate regression, the sensitivity curve indicated that our study had between 33% and 90% power to detect effect sizes ranging from f^2 = 0.04 (or R^2 = .04) to f^2 = 0.18 (or R^2 = .16). For a multivariate regression with two predictors (i.e., affective attitudes and participant type), the sensitivity curve showed that our study had between 33% and 90% power to detect effect sizes ranging from *f*2 = 0.06 (or R^2 = .06) to *f*2 = 0.25 (or R^2 = .20). For a multivariate regression with three predictors (i.e., sex, pain intensity, and participant type), the sensitivity curve demonstrated that our study had between 33% and 90% power to detect effect sizes ranging from f^2 = 0.07 (R^2 = .06) to f^2 = 0.29 (R^2 = .23). Additionally, we plotted a sensitivity curve for a logistic regression with an alpha level of .05 and a sample size of 59 participants. This curve showed that, for a positive effect of the independent variable on PA and SB levels, our study had between 33% and 90% power to detect effect sizes ranging from OR =1.50 to OR = 2.70. Conversely, for a negative effect of the independent variable, the study had between 33% and 90% power to detect effect sizes ranging from OR = 0.66 to OR = 0.37. Sensitivity curves are available in Supplementary Material 7, Figures S1 and S2, and are further discussed in the Discussion section.

Discussion

The present study showed that, during the first week following discharge from CR, outpatients were significantly more physically active compared to control participants in a typical week. Furthermore, motivational variables such as perceived capabilities and affective attitudes toward PA were associated with higher PA levels, while males spent more time in SB than females. Notably, no emotional health-related variables were significantly associated with PA or SB. The finding of higher PA levels in CR outpatients compared to healthy controls suggests that the CR program is effective in promoting PA, at least in the short term. However, this conclusion should be interpreted cautiously, as the groups differ in key demographic and motivational variables.

During the first week post-discharge, 88.2% of outpatients achieved the recommended 150 minutes of MVPA per week. This aligns with the findings of Bierbauer et al. [8], who reported that around 70% of outpatients met PA recommendations within the first three weeks following a CR program. Additionally, our study found that outpatients engaged in 18 more minutes of MVPA per day than control participants ($p = .038$). Although Barker et al. [40] showed that individuals with cardiovascular disease are typically less active than community-dwelling individuals without chronic disease, Steca et al. [41] reported that the proportion of coronary outpatients achieving the recommended PA levels increased from 35.6% before CR to 60% six months post-discharge. These findings are likely due to the key components of the CR program, which actively encouraged outpatients to increase PA levels and reduce time spent in SB (Kohl et al.). In the present study, outpatients followed a CR program that included exercise sessions every weekday for six weeks (see Supplementary Material 1 for further details). These sessions were structured following the guidelines of the European Association of Preventive Cardiology, which emphasize the importance of strategies that enhance individual empowerment to improve self-efficacy, self-care, and motivation [42]. Additionally, the program included 12 therapeutic patient education sessions focused on lifestyle modifications, dietary advice, smoking cessation, stress management, and psychological support. These education sessions have been shown to improve patients' biological outcomes (e.g., body mass index [BMI]), adherence to treatment regimens, and psychological well-being [43]. Thus, this comprehensive approach may have created a nurturing environment that increased outpatient’s engagement in PA behaviors. Finally, the proportion of outpatients meeting PA guidelines in our study (88.2%) was higher than reported in the literature. This gap may be attributed to selection bias, as only 25% of the 68 outpatients wore an accelerometer for the entire week at the end of the six-week rehabilitation period.

At the start of CR, outpatients reported significantly lower perceived capabilities and affective attitudes toward PA, along with higher levels of depressive symptoms, fatigue, and pain, compared to control participants. These findings align with existing literature, which highlights the high prevalence of pain, discomfort, and depression among cardiac patients [7, 44]. Although we observed significant differences in certain deliberative motivational variables, such as perceived capabilities and affective attitudes, between outpatients and control participants, no differences were found in automatic approach-avoidance tendencies toward PA and SB between the groups. This result is challenging to compare with the literature, as no previous studies, to our knowledge, have directly investigated or compared automatic motivational variables between patients and control participants. However, it has been suggested that automatic motivational variables in patients may be negatively biased due to fear, pain, and discomfort experienced during exercise [23, 45, 46]. For instance, fear of PA, which is particularly pronounced in cardiac patients [47], may trigger automatic avoidance tendencies toward PA [48]. Several factors may explain the lack of observable differences in our study. First, outpatients participating in the IMPACT trial (a 6-week study designed to improve PA behavior [23]) may have been more motivated to engage in regular PA than outpatients who were not involved in the study. Notably, although outpatients and control participants differed in perceived capabilities and affective attitudes, both groups scored highly (> 4 out of 5 and > 8 out of 10, respectively). Second, previous research has consistently shown that healthy individuals typically exhibit a positive approach bias toward PA stimuli and a negative bias toward SB stimuli [49-53]. However, our findings—along with those of a recent fMRI study using the same approach-avoidance task that the one used in this study [54]—failed to replicate these effects. This discrepancy may be due to the specific nature of the task used in our study. Previous research has typically used an explicit approach-avoidance task in which participants responded to the content of the images, specifically approaching or avoiding depending on whether the stimuli depicted PA or SB. In contrast, our study used an implicit approach-avoidance task in which participants responded to the format of the images (portrait vs. landscape) regardless of content. The literature suggests that implicit evaluations generally yield smaller effect sizes than explicit evaluations [55]. Therefore, the reliance on format-based responses in our task may explain the lack of the expected approach tendencies toward PA and avoidance tendencies toward SB. Moreover, this feature may also explain why we did not observe differences in such tendencies between outpatients with cardiovascular disease and healthy participants.

No significant association was found between emotional health-related variables and accelerometer-based daily MVPA during the first week after discharge from CR, or during a typical week for control participants. Our findings of no associations between emotional health-related variables and PA contrast with existing theoretical and empirical evidence, which suggests that such variables including pain, fear, anxiety, depression, and fatigue are typically associated with reduce PA [7, 20, 21, 25-27]. According to the AHBF, fear is hypothesized to lead individuals to avoid activities associated with past negative experiences or perceived threats [20, 21]. For example, negative emotional experiences associated with PA could contribute to fear of engaging in such activities. However, the focus of our study was on general fear and anxiety experienced in the past week, rather than specific fears related to PA or "anxiety sensitivity", which refers to the fear of experiencing anxiety-related symptoms, such as increased heart rate and breathing difficulties [20, 21, 56]. This lack of specificity may have limited our ability to detect significant associations. In addition, it is worth noting that the interaction of emotional health with PA and SB is complex and may be influenced by several factors not fully captured in our study. The broader literature highlights that these relationships may be mediated by multiple variables, including the intensity and context of emotional experiences, as well as individual differences in coping mechanisms and PA history [20, 57, 58]. Future research should explore these interactions in greater depth, possibly using more nuanced and targeted measures, to better understand the role of emotional health in PA behavior. Empirically, Dagner et al. [7] found that patients with lower levels of anxiety and depression had higher odds of engaging in more than 30 min of PA per week after CR discharge (OR = 0.6). Conversely, patients with high levels of pain had lower odds of engaging in PA (OR = 2.00). Similarly, Andersson et al. [26] reported that individuals with chronic obstructive pulmonary disease and high fatigue had lower odds of engaging in PA (OR = 2.33). However, our sensitivity analyses showed that the present study had approximately 43% power to detect an OR of 0.6 [7], 65% power to detect an OR of 2.0 [7], and 78% power to detect an OR of 2.33 [26] (Supplementary Material 9, Figure S2). These results suggest that the lack of significant associations in our study may be partly due to its limited statistical power, highlighting the need for further research with larger sample sizes to more robustly assess the association between emotional health-related variables and PA behavior and SB. Thus, caution should be exercised when interpreting the present findings.

In contrast to emotional health-related variables, several deliberative motivational variables were associated with daily MVPA. In particular, higher perceived capabilities, along with stronger affective attitudes toward PA were associated with a greater likelihood of meeting the recommended 150 min of MVPA per week. These findings align with Bermudez et al.'s study [2], which showed that patients with more positive affective attitudes toward PA were more likely to engage in higher PA levels after CR discharge. These motivational variables may be particularly important in the post-CR context. For example, perceived capabilities influence patients' confidence in their ability to engage in PA, which can encourage continued PA participation after CR [59, 60]. Moreover, increasing perceived capabilities may enhance the pleasure experienced during PA, which in turn may improve affective attitudes toward PA and promote long-term adherence [2, 20, 61]. Although these data are correlational, existing literature and theoretical models suggest that future interventions targeting both perceived capabilities and affective responses (pleasure-displeasure) during PA could be effective in sustaining PA behaviors. Such interventions might include providing positive feedback during CR exercise sessions (e.g., "You are doing an excellent work!" or "You are performing above average for your age"), or exercise intensity prescription targeting pleasure (e.g., self-selected intensity) [60, 62-64]. These interventions are particularly important for subpopulations such as those with high BMI, where reduced perceived capabilities may create both physical and psychological barriers to PA [61]. This may lead to a vicious cycle in which increased BMI further impedes PA engagement [61]. In addition, recent research suggests that age and sex may influence perceptions of effort and affective responses during PA, with older adults and females more likely to report higher perceived effort and less positive affective experiences during PA [65]. This highlights the need for tailored interventions that address the specific pressures and barriers faced by these groups. Future research should examine how age, sex, or baseline health status moderates the relationship between motivational variables and PA behaviors to better inform interventions for diverse CR populations. We found no evidence that automatic approach-avoidance tendencies toward PA and SB were associated with accelerometer-based MVPA or SB in either cardiac outpatients or healthy control participants. These findings contrast with previous research suggesting that automatic processes, including approach-avoidance tendencies, play an important role in regulating PA behavior [14-16]. Specifically, studies investigating automatic processes have shown that PA cues attract attention [66-68], elicit positive affective responses [22, 69], and prompt approach tendencies [49, 53, 70], particularly in highly active individuals. For example, Cheval et al. [70] found a positive correlation between automatic approach tendencies toward PA and accelerometer-based MVPA in healthy adults ($r = .21$). These findings suggest that insufficiently positive automatic responses to PA cues may partially explain reduced engagement in PA The absence of a significant association in the present study could be explained by at least two factors. As mentioned above, the implicit nature of the task that we used in the current study, coupled with the relatively low sample size ($N = 59$), may have resulted in insufficient statistical power to detect the true effect size. For example, sensitivity power analyses showed that our study had only 37% power to detect an effect size of $r = .21/f^2 = 0.05$ (Supplementary Material 9, Figure S1), as reported by Cheval et al. [70]. Therefore, before drawing firm conclusions about the lack of association between approach-avoidance tendencies and PA behavior or SB, further well-powered studies using alternative reaction-time tasks are needed.

Regarding device-measured SB, male participants spent significantly more time in SB than female participants. Additionally, we observed a significant negative association between pain intensity and SB, indicating that higher pain intensity was linked to lower SB levels. However, this association lost significance after adjusting the model for participant type and sex ($p = .139$). This finding differs with O'Leary et al.'s study [71], which found a positive correlation between pain intensity and SB in rheumatoid arthritis patients ($r = .31$). As in our study, this association became non-significant when other variables, such as age and gender, were included in multivariate models. Overall, these results suggest that motivational and emotional health-related variables related to PA are limited in their ability to explain SB levels. It is important to note, however, that most of the variables measured in this study pertained to PA, not SB (e.g., perceived capabilities related to PA). While other studies have used PA-related motivational measures to predict SB [72, 73], this approach may explain the lack of significant associations in our study. Future research should explore a broader range of variables directly targeting SB to better understand the role of motivational and emotional health-related variables in influencing SB (e.g., "During the next two weeks, I intend to spend no more than four hours in SB a day during my leisure-time.") [72].

Finally, no significant interactions were observed between motivational and emotional health-related correlates, PA or SB, and participant type (i.e., outpatient vs. control). However, due to the small sample of outpatients (n = 17).

Constraints on Generality and Strengths

This study has several limitations that affect the generalizability of its findings. First, the sample size was relatively small, with 17 CR outpatients and 42 community-dwelling participants, who had significantly different baseline characteristics. As a result, the lack of association with PA for some motivational and emotional health-related variables should be interpreted with caution, as the small sample may have led to underpowered analyses and distorted effect size estimates [74, 75]. A larger sample size is needed to provide more accurate estimates of motivational and emotional health-related PA determinants on patients. Second, all outpatients in the study were enrolled in a CR program at Geneva University Hospitals, Switzerland, limiting the applicability of the results to patients in other CR settings. Third, as with many longitudinal studies, there is a risk of selective attrition bias. More motivated outpatients may have been more likely to continue participating, which could explain the relatively high proportion of CR outpatients who met the weekly recommended 150 min of MVPA. Future studies that retain a larger proportion of patients could yield findings more representative of this population. Fourth, while this study used the Actigraph GT3X to measure SB, it is worth noting that the activPal™ device is considered the most reliable for SB measurement [76, 77]. Fifth, although our statistical analyses examined the associations of motivational and emotional variables with daily MVPA and SB levels, the correlational nature of this study precludes drawing causal conclusions. Therefore, further well-powered randomized controlled trials are necessary to establish causal relationships between these variables. Finally, although this study focused on PA and SB, other important lifestyle factors, such as diet and sleep, play a significant role in the management and outcomes of cardiovascular disease [78-80]. Proper nutrition supports both recovery and long-term health maintenance in clinical populations [81, 82], while adequate sleep is critical for mental and physical recovery [79, 83, 84]. Recent research also suggests that these factors interact with PA and SB to collectively influence health-related outcomes [85-88]. Future studies should consider the combined effects of PA, diet, and sleep to provide a more holistic understanding of disease management and improve patient well-being.

Despite these limitations, the study has several strengths. First, it included both CR outpatients and community-dwelling participants, enabling the observation of PA and SB across different contexts, including leisure time PA after CR. Second, the study focused on both PA and SB, addressing a gap in the literature, as most research considers these behaviors independently, despite their distinct impacts on the health benefits of rehabilitation [11-13]. Third, the use of accelerometer-based measures for PA and SB provided more reliable estimates than self-reported questionnaires [89-91]. Finally, the study examined motivational variables influencing PA and SB at both the deliberative (i.e., intention, perceived capabilities, attitudes) and automatic (i.e., approach-avoidance tendencies) levels. This approach is relatively rare in the literature and offers a more comprehensive view of the variables that regulate these behaviors.

Conclusion

The present study found that outpatients who completed a 6-week CR program engaged in higher levels of daily MVPA during the week post-discharge compared to community-dwelling individuals. Higher perceived capabilities and positive affective attitudes toward PA were significantly associated with higher daily MVPA among all participants. In addition, males spent significantly more time in SB compared to females. These results highlight the role of deliberative motivational factors in influencing PA behaviors in both CR patients and the general community. Although our findings suggest some associations, these results must be interpreted with caution due to several limitations, including potential selection bias and the correlational design, which limit the generalizability and causality of the findings, respectively.

List of Abbreviations

CR	Cardiac rehabilitation
HbA1c	glycated hemoglobin
IMPACT	Improving Physical Activity trial
LDL	low-density lipoprotein
LVEF	Left ventricular ejection fraction
MAP	Maximal aerobic power
MVPA	Moderate-to-vigorous physical activity
PA	Physical activity
PROMIS	Patients-Reported Outcomes Measurement Information System
SB	Sedentary behavior
VAAST	Visual-Approach/Avoidance-by-the-Self-Task

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Author Contribution

The first draft of the manuscript was written by L.F. and B.C. and all authors commented on the previous versions of the manuscript. All authors read and approved the final manuscript. L.F. contributed to conceptualization, methodology, formal analysis, investigation, writing—original draft; E.T. contributed to writing–review and editing, resources; C.C. contributed to writing–review and editing, investigation; P.S. contributed to supervision, writing–review and editing; P.M. contributed to writing–review and editing, resources; C.L. contributed to writing–review and editing, resources; E.H.D contributed to writing–review and editing, resources; B.C. contributed to conceptualization, methodology, supervision, formal analysis, investigation, writing—original draft.

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Availability of Data and Materials

Deidentified data, data management, analysis codes and research materials have been made publicly available on Zenodo (https://doi.org/10.5281/zenodo.11064184).

Declarations

Ethics Approval and Consent to Participate

The present study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Geneva Canton, Switzerland (reference number: CCER2019-02257). Prior to participation in the study, all participants signed an informed consent form.

Consent for Publication

Consent for Publication declaration: not applicable.

Competing Interests

The authors have no conflicts of interest relevant to this article to disclose.

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Résumé des résultats principaux de la Contribution empirique n°1

Cette première étude révèle qu'au début de leur prise en charge dans un programme de réadaptation cardiovasculaire ambulatoire, les **patient·es se déclarent significativement moins actifs·ves physiquement que les participant·es sans maladies chroniques** (contrôle). Les patient·es rapportent également des **attitudes affectives moins positives** envers l'activité physique, des **capacités perçues,** une **santé physique et une satisfaction de vie plus faibles** et des **niveaux de fatigue plus élevés** par rapport au groupe contrôle. Cependant, **aucune différence significative** n'a été observée concernant les **tendances automatiques** à approcher l'activité physique ou les comportements sédentaires entre ces deux populations. Dans l'ensemble, ces résultats suggèrent que les patient·es entrant dans un programme de réadaptation cardiovasculaire ambulatoire sont **moins actif·ves physiquement**, et pourraient **évaluer l'activité physique de manière moins positive** que les individus non atteints de maladies chroniques. Au cours de la semaine suivant la fin du programme de réadaptation, les **patient·es** ont consacré en moyenne ~**20 minutes de plus par jour** à des activités physiques d'intensité modérée à vigoureuse (**MVPA**), comparé aux participant·es contrôles. Les analyses de régressions linéaires univariées et multivariées ont révélé une **association positive significative** entre des **attitudes affectives positive**s envers l'activité physique et le niveau de **MVPA** sur une semaine, et ce, chez l'ensemble des participant·es. En pratique, dans notre échantillon, ces résultats suggèrent **qu'une augmentation d'un écart-type des attitudes affectives envers l'activité physique** est associé à une augmentation d'environ **10 minutes par jour de MVPA**.

Bien que nos résultats suggèrent certaines associations, ils doivent être **interprétés avec prudence** en raison de plusieurs limites, notamment un biais de sélection potentiel et la nature observationnelle de l'étude, qui limitent respectivement la généralisation et la causalité des conclusions.

5.2. Contribution empirique n°2

Basée sur le principe du « pic et de la fin » (Fredrickson, 2000), cette seconde étude avait pour objectif d'examiner si certains moments affectifs au cours d'une séance d'APA, par exemple au début ou à la fin, influençaient différemment l'activité physique quotidienne subséquente chez des personnes atteintes de maladies chroniques. L'étude explorait également les mécanismes potentiels sous-jacents à cette association et évaluait sa robustesse en tenant compte de facteurs de confusion possibles (e.g., IMC, sentiment d'efficacité personnelle). Les variables affectives (i.e., réponses affectives, affect remémoré, réponse affective anticipée, attitudes affectives, évaluations affectives automatiques et tendances automatiques d'approche-évitement) et motivationnelles (intention, sentiment d'efficacité personnelle, motivation autonome et contrôlée, attitudes instrumentales) ont été mesurées à l'aide de questionnaires et de tâches de temps de réaction informatisées. Toutefois, en raison d'environ 60 % de données manquantes, les évaluations affectives automatiques et les tendances automatiques d'approche-évitement n'ont pas été incluses dans les analyses de cette Contribution. Les niveaux d'activité physique ont été mesurés par accéléromètres et questionnaires auto-rapportés durant les huit jours suivant la séance d'APA. Au total, 109 participant·es atteints de maladies chroniques, inscrit·es dans des associations en APA du bassin grenoblois, ont été recruté·es. Les données ont été analysées à l'aide de modèles de régression linéaire, complétés par des analyses de modération. La technique de l'inférence à l'œil nu (*inference by eyes* ; Cumming & Finch, 2005) a été utilisée pour comparer certaines tailles d'effet.

Il convient de noter que certaines terminologies employées dans cet article diffèrent de celles utilisées dans ce travail doctoral. Notamment, les variables « plaisir remémoré » *(remembered pleasure)* et « plaisir anticipé » *(forecasted pleasure)* mesurées dans cet article renvoient à l'*affect remémoré* et à la *réponse affective anticipée*, respectivement.

Cet article est en phase finale de préparation pour soumission. L'article a été formaté selon les normes de l'American Psychological Association (APA). Le matériel supplémentaire est disponible en Annexe 1.

Predicting Daily Physical Activity in People with Chronic Diseases from Affective Responses During an Exercise Session: Spillover or Confounding Effect?

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Author Contributions

The first draft of the manuscript was written by Layan Fessler, Boris Cheval and Philippe Sarrazin all authors commented on the previous versions of the manuscript. All authors read and approved the final manuscript. Layan Fessler contributed to conceptualization, methodology, formal analysis, investigation, writing—original draft; Philippe Sarrazin conceptualization, methodology, supervision, formal analysis, writing—original draft; Dan Orsholits contributed to formal analysis, writing–review and editing; Alexis Lefaucheur contributed to formal analysis, writing–review and editing, Boris Cheval contributed to conceptualization, methodology, supervision, formal analysis, writing—original draft.

Abstract

Objectives: Affective responses (AR) during exercise may play a crucial role in promoting lifestyle physical activity (PA) in people with chronic diseases (PCD), suggesting a spillover effect. However, previous studies primarily focused on overall AR during exercise, neglecting specific moments that may significantly influence future PA engagement, such as the end of the exercise session. Here, we investigate whether the moment of AR assessment during an exercise session differentially influences subsequent daily PA in PCD. Additionally, we explore the potential mechanisms underlying this association and assess its robustness by carefully accounting for potential confounders.

Design: Prospective correlational design.

Methods: A total of 109 adults (79.41% women, M_{age} 66.56 years) with chronic diseases participated. AR was assessed during an exercise session at the start of the warm-up, at the beginning of the first and last exercise, and at the end of the session. Perceived exertion was assessed at the same time as AR, while remembered pleasure and forecasted pleasure were assessed immediately after the exercise session. Daily life moderate-to-vigorous physical activity (MVPA) was measured over the next seven days using accelerometers.

Results: Univariate linear regressions showed that only the last AR positively predicted daily MVPA (β = .24, p =.041). While this AR predicted remembered pleasure, forecasted pleasure, and perceived exertion, these factors were not significantly associated with MVPA, providing no support for mediation. Multivariate linear regressions further revealed that the association between the last AR and MVPA was no longer significant after accounting for body mass index, self-efficacy, and perceived exertion.

Conclusions: These findings suggest that AR assessed at the end of the exercise session, but not at other time points, predicts subsequent daily MVPA in PCD. However, the robustness of the association between AR and daily life MVPA is questionable, as it may be due to confounding factors rather than a true spill-over effect.

Keywords: physical activity, affect, noncommunicable disease, peak-end rule, intention-behaviour gap

Statement of Contribution

What is already known on this subject?

- Exercise-related affective responses (ARs) can influence engagement and maintenance of physical activity (PA).
- The peak-end rule, particularly its end-effect, posits that ARs experienced at the end of an activity are crucial for the likelihood of repeating the experience.
- Most studies have overlooked the importance of specific affective moments within an exercise session on subsequent PA behaviours.

What does this study add?

- Only the last exercise-related AR was associated with subsequent daily PA.
- This association was not mediated by the remembered and forecasted pleasure.
- After adjusting for body mass index, self-efficacy and perceived exertion, this association lost significance.

Introduction

Chronic diseases, such as cardiovascular diseases, cancers, and diabetes, account for 69% of all deaths worldwide and result in a cumulative global economic loss of US$7 trillion (Peter et al., 2022; World Health Organization, 2013; World Health Organization, 2023). Regular physical activity (PA) has been shown to play a key role in the prevention and management of diseases (Bierbauer et al., 2020; Durstine et al., 2013; Kanaley et al., 2022; Spence et al., 2020). For example, cancer survivors who meet the recommended level of 150 minutes of moderate-to-vigorous PA (MVPA) per week (Bull et al., 2020) can reduce the negative side effects associated with treatment and improve their quality of life (Spence et al., 2020). Despite this, many people with chronic diseases fail to achieve the recommended PA levels (Dagner et al., 2019; Goo et al., 2024). Thus, identifying the determinants of PA participations in people with chronic diseases is warranted.

In recent years, there has been a growing argument that exercise-related ARs may complement traditional socio-cognitive theories that focus on reflective processes such as attitudes, intentions, or perceived self-efficacy in predicting PA engagement and maintenance (Brand & Ekkekakis, 2018; Cheval & Boisgontier, 2021; Ekkekakis, 2017; Ekkekakis et al., 2020; Stevens et al., 2020). According to the “hedonic principle” (Cabanac, 1992; Higgins, 1997; Williams, 2008), individuals naturally tend to avoid or minimise displeasure and to seek or repeat pleasure. Consequently, the ARs experienced during a behaviour may significantly influence the decision to repeat the behaviour. This influence operates through its effects on both remembered pleasure (the recollection of the pleasure or displeasure experienced during the behaviour) and forecasted pleasure (predictions about the pleasure or displeasure expected in future similar behaviours; Kahneman et al., 1993; Zenko et al., 2024). Moreover, the Theory of Effort Minimisation in Physical Activity (TEMPA; Cheval & Boisgontier, 2021) posits that exercise-related ARs are expected to influence the perceived exertion associated with PA behaviour, which may facilitate the realisation of the intended PA behaviour in action (Cheval, Zou, et al., 2024; Maltagliati, Fessler, et al., 2024). Thus, experiencing negative ARs during PA may reduce the likelihood of engaging in this behaviour again in the future, thereby hindering the achievement of recommended PA levels (Brand et al., 2024; Cheval, Zou, et al., 2024; Rhodes & Kates, 2015). Crucially, these negative ARs may play a particularly significant role in explaining the high levels of physical inactivity observed in people with chronic diseases. In this population, exercise-related negative ARs may be more pronounced than in the general population, mainly due to factors such as chronic pain, discomfort, or kinesiophobia associated with exercise (Aydemir et al., 2022; Cheval et al., 2021; Fessler, Tessitore, et al., 2024; Goubran et al., 2024; Hoffmann et al., 2018).

Over the last two decades, studies have shown that positive exercise-related ARs are associated with higher levels of PA across various populations, including healthy adolescents (Schneider et al., 2009), healthy adults (Kwan & Bryan, 2010; Williams et al., 2012), and overweight-to-obese adults (Liao et al., 2017; Williams et al., 2008; Williams et al., 2016). For example, Williams et al. (2008) found that positive ARs during a laboratory moderate-intensity treadmill session predicted higher self-reported PA at 6 and 12 months in 37 overweight-to-obese, physically inactive adults. Similarly, Kwan and Bryan (2010) found that positive ARs during a laboratory exercise session not only predicted future exercise frequency but also strengthened the relationship between exercise intentions and actual PA in 127 healthy adults. This finding suggests that positive ARs could potentially bridge the so-called intention-behaviour gap in PA (Rhodes et al., 2022; Rhodes & Dickau, 2013). Furthermore, using an ecological momentary assessment, Liao et al. (2017) showed that in 82 overweight-to-obese physically inactive adults, fewer negative ARs during exercise were associated with higher accelerometer-based daily MVPA levels. Taken together, current literature supports the notion that positive exercise-related ARs may have a spillover effect on daily PA levels (i.e., engaging in behaviour A in context 1—such as an exercise session—affects the probability of engaging in behaviour A in context 2—such as lifestyle PA—; Nilsson et al., 2017). Nevertheless, although ARs hold great promise for understanding the factors contributing to physical inactivity in people with chronic diseases, current research primarily focuses on healthy or overweight populations. This oversight neglects other prevalent health conditions, such as cardiovascular diseases, cancer, chronic respiratory diseases, and diabetes, which are the most common chronic diseases (World Health Organization, 2023). This gap hinders a comprehensive understanding of ARs in the context of chronic diseases. Furthermore, the majority of studies were conducted in laboratory settings (Kwan & Bryan, 2010; Schneider et al., 2009;

Williams et al., 2008; Williams et al., 2012), which limits the capacity to assess potential spillover effects in ecological contexts. Additionally, previous studies have reported that the associations between ARs and PA levels becomes non-significant when adjusting for potential confounding variables, including age, gender, BMI, and perceived exertion (Liao et al., 2017; Williams et al., 2008; Williams et al., 2012). These findings cast doubt on the existence of a spillover effect and highlight the necessity of accounting for confounders when testing this association. Finally, inconsistencies across studies, such as variations in populations, different covariates, and a wide range of effect sizes (r =.18 to r =.51), suggest the presence of potential moderating factors. In particular, one such factor may be the timing of ARs assessments. Current research primarily examines the overall AR experiences during an exercise session, neglecting the possibility that specific moments within these experiences, such as the end of the session, may have a greater influence on subsequent behaviours.

The “peak-end rule” posits that not all affective moments are equal in their impact on subsequent behaviour (Alaybek et al., 2022; Fredrickson, 2000). This rule suggests that two key affective moments of an experience—the most emotionally intense moment (i.e., the “peak”) and the last affective moment (i.e., the “end”)—shaped how people remembered and repeated the experience. For instance, Brewer et al. (2000) found that participants preferred to repeat a longer exercise session with a low-intensity end than a shorter session with a moderate-to-vigorous-intensity end. Although this study did not directly assess ARs, it underscores the importance of the end of an exercise session for future engagement. Recent studies have investigated this “end-effect” on the remembered and forecasted pleasure of an exercise session and subsequent PA (Fessler, Sarrazin, et al., 2024; Hargreaves & Stych, 2013; Hutchinson et al., 2023; Hutchinson et al., 2020; Zenko et al., 2016). For example, Zenko et al. (2016) showed that an increasing slope of ARs during a cardiovascular exercise session (i.e., greater pleasure at the end of the exercise session) was positively associated with the remembered pleasure of the session and the forecasted pleasure of the subsequent session. Hutchinson et al. (2023; 2020) replicated these findings using either a single session or six repeated sessions of a resistance training circuit. To the best of our knowledge, only one early-phase study by Fessler, Sarrazin, et al. (2024) has investigated the end-effect on remembered pleasure and subsequent daily PA in patients with chronic diseases (i.e., Parkinson's disease). Results showed that adding 9 minutes of low-intensity exercise at the end of a weekly exercise session for four weeks improved affective attitudes towards PA. However, no significant improvement in PA levels was observed. Although promising, this study was based on a very small sample size (n = 7) and did not directly measure the ARs during exercise. Instead, it relied on participants' remembered pleasure and affective attitudes, where the former reflected the ARs during the session while the latter reflected the accumulation of exercise-related ARs over time (Stevens et al., 2020). Consequently, there is a paucity of knowledge regarding the relationship between exercise-related ARs and daily PA in people with chronic diseases.

To fill this knowledge gap, the primary objective of the present study was to examine whether ARs assessed at different moments during an exercise session could predict subsequent daily accelerometer-based PA in people with chronic disease. Building on the end-effect rule, we hypothesised that ARs reported at the end of an exercise session would be more strongly associated with subsequent PA compared to ARs reported earlier in the session (H_1, Figure S1A). The secondary objective of the present study was to delve deeper into the mechanisms explaining the associations between ARs and subsequent PA behaviours. Based on the literature, several mediating and moderating mechanisms can be hypothesised. First, regarding potential mediation pathways and grounded in the hedonic principle, we hypothesised that the predictive value of AR on subsequent PA would be mediated by the remembered pleasure of the exercise session (H_2, Figure S1B) and the forecasted pleasure of the next exercise session (H_3, Figure S1C). In addition, based on the TEMPA, it can be hypothesised that the association between ARs and subsequent PA would be mediated by perceived exertion during the exercise session and PA behaviour (H_4, Figure S1D). Second, concerning potential moderation pathways, drawing from the aforementioned literature (Kwan & Bryan, 2010), we explored the potential moderating effect of positive exercise-related AR on the association between intention and PA (E_1, Figure S1E). Finally, we assessed the robustness of the previous associations by carefully accounting for potential confounders (i.e., variables related to both ARs and daily MVPA).

Methods

Data, analysis code, and supplementary materials will be available on the associated Zenodo project (*URL*).

Participants

Following current guidelines (Lakens, 2022), we conducted the power analysis using the smallest effect size of interest (SESOI) approach. This approach identifies the smallest effect size deemed theoretically or practically meaningful (Lakens, 2022). The SESOI was determined on the smallest effect size reported in similar previous studies on adult participants (i.e., r =.21; Williams et al., 2012). However, based on the peak-end rule, we anticipate that the effect of the last AR of the session on subsequent PA would be larger than the effect of the overall AR reported by Williams et al. (2008) (i.e., r >.24). Therefore, the SESOI for the main hypothesis (H_1) was set at r_{SESOI} =.25. Using G*Power (v. 3.1; Faul et al., 2009), an a priori power analysis for a linear regression, an f^2_{SESOI} = .07/r_{SESOI} =.25, an alpha level of .05, and a power of .90, for one predictor tested and four predictors in total (four measurement times), indicated that a sample of 153 participants would be required to detect the SESOI (Figure S1). Given our limited resources and time constraints (Lakens, 2022), 116 participants were recruited from sport and health programmes based in France, using flyers, emails, and word of mouth. Of the 116 participants, 109 met the inclusion criteria.

Sensitivity Analyses

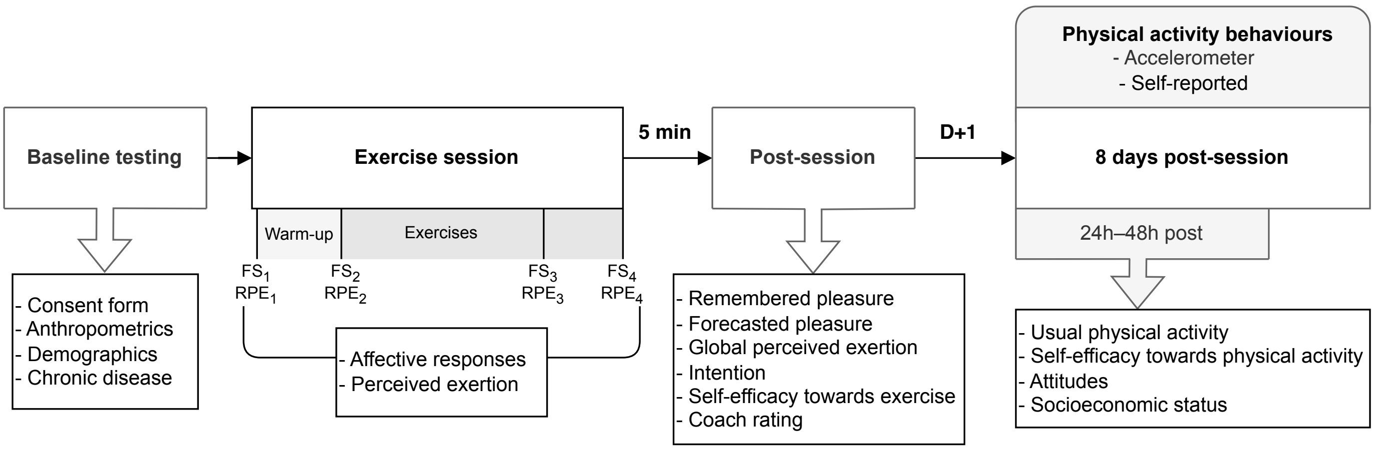
To determine what effects the present study can detect with 109 participants, an alpha level of .05, and a power between 33%—considered the lower threshold for insufficient power (Simonsohn et al., 2014)— and 90%, a sensitivity power analysis was computed using G*Power (see Fessler, Tessitore, et al., 2024 for a similar procedure). Results suggest that for the main hypothesis (H_1), the effect size we can detect with 33% and 90% power is f^2 = .02/ r = .14 and f^2 = .10/r =.31, respectively (Supplementary Material 3). Additionally, the sensitivity power plot showed that the present study had 73% power to detect the minimum effect size observed in the literature (f^2_{SESOI} = .07/r_{SESOI} =.25; Figure S4).

Procedure

Figure 1 provides an overview of the study protocol. Exercise session characteristics are presented in Supplementary Material 4. The study was approved by the French National Ethics Committee for Research in Sport Sciences (reference number: IRB00012476-2022-08-03-159). All participants signed an informed consent form to participate in the study. Participants received no compensation for their participation. After enrolment and completion of the informed consent form, participants provided their date of birth, height, weight, gender, number of months enrolled in the sport and health programme, and any chronic diseases or health issues. The list of chronic diseases was derived from the Survey of Health, Ageing and Retirement in Europe (SHARE; see Fessler et al., 2023) database. The participants then performed their usual exercise session. All sessions were supervised by a sport and health programme coach.

Figure 1

Overview of the Study Procedure



Note. FS = Feeling Scale; RPE = rating of perceived exertion; D+1 = the day after the exercise session; PA = physical activity; Post-session = 5 minutes after the exercise session. FS and RPE were measured four times during an exercise session: at the start of the warm-up (FS_1, RPE_1), at the start of the first exercises (FS_2, RPE_2), at the start of the last exercises (FS_3, RPE_3), and at the last minute of the session (FS_4, RPE_4).

Participant Characteristics

Twenty-four to forty-eight hours after the exercise session, participants were asked to answer an online questionnaire and two reaction time tasks[4]. The aforementioned measures included but were not limited to, self-reported usual PA level, self-efficacy towards PA, instrumental and affective attitudes towards PA. These are described in detail in Supplementary Material 2.

Exercise-Related Measures

Affective valence was measured using the following item: “How do you feel right now, at this moment?” (Feeling Scale [FS]; Hardy & Rejeski, 1989). Participants answered on a scale from -5 *(very bad)* to +5 *(very good)* with verbal anchors at odd numbers and zero.

Perceived exertion was measured using the following item: “What level of effort are you putting in at this very moment?” (Foster et al., 2001). Participants answered on a scale from 0 *(no effort at all)* to 10 *(maximal effort)*.

Post-Exercise Measures

Remembered pleasure was measured using the following item: “How would you qualify the time you spent during today's physical activity session?” Participants answered on a scale from -5 *(very unpleasant)* to +5 *(very pleasant)* (Kwan et al., 2017).

Forecasted pleasure was measured using the following item: “How would you qualify the time you expect to spend during your next physical activity session?” Participants answered on a scale from -5 *(very unpleasant)* to +5 *(very pleasant)* (Kwan et al., 2017). In order to minimise the common method variance between the FS and the remembered and forecasted pleasure scales (Podsakoff et al., 2003; Podsakoff et al., 2012), the FS had a vertical orientation, whereas the remembered and forecasted pleasure scales had a horizontal orientation (Hutchinson et al., 2023).

Intention to engage in PA the week following the exercise session was measured using the following item: “Over the next 7 days, I intend to do at least 30 minutes of MVPA a day on most days of

[4] Some variables in the online questionnaire and the two reaction time tasks (i.e., the Single Category Implicit Association Test and the Manikin Task) belong to another project associated with the same ethics number and are not relevant to the present study.

the week during my free time or when travelling.” (Cheval et al., 2015). Participants answered on a scale from 1 *(strongly disagree)* to 7 *(strongly agree)*.

Physical Activity Measure

Daily PA was measured using a three-axis accelerometer (Movisens Move4) for eight consecutive days after each exercise session. The Movisens Move4 accelerometers showed strong agreement (>80%) in estimating daily time spent at each PA intensity (Migueles et al., 2022). Participants were asked to remove the accelerometer overnight. Daily data were considered valid if the device was worn for at least 10 waking hours per day (Evenson & Terry, 2009) and if at least 4 days met the above conditions, including one weekend day (Matthews et al., 2012). Accelerometer-based daily times spent in PAs of light, moderate, and vigorous intensity were used as indicators of PA levels. Daily time spent in MVPA was used as the dependent variable in the analyses.

Statistical analyses

The statistical analyses were performed using R (v.4.2.3). After conducting descriptive analyses, univariate linear regressions were performed to examine the association between the four ARs scores and subsequent daily MVPA. To determine which ARs scores had the strongest association with MVPA (H_1), we compared the overlap of the 95% confidence intervals (CI) of the standardised beta coefficients (β) using the “inferences by eyes” method (Cumming & Finch, 2005). This method states that when comparing two independent means, *p* <.05 if the *proportion of overlap* (i.e., the vertical distance between the upper CI of the lowest mean and the lower CI of the highest mean) of the 95% CIs is lower than 0.50. Specifically, we compared the β and its 95% CI of the four univariate linear regressions (four measures) two by two. To do so, we first computed the *margin of error* for each β as follows: $\frac{Upper\ CI - Lower\ CI}{2}$. Then, we computed the *average margin of error* as follows: $\frac{Margin\ of\ error\ model\ 1 + Margin\ of\ error\ model\ 2}{2}$. The *overlap* between the upper CI of the lowest β and the lower CI of the highest β were then computed as follows: $\text{upper CI of the lowest } \beta - \text{ lower CI of the highest } \beta$. Finally, we computed the *proportion overlap* as follows: $\frac{Overlap}{Average\ margin\ of\ error}$.

A series of additional models were then performed to examine the potential mediating and moderating mechanisms explaining the association between ARs and daily MVPA. To examine the potential mediating effect of remembered pleasure, forecasted pleasure, and perceived exertion on this association (H_2, H_3, H_4), mediation models were computed using the component approach (Yzerbyt et al., 2018). First, we tested whether ARs predicted remembered pleasure (*path a*). Then, we tested whether remembered pleasure predicted daily MVPA (*path b*). Based on the component approach, a significant indirect effect is supported when the two paths of the indirect effect (i.e., *path a* and *path b*) are statistically significant. This method is anticipated to diminish the likelihood of committing Type 1 errors while maintaining statistical power, in contrast to bootstrap methodologies such as the single test of a mediational index (Maltagliati et al., 2023; Yzerbyt et al., 2018). The same strategy was used for forecasted pleasure and perceived exertion as potential mediators.

To explore the potential moderating effect of ARs on the association between intention and daily MVPA (E_1), a regression analysis was conducted in which ARs, intention, and their interaction were included in the model. A significant interaction effect between AR and intention would indicate that AR moderated the association between intention and daily MVPA. In such a case, simple slopes analyses would be carried out to decompose the significant interaction (for a similar procedure, see Maltagliati, Raichlen, et al., 2024).

After identifying potential confounders (i.e., variables that may causally predict both ARs and daily MVPA), we performed multivariate linear regression analyses adjusting for these variables. Potential confounders were identified using a correlation matrix, specifically selecting variables that were correlated with both ARs and daily MVPA. However, we excluded variables that could not conceptually influence ARs—such as the forecasted pleasure of the next exercise—as they do not meet the criteria for being true confounders (i.e., causally predict both ARs and MVPA).

Statistical assumptions of normality of the residuals, linearity, multicollinearity, and undue influence were checked for all models using the Performance R package (Lüdecke et al., 2021). Univariate and multivariate outliers were checked for all models using the Performance R package (Lüdecke et al., 2021). The dependent variable and confounders were centred around the mean with standard deviation units.

Missing data were inspected for potential patterns of missingness using Little's missing completely at random (MCAR) test (Little, 1988) and patterns visualisation. No specific patterns were detected. Consequently, missing data were addressed using multiple imputation with the Multivariate Imputation by Chained Equations (MICE) package in R (van Buuren & Groothuis-Oudshoorn, 2011), resulting in 10 imputed datasets. The default imputation method was employed to appropriately handle numeric, binomial, and multinomial data (van Buuren & Groothuis-Oudshoorn, 2011).

Results

Descriptive Results

Table 1 presents the characteristics of the participants. Most of the participants were women (79.41%), older adults (M_{age} = 66.56±12.55 years), overweight (M_{BMI} = 26±46 kg/m^2) and reported having a chronic disease (88.1%). Participant self-reported typically spending an average of 9.94 (±20.77) hours per week in usual MVPA. Accelerometer-based MVPA showed that participants spent an average of 4.59 hours per week (39.38 [± 24.48] min per day) in MVPA the week after the exercise session (Table 1). 72.50% of participants met the recommended 150 minutes of MVPA per week, measured with accelerometer.

Association Between Affective Responses at Different Moments of the Exercise Session and Subsequent Daily MVPA

The primary hypothesis was that the last AR of an exercise session (FS_4) would be more strongly associated with subsequent daily MVPA compared to the ARs reported earlier in the session (FS_1, FS_2, FS_3; H_1). Univariate linear regressions showed that FS_1, FS_2, and FS_3 were not significantly associated with subsequent MVPA (b = -0.47, 95% CI [-6.41; 5.47], R^2 = -.05, p = .874; b = 4.12, 95% CI [-0.99; 9.28], R^2 =.15, p = .113; b = 3.85, 95% CI [-1.23; 8.94], R^2 =.16, p = .874; respectively), while this was the case for FS_4 (b =

5.84, 95% CI [0.26; 11.42], R^2 =.06 p = .041; Table 3 and Figure 2). Nevertheless, while the effect size of FS_4 on MVPA was descriptively larger than the effect sizes of FS_1, FS_2 and FS_3, the proportion overlap between the CIs of all effect sizes was superior to 0.50, suggesting non-significant differences (p>.05; Figure 3).

Table 1

Descriptive Characteristics

***N* = 109**	***N (%)***	**Missing (*n*, %)**
Age (year*s,* mean*, SD*)	66.56 (12.55)	7 (4.42)
<50 (years)	7 (6.86)	
50–59 (years)	12 (11.76)	
60–69 (years)	44 (43.14)	
70–79 (years)	24 (23.53)	
>80 (years)	15 (14.71)	
Gender		7 (4.42)
Woman	81 (79.41)	
Man	21 (20.58)	
Body mass index (kg/m²)	26.46 (5.84)	7 (4.42)
Underweight (< 18.5)	4 (3.92)	
Normal (18.5–24.9)	40 (39.22)	
Overweight (25–29.9)	35 (34.31)	
Obesity (> 30)	23 (22.55)	
Chronic disease (*n, frequency*)		11 (10.09)
Cardiovascular disease	9 (9.18)	
Hypertension	20 (20.41)	
Hypercholesterolemia	12 (12.24)	
Stroke	1 (1.02)	
Diabetes	11 (11.22)	
COPD	7 (7.14)	
Cancer	15 (15.31)	

Continued

Table 1 *(Continued)*

***N* = 109**	***N* (%)**	**Missing (*n*, %)**
Stomach ulcer	0 (0)	
Gastroduodenal ulcer	3 (3.06)	
Parkinson's disease	3 (3.06)	
Alzheimer's disease	0 (0)	
Dementia	1 (1.02)	
Senility	1 (1.02)	
Affective disorders	15 (15.31)	
Scoliosis	0 (0)	
Cataract	8 (8.16)	
Rheumatoid arthritis	7 (7.14)	
Osteoarthritis	39 (39.80)	
Other	25 (25.51)	
None	14 (14.29)	
Multimorbidity		11 (10.09)
Yes	52 (53.06)	
No	46 (46.934)	
Financial comfort		23 (21.10)
Very comfortable	4 (4.65)	
Fairly comfortable	36 (41.86)	
With some difficulties	44 (51.16)	
With great difficulties	2 (2.33)	
Education		23 (21.10)
Primary	85 (98.84)	
Secondary	77 (89.53)	
Tertiary	77 (89.53)	

Continued

Table 1 *(Continued)*

N = 109	**Mean (*SD*)**	**Missing (*n*, %)**
Usual self-reported PA (hour/day)		22 (20.18)
GPAQ transport	8.79 (19.62)	
GPAQ moderate	7.50 (18.78)	
GPAQ vigorous	2.44 (4.61)	
GPAQ MVPA	9.94 (20.77)	
GPAQ sedentary	5.50 (2.73)	
Accelerometer-based PA levels (min/day)		29 (26.61)
Light activity	102.34 (46.41)	
Moderate activity	37.51(23.06)	
Vigorous activity	1.88 (3.86)	
MVPA	39.38 (24.48)	
Total PA	141.73 (60.35)	
Meeting the PA recommended level (*n*, %)	58 (72.50)	
Sport health programme membership (months)	74.66 (110.48)	22 (20.18)
Intention [1–7]	5.53 (1.65)	17 (15.60)
Affective attitudes [1–7]	5.26 (1.45)	23 (21.10)
Instrumental attitudes [1–7]	6.07 (1.67)	23 (21.10)
Self-efficacy towards PA [1–7]	5.323 (1.68)	23 (21.10)

Note. GPAQ = Global Physical Activity Questionnaire; PA = physical activity MVPA = moderate-to-vigorous physical activity; COPD = chronic obstructive pulmonary disease. Body mass index was calculated by dividing weight (kg) by height^2 (m). Multimorbidity was defined as the presence of two or more chronic diseases (Duggal et al., 2019). PA recommendations correspond of at least 150 minutes of MVPA a week, or 22 minutes per day (Bull et al., 2020). Descriptice statistics were carried out on nonimputed data.

Table 2

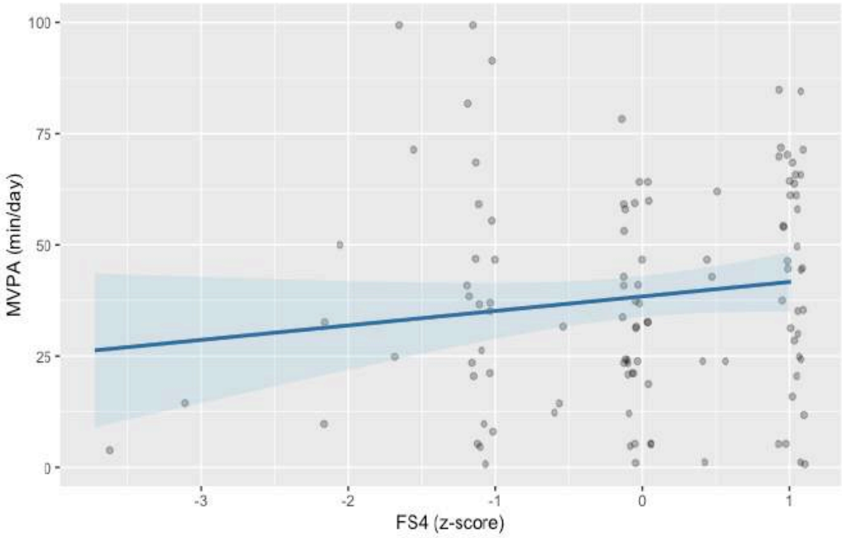
Association Between Affective Responses and Subsequent Daily Time Spent in MVPA

Predictors	Univariate models				Multivariate model		
	b (95% CI)	*ß* (95% CI)	R^2 adj.	*p*	b (95% CI)	*ß* (95% CI)	*p*
Intercept	40.18 (34.58; 45.79)	.01 (-.22; .22)		<.001			
FS_1	-0.46 7 (-6.41; 5.47)	-.05 (-.27; .16)	.002	.874			
Intercept	40.24 (34.76; 45.72)	.01 (-.20; .22)		<.001			
FS_2	4.12(-0.99; 9.28)	.15 (-.07; .37)	.03	.113			
Intercept	40.26 (34.72; 45.81)	.01 (-.20; .22)		<.001			
FS_3	3.85 (-1.23; 8.94)	.16 (-.06; .38)	.02	.136			
Intercept	40.20 (34.80; 45.59)	.00 (-.21; .21)		<.001			
FS_4	5.84 (0.26; 11.42)	.24 (.03; .45)	.06	.041			
Intercept	40.53 (35.67; 45.39)	.00 (-.22; .22)		<.001			
FS_{mean}	4.76 (-0.29; 9.81)	.18 (-.03; .39)	.04	.064			
Intercept					40.08 (34.93; 45.23)	.00 (-.20; .20)	<.001
FS_4					0.17 (-5.85; 6.19)	.00 (-.23; .23)	.954
BMI (Kg/m^2)					-7.33 (-12.71; -1.94)	-.31 (-.51; -.11)	.009
Self-efficacy towards PA					5.78 (0.91; 10.64)	.26 (-.05; .47)	.021
Self-efficacy towards exercise					2.03 (-3.81; 7.89)	.08 (-.14; .29)	.485
RPE_3					-3.23 (-8.37; 1.90)	-.15 (-.36; .07)	.213
R^2 adj.							.23

Note. FS = Feeling Scale; BMI = body mass index; PA = physical activity; RPE = rating of perceived exertion. FS and RPE were measured four times during an exercise session: at the start of the warm-up (FS_1, RPE_1), at the start of the first exercises (FS_2, RPE_2), at the start of the last exercises (FS_3, RPE_3), and at the last minute of the session (FS_4, RPE_4). FS_{mean} represents the mean score of the four FS scores. Usual PA was assessed using the Global Physical Activity Questionnaire (GPAQ; Armstrong & Bull, 2006). Independant variables were standardised (z-score). Univariate and multivariate linear regression analyses were carried out on the imputed data (*N* = 109).

Figure 2

Association Between the Last Affective Response and MVPA



Note. MVPA = moderate-to-vigorous physical activity; FS4 = affective response measured at the last minute of the session

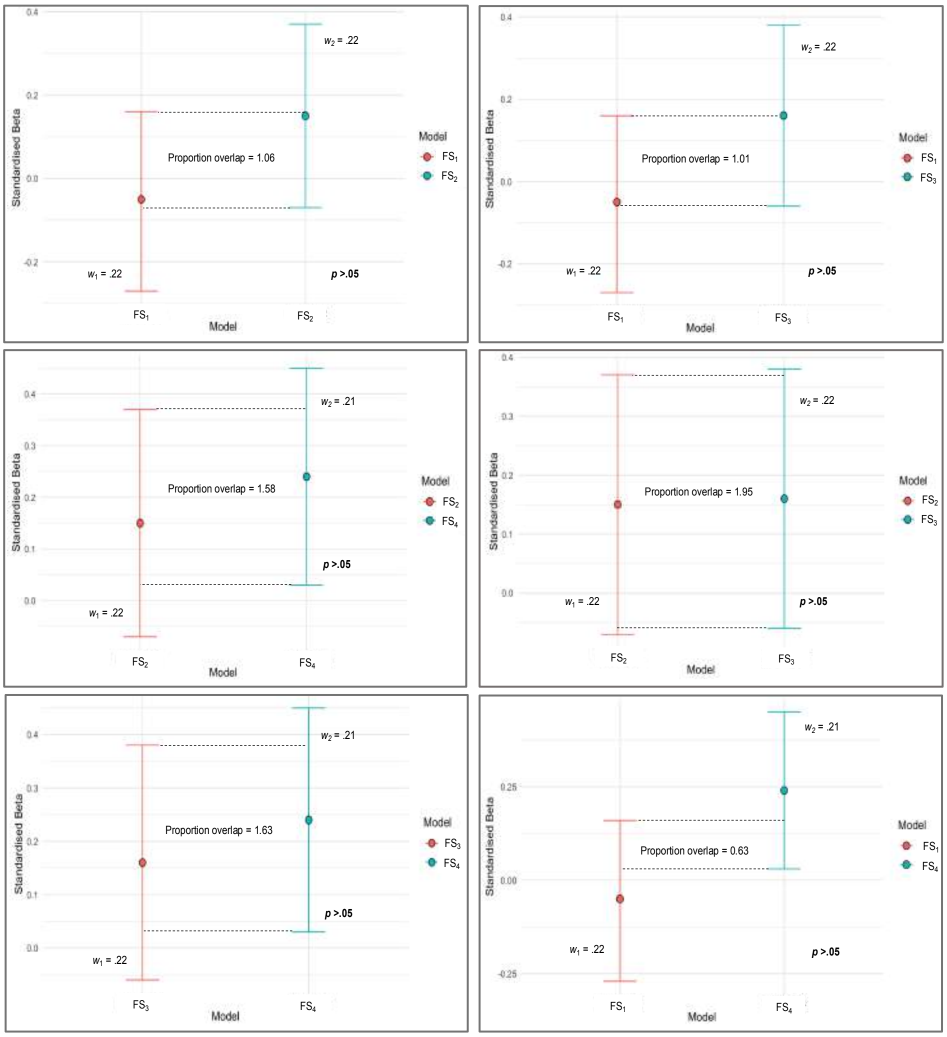
Potential Mechanisms Underlying the Association Between Affective Responses and Subsequent Daily MVPA

The secondary hypotheses were that the association between ARs and daily MVPA would be mediated by the remembered pleasure of the exercise session (H_2), the forecasted pleasure of the next exercise session (H_3), and perceived exertion during the exercise session (H_3). Given that the association between ARs and daily MVPA was only statistically significant for FS_4, subsequent analyses were conducted exclusively on this AR. Additionally, since RPE scores reported earlier in the session cannot mediate the relationship between FS_4 and daily MVPA, only RPE_4, measured at the same time as FS_4, was included in the mediation model. Mediation analyses showed that FS_4 was significantly and positively associated with remembered pleasure (b = 0.31, 95% CI [0.18; 0.46], p <.001), forecasted pleasure (b = 0.23, 95% CI [0.08; 0.38], p = .003), and perceived exertion score measured at the end of the session (RPE_4; b = -0.49, 95% CI [-0.69; -0.30], p = <.001)—*path a* (Table 3). However, remembered pleasure (b = -1.13, 95% CI [-5.37; 3.11], p = .593), forecasted pleasure (b = 3.25, 95% CI [-0.70; 7.20], p = .104), and RPE_4 (b = -1.04, 95% CI [-3.68; 1.59], p = .432) were not significantly associated with daily MVPA—*path b* (Table 3). Accordingly, we found no evidence that remembered pleasure, forecasted pleasure, or perceived exertion mediated the association between FS_4 and daily MVPA.

The potential moderating effect of ARs on the association between intention and daily MVPA was explored (E_1). Univariate regression analysis showed that intention towards PA was significantly associated with subsequent daily MVPA (b = 8.50, 95% CI [2.18; 14.81], R^2 =.11 p = .010). However, moderation analysis showed no significant interaction between intention and FS_4 in predicting subsequent daily MVPA (b = -1.50, 95% CI [-6.11; 3.10], R^2 =.15 p = .518), suggesting no evidence that FS_4 moderated the relationship between intention and subsequent daily MVPA (Table 4).

Figure 3

Comparison of the Overlap of the 95% Confidence Intervals of the Standardised Beta Coefficients on the Association Between Affective Responses and Daily MVPA



Note. w = margin of error. Affective responses were measured four times during an exercise session: at the beginning of the warm-up (FS_1), at the beginning (FS_2) and at the end (FS_3) of the workout, and at the end of the cool-down (FS_4). Proportion overlap of the 95% confidence intervals (CIs) are all > 0.50, suggesting that the difference between the coefficient is not significant (p >.05)

Multivariate Analyses for Potential Confounders

After adjusting for BMI, self-efficacy towards PA, self-efficacy towards exercise, and the rating of perceived exertion score measured during the last exercise of the session (RPE_3; Table S7), multivariate linear regressions showed that FS_4 was no longer significantly associated with daily subsequent MVPA (*p* =.954, Table 2). However, BMI and self-efficacy towards PA (b = -7.33, 95% CI [-12.71; -1.94], *p* =.009; b = 5.78, 95% CI [0.91; 10.64], *p* =.021; respectively) were significantly associated with subsequent daily MVPA.

Table 3

Mediation Analyses on the Association Between the Last Affective Valence Score and Subsequent Daily Time Spent in MVPA

Models	b (95% CI)	*ß* (95% CI)	*p*
Model 1			
FS_4–RP–MVPA			
Path a	0.31 (0.18; 0.46)	.41 (.22; .59)	<.001
Path b	-1.13 (-5.37; 3.11)	-.04 (-.28; .20)	.593
Path c	2.89 (0.21; 5.58)	.24 (-.03; .45)	.035
Model 2			
FS_4–FP–MVPA			
Path a	0.23 (0.08; 0.38)	.31 (.11; .50)	.003
Path b	3.25 (-0.70; 7.20)	.20 (-.01; .41)	. 104
Path c	2.89 (0.21; 5.58)	.24 (-.03; .45)	.035
Model 3			
FS_4–RPE_4–MVPA			
Path a	-0.49 (-0.69; -0.30)	-.46 (-.63; -.29)	<.001
Path b	-1.04 (-3.68; 1.59)	-.07 (-.32; .17)	. 432
Path c	2.89 (0.21; 5.58)	.24 (-.03; .45)	.035

Note. The independent variables were not standardised (i.e., not z-scores).

Table 4

Moderation Analysis Using Daily Time Spent in MVPA as Dependant Variable

Predictors	b (95% CI)	*ß* (95% CI)	*p*
Model 1			
Intercept	40.15 (34.65; 45.66)	-.01 (-.18; .22)	<.001
Intention	8.50 (2.18; 14.81)	.31 (.11; .52)	.010
R^2 adj.			.11
Model 2			
Intercept	40.04 (34.44; 45.63)	-.01 (-.19; .22)	<.001
FS_1	-1.13 (-6.93; 4.67)	-.07 (-.28; .13)	.694
Intention	8.68 (2.32; 15.04)	.32 (.11; .53)	.009
Intention × FS_1	0.92 (-4.34; 6.19)	.03 (-.16; .22)	.726
R^2 adj.			.12
Model 3			
Intercept	40.14 (34.51; 45.77)	-.01 (-.19; .22)	<.001
FS_2	2.86 (-2.15; 7.87)	.11 (-.10; .32)	.259
Intention	8.08 (1.44; 14.72)	.30 (.09; .51)	.019
Intention × FS_2	0.14 (-4.67; 4.94)	.02 (-.19; .23)	.955
R^2 adj.			.13
Model 4			
Intercept	40.19 (34.61; 45.77)	.01 (-.19; .22)	<.001
FS_3	2.91 (-2.17; 7.99)	.13 (-.11; .36)	.257
Intention	8.16 (1.78; 14.54)	.30 (.10; .51)	.014
Intention × FS_3	-0.12 (-4.57; 4.33)	.01 (-.18; .20)	. 9.56
R^2 adj.			.13
Model 5			
Intercept	40.40 (34.94; 45.86)	.02 (-.18; .23)	<.001
FS_4	4.37 (-1.05; 9.78)	.19 (-.02; .40)	.111
Intention	7.65 (1.37; 13.93)	.28 (.08; .49)	.019
Intention × FS_4	-1.50 (-6.11; 3.10)	-.04 (-.24; .15)	.518
R^2 adj.			.15

Note. FS = Feeling Scale. FS was measured four times during an exercise session: at the start of the warm-up (FS_1), at the start of the first exercises (FS_2), at the start of the last exercises (FS_3), and at the last minute of the session (FS_4). Independent variables were standardized (z-score). Univariate and multivariate linear regression analyses were carried out on the imputed data (N = 109).

Discussion

Main findings

The present study investigated the predictive value of four different moments of ARs during an exercise session on subsequent accelerometer-based daily MVPA in people with chronic diseases. The findings showed that higher positive ARs at the end of an exercise session were associated with higher daily MVPA levels in the week following the session. This result aligns with the concept of a spillover effect (Nilsson et al., 2017), which suggests that experiences in one specific context (e.g., an exercise session) can influence the likelihood of engaging in similar types of behaviours implemented in other contexts (e.g., lifetsyle PA). Furthermore, we found no evidence that ARs measured at other moments during the exercise session (i.e., at the start of the warm-up and at the beginning of the first and last exercise) were significantly associated with daily MVPA. This finding supports the peak-end rule principle, particularly its end-effect, suggesting that the last affective moment of an experience may be particularly relevant in influencing the likelihood of repeating similar type of behaviours (Alaybek et al., 2022; Fredrickson, 2000).

Although promising, these results were challenged by further analyses. Specifically, the association between the AR at the end of the session and daily MVPA did not remain significant after controlling for potential confounding variables such as BMI and self-efficacy towards PA and exercise, and perceived exertion. To summarise, while this study provides some evidence for the potential relevance of considering different moments of ARs during an exercise session to predict future participation in subsequent daily MVPA, the current evidence is more suggestive than conclusive. In the remainder of the discussion, we relate our findings to existing literature, discuss the limited evidence for a spillover effect from specific ARs during exercise on engagement in daily MVPA, and highlight the limitations and strengths of our study before concluding.

Comparison with Other Studies

The study found that only the last exercise-related AR was significantly and positively associated with subsequent daily MVPA, not the overall (mean) AR or the ARs assessed at other moments of the exercise session (i.e., at the start of the warm-up and at the beginning of the first and last exercise). These results diverge from prior research, which has shown a significant and positive association between overall exercise-related AR and subsequent PA levels (Kwan & Bryan, 2010; Liao et al., 2017; Schneider et al., 2009; Williams et al., 2008; Williams et al., 2012). However, although binary statistical decisions may suggest conflicting results (Amrhein et al., 2019), it is important to note that both the directionality (i.e., positive) and the magnitudes of the effect observed in our current study for the overall AR (i.e., r =.18) align with those reported in the existing literature in similar context (i.e., ranging from r =.24 to r =.51; Williams et al., 2008; Williams et al., 2012). Moreover, sensitivity analyses showed that our study had 38% power to detect an effect size of r =.18/f^2 = 0.03 (Figure S5A). Consequently, the non-significant effect of overall AR on MVPA might be attributable to insufficient statistical power.

At the theoretical level, these findings support the validity of the peak-end rule, particularly its end-effect, in the context of exercise (Fessler, Sarrazin, et al., 2024; Hargreaves & Stych, 2013; Hutchinson et al., 2023; Hutchinson et al., 2020; Zenko et al., 2016). As hypothesised (H_1), study highlights that not all moments of ARs are equivalent; the end of the experience may exert a particularly influential effect on predicting future behaviour. To the best of our knowledge, this study is the first to assess ARs at different moments during an exercise session and demonstrate that only the AR reported at the end of the exercise session—rather than at preceding moments or the overall AR—was significantly associated with subsequent accelerometer-based daily MVPA. Although direct comparisons with existing literature are challenging, our findings align with prior research grounded in the peak-end rule principle. This principle suggests that the remembered pleasure of an experience and the desire to repeat it in the future are highly shaped by the last AR of the experience (Brewer et al., 2000; Garbinsky et al., 2014; Redelmeier & Kahneman, 1996). Despite the small-to-modest relationship between the last AR and subsequent daily MVPA ($ß$ =.24), the unstandardized coefficient (b = 5.84) indicates that an increase of one standard deviation in AR (measured using the Feeling Scale) at the end of the session corresponds to an estimated increase of approximately 5.84 minutes per day of MVPA, or ~41 minutes per week.

However, we found no explicative mechanism underlying the association between the last AR and daily MVPA. Contrary to our hypotheses (H_2 and H_3) remembered pleasure and forecasted pleasure did not mediated the association between the last AR and daily MVPA. The lack of significant mediation is explained by the fact that although the last AR was significantly associated with remembered pleasure and forecasted pleasure (i.e., the first path of mediation), these variables were not significantly associated with daily MVPA (i.e., the second path of mediation). These results provide two important points for discussion. First, as supported by the existing literature (Hargreaves & Stych, 2013; Hutchinson et al., 2023; Hutchinson et al., 2020; Zenko et al., 2016), our results provide further evidence that ARs significantly influence both remembered and forecasted pleasure, highlighting the association of affective variables within the same context (i.e., exercise session). Notably, when including all ARs scores, the association with remembered pleasure emerged only for ARs assessed during the latter part of the exercise session, showing a moderate association for FS_3 ($ß$ =.40, p <.001) and a small association for FS_4, which approached statistical significance ($ß$ =.19, p = .052, Table S3). Furthermore, when both ARs scores and remembered pleasure were included in the analysis, the association with forecasted pleasure emerged only for remembered pleasure ($ß$ =.70, p <.001), suggesting a mediation effect (Table S4). This finding aligns with the peak-end rule, indicating that ARs, particularly those at the end of an exercise session, predict the remembered pleasure of the session, which subsequently influences the forecasted pleasure of future sessions. These findings are consistent with seminal studies showing how the end of an experience influences remembered and forecasted pleasure (Fredrickson, 2000; Kahneman et al., 1993; Redelmeier & Kahneman, 1996), as well as recent research applying the peak-end rule to PA behaviours (Fessler, Sarrazin, et al., 2024; Hargreaves & Stych, 2013; Hutchinson et al., 2023; Hutchinson et al., 2020; Zenko et al., 2016). Second, although we hypothesised that better remembered and forecasted pleasure would promote future engagement PA (Fredrickson, 2000), empirical support for this is limited, with only one study demonstrating a significant association between remembered pleasure and exercise adherence (Kwan et al., 2017). However, other studies have not replicated this finding, failing to establish a significant link between remembered pleasure and PA behaviours (Hargreaves & Stych, 2013; Rhodes & Kates, 2015;

Zenko et al., 2024). Furthermore, while some research suggests that forecasted pleasure may be associated with PA behaviours, many of these studies are of questionable quality, and their results should be interpreted with caution (Katharina Feil et al., 2023).

Contrary to our hypothesis (H4), a similar pattern was observed for perceived exertion. While the last AR was significantly associated with perceived exertion, this variable was not significantly associated with subsequent daily MVPA. According to the TEMPA (Cheval & Boisgontier, 2021), perceived exertion related to a specific behaviour (e.g., taking the stairs) is considered a proximal determinant of the decision to engage in that behaviour or to choose an alternative (e.g., taking the escalator). However, a single instance of perceived exertion from a specific exercise session may not be strong enough to influence general PA behaviours in daily life. It may be necessary to account for repeated experiences of perceived exertion or to use measures that capture broader tendencies to approach or avoid exertion (Cheval, Maltagliati, et al., 2024; Maltagliati, Raichlen, et al., 2024).

Finally, we did not find a significant moderation effect of ARs on the association between intention towards PA and daily MVPA (E_1). This finding contrasts with previous studies suggesting that ARs could potentially bridge the intention-behaviour gap in PA (Faries, 2016; Feil et al., 2023; Kwan & Bryan, 2010; Rhodes et al., 2022). This discrepancy may stem from the misalignment between the specific context of ARs and the intentions of engaging in overall PA and PA behaviour being measured, suggesting that a closer alignment is necessary for ARs to effectively influence the intention-behaviour relationship (see, for example, Kwan & Bryan, 2010; Rhodes et al., 2023).

The results of our study, alongside those of existing literature, suggest that the role of ARs during a specific exercise session in the regulation of daily MVPA may be significant. However, a closer examination of these studies reveals that, as observed in our study, the association between ARs and subsequent MVPA does not remain significant after adjusting for potential confounding variables, including age, gender, BMI, and perceived exertion (Liao et al., 2017; Williams et al., 2008; Williams et al., 2012). These findings call into question the existence of the spillover effect, as the associations may be largely explained by confounding factors like BMI or self-efficacy, which can influence both ARs during exercise (the exposure) and daily MVPA levels (the outcome; Bandura, 1997; Bauman et al., 2012; Biddle et al., 2021; Ekkekakis, 2003; Ekkekakis et al., 2016). This lack of a significant association may stem from the fact that experiences in a specific context can be difficult to generalise to other contexts, and the potential influence of several moderators (e.g., context similarity, personality traits; Nilsson et al., 2017). This may also reflect the design of the study, which primarily focused on ARs during a single short (i.e., 10–20min) session (Williams, 2008; Williams et al., 2012), rather than across multiple exercise sessions over an extended period (e.g., Liao et al., 2017). According to dual-process theories (Brand & Ekkekakis, 2018; Cheval & Boisgontier, 2021; Cheval, Zou, et al., 2024), it is the repetition of affective exercise experiences that leads to the storage of affective associations with the concept of PA in memory. As a result, measures on a single affective exercise experience may be insufficient to influence a broad range of behaviours, suggesting that the current study design, along with similar designs in the literature, may be inadequately suited for effectively testing the spill-over effect hypothesis. Future research should address this limitation to effectively test the spill-over effect hypothesis in PA context.

Limitations and Strengths

The current study has several limitations. First, accelerometer-based measurements of MVPA do not distinguish between different contexts in which PA occurs, such as whether it was performed during a subsequent exercise session (same context as exercise-related ARs) or during leisure time (different context), which may have inflated the observed association between ARs and daily MVPA. Second, ARs were not assessed prior to the exercise session, potentially conflating exercise-related AR with incidental affect unrelated to exercise (Williams & Rhodes, 2023). Third, ARs were measured during a single exercise session, whereas theoretical frameworks suggest that repeated positive experiences are necessary to shape affective associations and promote sustained engagement in PA (Brand & Ekkekakis, 2018; Cheval & Boisgontier, 2021; Conroy & Berry, 2017). Fourth, the observational design of the study limits causal inference. Finally, the power analysis was conducted for a univariate regression analysis (H_1). Thus, the lack of significant results in the multivariate and mediation analyses may be due to insufficient power, as indicated by the sensitivity power analyses (Supplementary Material 3).

The current study has, however, several strengths. First, it extends existing literature by investigating the spillover effect of exercise-related ARs on daily MVPA and the end-effect principle in people with chronic diseases. Second, ARs were assessed in an ecological setting during a habitual exercise session within the customary participants' sports health programme. Third, daily MVPA was measured using accelerometers. Fourth, we examined investigated the mechanisms underlying the association between exercise-related ARs and subsequent daily MVPA through both mediation and moderation analyses. Finally, models were adjusted for potential confounders, providing a more nuanced understanding of the relationship between exercise-related ARs and subsequent daily MVPA.

Conclusion

In conclusion, this study suggests that the last AR of an exercise session may influence how people with chronic diseases affectively remember the session and anticipate future ones. However, the initial association between the last AR and subsequent daily MVPA lost significance after adjusting for confounders such as BMI, self-efficacy towards PA and exercise, and perceived exertion. These results raise questions about the existence of a spillover effect, where specific affective experiences during an exercise session influence broader PA behaviour in daily life. Future research should explore how repeated affective experiences in specific contexts, such as during rehabilitation programmes, impact overall PA levels in people with chronic diseases. Understanding these dynamics could provide valuable insights for designing effective interventions to promote sustained PA in this physically inactive population.

Data availability statement:

All data analysed for this manuscript alongside the code for R software will be available on Zenodo (*URL*).

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Résumé des résultats principaux de la Contribution empirique n°2

Cette seconde étude révèle que seule la **réponse affective mesurée à la fin d'une séance d'APA** est **positivement associée au niveau quotidien de MVPA** durant la semaine suivante. Toutefois, après ajustement pour **des facteurs de confusion** potentiels, tels que **l'IMC** et le **sentiment d'efficacité personnelle** envers l'activité physique, cette association n'est **plus statistiquement significative**. Ces résultats soulèvent des interrogations quant à la possibilité d'un effet de débordement, où les réponses affectives spécifiques ressenties lors d'une séance d'APA pourraient influencer le niveau global d'activité physique au quotidien. En effet, il est possible que les liens observés dans la littérature entre réponses affectives et activité physique subséquente résultent d'un biais de confusion. Les réponses affectives dépendraient des caractéristiques individuelles des pratiquant·es (i.e., IMC et sentiment de compétence), qui prédisent ensuite l'engagement subséquent dans l'activité physique. De plus, les analyses exploratoires montrent une **corrélation modérée à forte** entre les **réponses affectives** mesurées lors de la séance d'APA et des variables directement liées à cette séance, telles que l'**effort perçu**, le **plaisir remémoré** de la séance ou le **plaisir anticipé** de la prochaine séance. Ces résultats suggèrent que les **variables affectives expérientielles** pourraient jouer un rôle dans l'engagement et le maintien de comportements d'activité physique **spécifiques**, comme la participation à des séances d'APA, plutôt que dans l'activité physique générale.

Il est important de noter que cette étude n'a mesuré les réponses affectives que lors **d'une seule séance**. Théoriquement, la **répétition d'expériences affectives** pourrait influencer des variables affectives **non-expérientielles**, telles que les attitudes affectives, qui sont associées à des comportements d'activité physique plus **généraux**. Des recherches futures devraient explorer comment la répétition d'expériences affectives dans des contextes spécifiques, tels que des **programmes de réadaptation hospitaliers**, pourrait influencer les niveaux globaux d'activité physique chez les personnes atteintes de maladies chroniques.

PARTIE 2

Identification des stratégies d'intervention permettant l'amélioration des variables affectives chez les personnes atteintes de maladies chroniques

Chapitre 6 **Intervenir sur les variables affectives**

La deuxième question de ce projet doctoral s’interroge sur les possibilités de manipulation des variables affectives. Autrement dit, quelles stratégies d’intervention sont efficaces pour améliorer ces variables ? Ce chapitre abordera ces stratégies en les regroupant en trois catégories : (1) les stratégies d’intervention « endogènes » basées sur l’expérience directe de l’activité physique, ciblant les réponses affectives, l’affect remémoré et la réponse affective anticipée (e.g., moduler l’intensité de l’effort à la fin d’une séance d’APA) ; (2) les stratégies d’intervention « exogènes » basées sur l’expérience directe de l’activité physique, visant les mêmes variables affectives (e.g., ajouter de la musique à différents moments d’une séance d’APA) ; et (3) les stratégies d’intervention digitales, qui ciblent les réponses automatiques, telles que les tendances d’approche-évitement, sans nécessiter d’expérience physique directe avec l’activité physique. Les deux premières stratégies seront traitées à travers un chapitre d’ouvrage et un protocole de recherche (Contribution n°3 et Contribution empirique n°4), tandis que la troisième sera abordée sous une forme narrative dans la section 6.3 de ce Chapitre, et développée dans la Contribution n°6.

6.1 Contribution n°3 : stratégies d’intervention endogènes et exogènes basées sur l’expérience directe de l’activité physique

Cette Contribution avait pour objectif de proposer une liste non exhaustive des stratégies d’intervention endogènes et exogènes ciblant les variables affectives, telles que les réponses affectives, l’affect remémoré et la réponse affective anticipée, dans le contexte de l’activité physique chez la population générale. Après avoir présenté les bienfaits de l’activité physique sur la santé et mis en lumière la prévalence de l'inactivité physique chez la population générale, nous avons exposé certaines théories affectives de l'activité physique. Finalement, nous avons proposé une liste non exhaustive des stratégies endogènes et exogènes à l'activité physique, conçues pour favoriser des expériences affectives positives. Il convient de noter que certaines terminologies employées dans cette Contribution diffèrent de celles utilisées dans ce travail doctoral. Notamment, les termes « affect de base » et « réponse affective » mentionnés dans cette Contribution correspondent à « l'affect fondamental » (*core affect*) utilisé dans ce projet doctoral. De plus, les variables « plaisir remémoré » et « plaisir anticipé » abordées dans cette Contribution renvoient à l'affect remémoré et à la réponse affective anticipée, respectivement. Enfin, les « mécanismes affectifs » y sont décrits comme « *l'ensemble des variables constitutives des affects* » (p. 3), tandis que dans ce travail doctoral, nous les définissons comme les « processus par lesquels les différentes variables affectives interagissent et se manifestent » (Schiller et al., 2024 ; traduction libre).

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Chapitre 9

S'engager dans une activité physique régulière : le rôle des expériences affectives positives[1]

Fessler, L., Maltagliati, S., Cheval, B., Sarrazin, P. (2024). S'engager dans une activité physique régulière : le rôle des expériences affectives positives. In C. Martin-Krumm et C. Tarquinio (Eds.), Psychologie positive des activités physiques et sportives (pp. 153-164). Malakoff : Dunod. ISBN : 978-2100849604

1. Par **Layan Fessler, Silvio Maltagliati, Boris Cheval** et **Philippe Sarrazin.**

S'engager dans une activité physique régulière : le rôle des expériences affectives positives

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Introduction : les bénéfices de l'activité physique sur la santé

L'activité physique, définie comme tout mouvement corporel produit par les muscles squelettiques qui entraîne une dépense énergétique au-dessus du métabolisme de repos (Caspersen, Powell, & Christenson, 1985), ne se limite pas à la pratique sportive en compétition. Elle englobe des pratiques variées telles que la marche, la natation, le vélo, la danse, ou encore les travaux ménagers ou les transports actifs. L'Organisation Mondiale de la Santé (OMS) recommande la pratique d'activités d'endurance d'intensité modérée pendant 150 à 300 minutes par semaine ou 75 à 150 minutes par semaine à intensité vigoureuse, ou une combinaison des deux. Il est également préconisé de consacrer au moins deux jours hebdomadaires de renforcement musculaire, tout comme la réduction du temps sédentaire. Ces recommandations ont été élaborées en se fondant sur les relations positives établies entre la pratique régulière d'une activité physique et la santé physique (e.g., force musculaire ; Ramsey et al., 2021), mentale (Schuch et al., 2018) et cognitive (e.g., mémoire ; Falck et al., 2019). Par exemple, il a été démontré que l'activité physique réduit la prévalence de nombreuses maladies chroniques telles que le diabète, le cancer ou l'hypertension (Rhodes et al., 2017), tout en améliorant la condition physique et la qualité de vie des personnes déjà confrontées à ces pathologies (Bierbauer et al., 2020 ; Scott et al., 2013).

Ces bienfaits pour la santé sont désormais largement connus du grand public (Canadian Fitness and Lifestyle Research Institute, 2018 ; Fredriksson et al., 2018). Cependant, force est de constater que malgré cette prise de conscience, les niveaux d'activité physique continuent de stagner. Par exemple, dans une enquête réalisée en 2022 au niveau des 27 états membres de l'Union Européenne, 45% des européens ont admis ne jamais pratiquer de sport ou d'activité physique, et 17% en faire rarement (Eurobarometer, 2022). Même parmi les individus qui manifestent l'intention d'adopter une pratique physique, près de la moitié ne parviennent pas à concrétiser leur intention, comme l'ont souligné Feil, Fritsch, et Rhodes (2023). Or, cet écart entre intention et action n'est pas sans conséquences : aujourd'hui, l'inactivité physique est le quatrième facteur de risque de mortalité, après l'hypertension artérielle, le tabagisme et l'hyperglycémie. Elle provoque un décès prématuré toutes les six secondes dans le monde, soit environ 5,3 millions de décès par an (Bull et al., 2020).

Promouvoir les bienfaits de l'activité physique sur la santé semble donc crucial, mais cela s'avère insuffisant pour susciter un engagement durable dans ce comportement. Récemment, notre équipe de recherche a mis en évidence que la valeur motivationnelle des bienfaits pour la santé est diminuée en raison du délai associé *(i.e., delay-discounting)*, de l'effort substantiel requis pour les atteindre *(i.e., effort-discounting)*, ainsi que de l'incertitude qui les entoure (i.e., *belief distorsion* ; Maltagliati et al., 2022). Dans ces circonstances, lorsque l'activité physique est motivée uniquement par ses avantages pour la santé, l'engagement des individus dans cette pratique semble fragile. Il devient donc impératif d'explorer d'autres variables capables de nourrir un engagement pérenne dans l'activité physique. Ce chapitre se concentrera sur le rôle des expériences affectives positives liées à l'activité physique.

L'importance d'une expérience d'activité physique agréable

Les travaux les plus récents s'accordent sur le fait que le comportement humain ne peut être expliqué, voire modifié, sans prendre en compte les mécanismes affectifs, tels que les émotions ou les humeurs, qui sont à la base de sa régulation (Dukes et al., 2021). En accord avec cette perspective, les mécanismes affectifs occupent une place centrale dans les théories contemporaines de l'activité physique (Brand & Ekkekakis, 2018 ; Cheval & Boisgontier, 2021b ; Conroy & Berry, 2017). Par exemple, ressentir du déplaisir lors d'une activité physique intense peut dissuader certaines personnes de maintenir cette pratique dans la durée. Afin de soutenir cette relation entre les mécanismes affectifs et l'activité physique, ce chapitre commence par définir les termes clés, présente les différentes théories mobilisant ces concepts, et enfin, propose des stratégies concrètes pour améliorer l'expérience affective des individus.

Définition des différents mécanismes affectifs

La littérature sur les mécanismes affectifs utilise une variété de concepts interconnectés, qui se recouvrent plus ou moins, ce qui peut rendre la compréhension des phénomènes étudiés complexe. Le Tableau 1 regroupe les définitions des principaux concepts identifiés dans ce chapitre.

Tableau 1.

Définitions des différents mécanismes affectifs utilisés dans ce chapitre

Terme	Définition
Affect	Terme générique décrivant les états affectifs tels que les émotions et les humeurs (Niven, 2013).
Mécanisme affectif	Les mécanismes affectifs font références à toutes les variables constitutives des affects (e.g., affect de base, évaluation affective automatique et réfléchie, plaisir remémoré).
Affect de base *(core affect)*	État neuro-physiologique accessible consciemment, qui se manifeste le plus souvent à travers l'humeur et l'émotion, mais qui est accessible à la conscience (Russell & Feldman Barrett, 2009). Il est caractérisé par deux dimensions élémentaires indépendantes et transculturel : la valence (sensation de plaisir-déplaisir) et l'activation (ou arousal, sensation d'énergie-épuisement).
Réponse affective	Affect de base vécu et ressenti par l'individu à un moment précis pendant un évènement singulier.
Plaisir anticipé	Degré de plaisir ou de déplaisir anticipé lors d'évènements à venir (Zenko, Ekkekakis, & Ariely, 2016).

Continue

Tableau 1. *Continue*

Terme	Définition
Plaisir remémoré	Évaluation rétrospective globale du plaisir ou déplaisir associé à un évènement particulier (Hutchinson et al., 2023).
Évaluations affectives réfléchies (ou attitudes affectives)	Évaluations d'un comportement basées sur l'agrégation de différentes réponses affectives potentielles anticipées (e.g., l'activité physique est agréable plutôt que pénible à mes yeux ; Williams & Evans, 2014).
Évaluations affectives automatiques (ou attitudes implicites)	Association spontanée entre un objet (e.g., activité physique) et des attributs positifs (e.g., plaisir) ou négatifs (e.g., déplaisir ; Conroy & Berry, 2017)

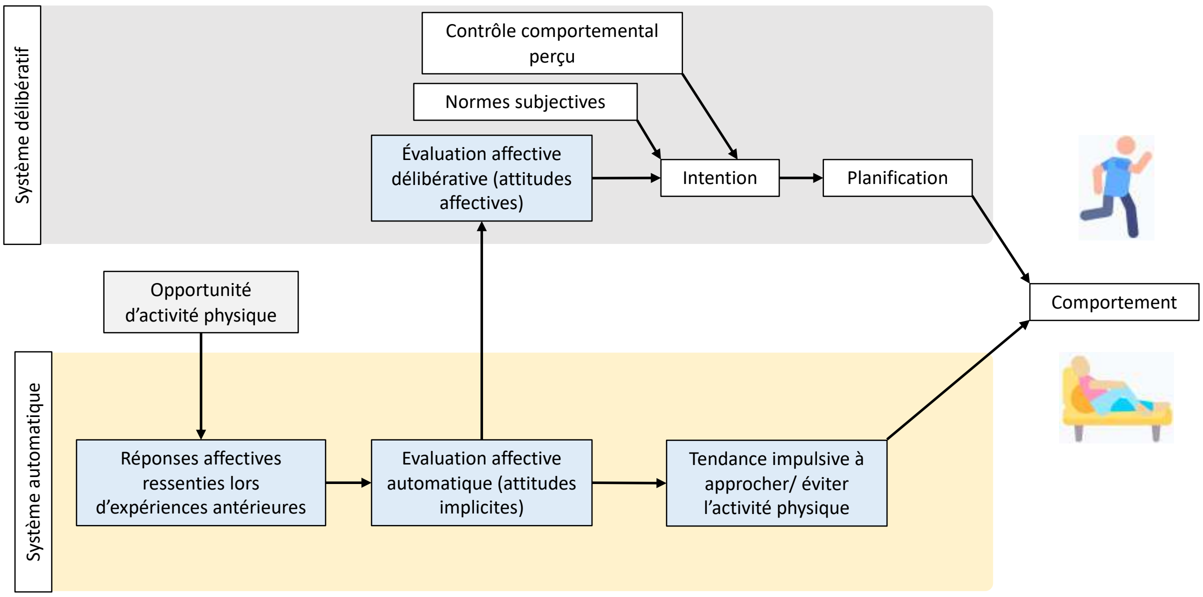
Les modèles théoriques

De nombreux modèles théoriques considèrent les mécanismes affectifs comme des variables centrales dans la régulation de l'activité physique (voir Figure 1 pour un résumé). Par exemple, les modèles duaux proposés par Conroy et Berry (2017) ou Brand et Ekkekakis (2018) soulignent l'existence de processus automatiques qui sous-tendent l'engagement dans un comportement d'activité physique. Ainsi, à côté des mécanismes réfléchis – ceux qui conduisent, par exemple, une personne à formuler l'intention d'être physiquement active et à planifier ce comportement – ces modèles proposent que, face à la perception d'une opportunité d'activité physique (e.g., voir un sentier dans un parc boisé), des réponses affectives, et plus précisément leur valence, sont automatiquement déclenchées. Cette évaluation affective automatique, basée sur les expériences affectives passées, colore à son tour l'évaluation réfléchie associée à l'engagement dans l'activité physique. Par exemple, des réponses affectives positives éprouvées lors de sessions d'activité physique (e.g., « *J'ai pris beaucoup de plaisir à courir le long du lac* ») auront un impact positif sur l'évaluation de cette activité physique, que ce soit au niveau réfléchi (i.e., dire que l'activité physique est quelque chose de plaisant) ou automatique (i.e., associer spontanément l'activité physique à des attributs positifs). Ces modèles permettent notamment d'expliquer pourquoi les personnes éprouvant ou ayant éprouvé du déplaisir lors de la pratique de l'activité physique ont du mal à s'engager durablement dans une pratique physique régulière, même si elles sont par ailleurs convaincues de l'importance de ce comportement pour leur santé.

Pour préciser encore davantage ces modèles, Cheval et Boisgontier (2021a ; 2021b) ont développé la théorie de la minimisation de l'effort en activité physique. Selon celle-ci, il existerait une tendance naturelle, issue de notre évolution, à minimiser les efforts physiques afin de conserver les ressources énergétiques de l'individu. Cette propension à minimiser l'effort constitue un incitateur automatique puissant qui peut prendre le pas sur l'intention d'être physiquement actif. Selon ce modèle, des expériences affectives positives liées à l'activité physique pourraient contribuer à réduire la perception de l'effort, facilitant ainsi l'engagement et le maintien de cette pratique.

Figure 1

Représentation simplifiée des théories de Conroy et Berry (2017), Brand et Ekkekakis (2018), et Cheval et Boisgontier (2021b).



Note. Les mécanismes affectifs sont représentés dans les encadrés bleus. Les pictogrammes proviennent du site www.flaticon.com.

En appui à ces théories, des travaux empiriques ont montré que les réponses affectives, et particulièrement leur valence affective, éprouvées durant la pratique d'une activité physique étaient associées à l'engagement dans celle-ci (Rhodes & Kates, 2015). Par exemple, Schneider, Dunn et Cooper

(2009) ont évalué la valence affective chez des adolescents en bonne santé lors d'une séance de 30 minutes sur un vélo stationnaire, à intensité modérée ou vigoureuse. Le niveau d'activité physique de la semaine suivante a été mesuré à l'aide d'accéléromètres. Les résultats ont révélé que lors des séances à intensité modérée (uniquement à cette intensité), une valence affective positive plus élevée était associée à un niveau d'activité physique supérieur mesuré la semaine suivante. Williams et al. ont étendu ces conclusions sur une période de six et douze mois. Dans une première étude (2008), ils ont mesuré la valence affective chez des adultes en bonne santé et sédentaires pendant une marche à intensité modérée sur un tapis roulant. Les résultats ont montré que la valence affective positive pendant la séance d'activité physique prédisait positivement, mais de manière modérée, l'activité physique six et douze mois après l'étude. Dans une seconde étude, un protocole similaire a été conduit chez des adultes sédentaires et en surpoids (Williams et al., 2012). Les auteurs ont trouvé un effet – certes de faible amplitude – des réponses affectives sur l'activité physique six mois plus tard. En d'autres termes, plus les individus prennent du plaisir lors de la pratique d'une activité physique, plus ils ont de chances de s'engager à nouveau dans cette pratique.

Améliorer l’expérience affective liée à l’activité physique

Si les modèles théoriques et travaux empiriques convergent sur l’importance des expériences affectives dans la régulation du comportement d’activité physique, force est de constater que toutes les personnes ne ressentent pas systématiquement du plaisir en s'engageant dans cette activité (Ekkekakis, Parfitt, & Petruzzello, 2011). Dans le but d’améliorer ces réponses affectives, plusieurs stratégies visant à agir sur des facteurs dits « endogènes » (i.e., fréquence, intensité, durée et type d’activité physique) et « exogènes » (i.e., facteurs situationnels et environnementaux) ont été identifiées (Jones & Zenko, 2021 ; 2023). Dans ce chapitre, nous proposons une liste non exhaustive des stratégies *endogènes* et *exogènes* qui ont donné lieu à des recherches importantes.

Au niveau *endogène*, une première stratégie consiste à privilégier une intensité modérée d'effort, se situant en dessous du premier seuil ventilatoire[5] (i.e., 60–70% de la fréquence cardiaque maximale : l'activité doit être légèrement fatigante, la respiration s'accélère, mais il est toujours possible de tenir une conversation sans interruption ; Mezzani et al., 2013). En général, la valence des réponses affectives induite par une intensité d'exercice modérée est positive pour la plupart des individus (Ekkekakis, Hartman, & Ladwig, 2020). En revanche, des intensités plus élevées (i.e., vigoureuse[6] ou extrême[7]), suscitent soit des réponses mêlées de plaisir et déplaisir (intensité vigoureuse), soit des réponses de déplaisir (intensité extrême ; Ekkekakis et al., 2020). Il convient toutefois de noter que l'effet de l'intensité de l'effort sur les réponses affectives varie d'un individu à l'autre en fonction de leur préférence pour un certain type d'intensité et de leur tolérance à l'intensité de l'exercice (un trait qui influe sur la capacité d'une personne à continuer de pratiquer à un niveau d'intensité imposé, même lorsque l'activité devient inconfortable ou désagréable ; Ekkekakis, Hall, & Petruzzello, 2005 ; Zenko & Ekkekakis, 2019). Une deuxième stratégie consiste donc à évaluer la préférence et la tolérance de chaque individu, en amont d'une séance ou d'un programme d'activité physique, à l'aide d'un questionnaire dédié (PRETIE-Q ; Ekkekakis, Hall, & Petruzzello, 2005). Grâce à ce questionnaire, il devient possible de personnaliser l'intensité de l'exercice en fonction des caractéristiques spécifiques de chaque personne et, en fin de compte, d'optimiser leurs réponses affectives. Une troisième stratégie consiste à manipuler la répartition de l'intensité de l'effort au cours d'une séance d'activité physique. Cette stratégie repose sur des travaux en économie comportementale suggérant que le plaisir remémoré est accru lorsque celui-ci augmente au cours de l'activité pratiquée, plutôt que de décroître au fil du temps (e.g., Zauberman, Diehl, & Ariely, 2006). Ce principe a été étendu au domaine de l'activité physique en modifiant la répartition de l'intensité de l'effort au cours d'une séance. Notamment, Zenko et ses collaborateurs (2016) ont examiné l'effet de cette stratégie lors d'une tâche de pédalage de 15 minutes sur vélo stationnaire, chez des adultes en bonne santé. Dans cette étude, un groupe a vu son intensité d'exercice augmenter progressivement tout

[5] Seuil au-dessus duquel le lactate sanguin commence à augmenter et le pH à diminuer (Mezzani et al., 2013).
[6] Entre le premier et le second seuil ventilatoire, la durée d'exercice est d'environ 3 à 20 minutes (Mezzani et al., 2013)
[7] Au-dessus du deuxième seuil ventilatoire, la durée d'exercice est inférieure ou égale à 3 minutes (Mezzani et al., 2013)

au long de la séance (de 0 watt à 120% de la puissance correspondant à leur premier seuil ventilatoire ; Condition X), tandis qu'un autre groupe a vu son intensité diminuer au cours de la séance (Condition Y). Les résultats ont révélé que les participants de la condition X se souvenaient de la séance comme étant plus agréable et anticipaient des expériences plus positives pour les séances futures d'exercice, par rapport aux participants de la condition Y. Des effets similaires ont été observés lors de séances de renforcement musculaire (Hutchinson et al., 2023) ou chez des patients atteints de la maladie de Parkinson (Fessler et al., 2024).

Les réponses affectives positives à l'exercice peuvent également être maximisées en utilisant d'autres stratégies ciblant les facteurs dits *exogènes*. Une première stratégie exogène consiste à utiliser la musique durant les séances d'activité physique. Une méta-analyse menée par Terry et collaborateurs (2020) incluant 139 études, a révélé que pratiquer une activité physique en musique était associé une valence affective plus positive, de meilleures performances physiques, une diminution de la perception de l'effort et une meilleure consommation d'oxygène liée à cette pratique. Il convient de noter que le tempo de la musique semble être le facteur le plus influent sur l'occurrence de ces états affectifs positifs. Plus précisément, des morceaux à tempo modéré (i.e., 120–125 bpm) semblent davantage augmenter la valence affective positive lors de séances d'activité physique, comparativement à des musiques à un tempo élevé (i.e., 135–140 bpm) ou à l'absence de musique (Karageorghis et al., 2021). Cependant, l'environnement de pratique ne se limite pas aux stimuli auditifs. Une deuxième stratégie exogène consiste à pratiquer une activité physique en extérieur. Une récente revue narrative a montré que la pratique d'activités physiques en extérieur induisait des réponses affectives plus positives que les activités physiques effectuées en intérieur (Bourke, Hilland, & Craike, 2021). Cependant, il semble que tous les environnements extérieurs ne se valent pas. Dans une étude expérimentale, Kinnafick et Thøgersen-Ntoumani (2014) ont montré que la marche en extérieur, dans un environnement naturel (e.g., à la campagne), induisait de meilleures réponses affectives que la même activité pratiquée en ville. Privilégier les activités de pleine nature, lorsque cela est permis par la météo ou la situation géographique, serait donc une stratégie efficace pour maximiser les réponses affectives positives à l'exercice. Une troisième stratégie consiste à agir sur le climat motivationnel instauré par l'intervenant lors d'une séance d'activité physique, de manière à soutenir les besoins psychologiques fondamentaux des participants (Sarrazin et al., 2011). Selon la théorie de l'autodétermination (Ryan & Deci, 2017), il existe trois besoins psychologiques fondamentaux : le besoin (a) d'autonomie (i.e., se sentir à l'origine de ses actions et libre de faire des choix sans contrainte externe), (b) de compétence (i.e., se sentir efficace dans ses activités) et (c) de proximité sociale (i.e., se sentir connecté et soutenu par des autrui significatifs). La satisfaction de ces besoins conduit au bien-être et au fonctionnement optimal des individus. Les différents comportements d'un intervenant qui sont de nature à soutenir chacune des trois besoins sont décrits ailleurs (Sarrazin et al., 2011 ; Teixeira et al, 2020) ; nous en développons quelques-uns à titre d'exemple. Pour soutenir le besoin d'autonomie, l'intervenant peut accorder aux pratiquants le choix de leur propre intensité d'activité physique. Williams et al. (2015 ; 2016) ont montré que les participants qui sélectionnaient leur propre rythme de marche, comparativement à ceux invités à marcher à une intensité prédéfinie, ressentaient des réponses affectives plus positives. Afin de soutenir le besoin de compétence, l'intervenant peut encourager les pratiquants et leur fournir des retours positifs réguliers. Des études ont montré que lors d'une session d'exercice d'intensité vigoureuse à extrême, les participants ayant reçu des feedbacks positifs pendant la séance (e.g., « *Vous faites un travail formidable !* » ; « *Vous vous situez au-dessus des performances moyennes des personnes de votre âge* ») ont rapporté avoir ressenti plus de plaisir, comparativement aux participants ayant reçu des feedbacks négatifs ou aucun retour (Hu et al., 2007 ; Tritter et al., 2013). Finalement, pour satisfaire le besoin de proximité sociale, il est essentiel que l'intervenant fasse preuve d'empathie et de compréhension envers les pratiquants, et qu'il favorise l'entraide et la coopération entre eux lors de séances d'activité physique en groupe (Sarrazin et al., 2011). À cet égard, Graupensperger et al. (2019) ont notamment montré que lors de séances collectives de fitness, plus les pratiquants se sentaient appartenir au groupe, plus leurs réponses affectives étaient positives pendant les séances.

Conclusion

Dans ce chapitre, nous avons mis en évidence que, au-delà des bénéfices de l'activité physique pour la santé, les théories récentes accordent une place centrale aux expériences affectives dans la régulation de ces comportements. L'intégration de cette dimension affective, associée à l'accumulation de preuves empiriques, contribue à une meilleure compréhension des mécanismes sous-jacents à l'engagement et au maintien dans une activité physique. De plus, cette approche fournit des pistes d'intervention concrètes pour différents professionnels (e.g., enseignants en activité physique adaptée, professeurs d'éducation physique et sportive, kinésithérapeutes, ergothérapeutes) dans la conception d'interventions visant à promouvoir l'engagement durable des individus dans l'activité physique.

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Résumé des résultats principaux la Contribution n°3

La Contribution n°3 met en lumière l'importance des **expériences affectives positives** pour favoriser l'engagement dans une pratique régulière d'activités physiques chez la population générale. Bien que les bienfaits physiques, mentaux et cognitifs de l'activité physique soient connus, ces avantages seuls ne suffisent souvent pas à motiver une pratique régulière. Cela pourrait s'expliquer par le **délai** associé à l'apparition des bénéfices de l'activité physique sur la santé (i.e., *delay-discounting*), l'**effort** substantiel requis pour les atteindre (i.e., *effort-discounting*), ainsi que l'**incertitude** qui les entoure (i.e., *belief distorsion*). Cette contribution permet également de distinguer deux types de stratégies d'intervention visant à améliorer les expériences affectives d'activité physique : (1) les stratégies « **endogènes** », basées sur l'expérience directe de l'activité physique, qui ciblent les réponses affectives, l'affect remémoré et la réponse affective anticipée (e.g., ajustement de l'intensité de l'effort en fonction des préférences individuelles ou du moment de la séance) ; (2) les stratégies « **exogènes** », également basées sur l'expérience directe, mais visant à moduler les mêmes variables affectives par des éléments externes (e.g., utilisation de la musique ou pratique en plein air). En optimisant ces expériences affectives positives à travers ces deux types de stratégies, il semble alors possible de faciliter l'engagement à l'activité physique, notamment en influençant positivement l'**évaluation affective globale** de cette pratique.

Ces résultats doivent permettre d'encourager les professionnel·les de santé et de l'activité physique à intégrer ces stratégies endogènes et exogènes dans la conception d'interventions visant à promouvoir un engagement dans des activités physiques. Comme nous le verrons lors de la **Contribution empirique n°4** l'utilisation stratégique de la **musique** à des **moments clés** au cours d'une séance d'APA pourrait constituer un moyen efficace de renforcer l'expérience affective positive.

6.2 Contribution empirique n°4 : protocole d'une stratégie d'intervention endogène et exogène basée sur l'expérience directe de l'activité physique

Cette quatrième contribution visait à élaborer un protocole de recherche permettant d'évaluer l'efficacité de l'écoute de musique à certains moments de séances d'APA d'intensité modérée sur vélo stationnaire, sur les réponses affectives ainsi que sur l'affect remémoré et la réponse affective anticipée chez des patient·es participant·es à un programme de réadaptation cardiovasculaire stationnaire aux Hôpitaux Universitaires de Genève. Plus précisément, cette Contribution combinait l'effet positif de musiques motivantes sur les réponses affectives (Terry et al., 2020) – une stratégie exogène – avec le principe du « pic et de la fin » (Fredrickson, 2000) – une stratégie endogène. En d'autres termes, nous avons exploré la question suivante : l'écoute de musique à différents moments d'une séance d'activité physique d'intensité modérée (i.e., au début, à la fin, tout au long, ou sans musique) influence-t-elle différemment certaines variables psychologiques (affects fondamentaux [*core affect*] immédiats, affect remémoré de la séance, et réponse affective anticipée de la séance suivante), psychophysiques (effort perçu) et psychophysiologiques (variabilité de la fréquence cardiaque), par rapport à l'écoute de musique tout au long de la séance ou à l'absence de musique ? Une fois collectées, les données seront analysées à l'aide de modèles linéaires mixtes, ainsi que des analyses de médiation. Il convient de noter que certaines terminologies employées dans cette Contribution diffèrent de celles employées dans ce travail doctoral. Notamment, les variables « plaisir remémoré » *(remembered pleasure)* et « plaisir anticipé » *(forecasted pleasure)* mesurées dans cet article renvoient à l'affect remémoré et à la réponse affective anticipée, respectivement.

Cette contribution a été réalisée sous la forme d'un rapport enregistré *(registered report)*, un type spécifique de protocole de recherche. Ce choix a été motivé par plusieurs raisons, en comparaison avec la publication d'un pré-enregistrement *(preregistration)* sur une plateforme ouverte gratuite (e.g., Zenodo, OSF) ou d'un protocole *(study protocol)* dans un journal scientifique. Ces trois formats de publication fournissent une trace écrite du plan de recherche, détaillant à l'avance la justification, la méthodologie et les analyses prévues, et renforcent la transparence du processus tout en limitant les pratiques de recherche préjudiciables, telles que la formulation d'hypothèses *a posteriori* (BMJ Blogs, 2015 ; Lakens et al., 2024). Cependant, contrairement au pré-enregistrement, le rapport enregistré et le protocole font l'objet d'une évaluation par les pairs avant la collecte des données. Cette évaluation porte à la fois sur la qualité de la conception (introduction, méthodologie, analyses statistiques) et sur l'importance de la question de recherche. Une fois accepté par le journal, le protocole *(study protocol)* est publié sous forme d'article, moyennant des frais de publication habituels. Toutefois, cette publication ne garantit pas celle de l'article final – une fois les données collectées et analysées.

En revanche, dans le cadre d'un rapport enregistré, la revue peut – à l'issue de l'évaluation du rapport par les pairs – rejeter la soumission, demander des révisions ou accorder une « acceptation de principe » *(in-principle acceptance)*. Cette acceptation de principe garantit que, si les chercheur·euses suivent le plan pré-enregistré, leur article final sera publié, indépendamment des résultats obtenus – qu'ils soient statistiquement significatifs ou non (Lakens et al., 2024). Une fois approuvé, le rapport peut être publié dans le journal ciblé, généralement moyennant des frais de publication, ou sur une plateforme gratuite dédiée (e.g., https://rr.peercommunityin.org/), sans frais. Après la collecte et l'analyse des données, le manuscrit final est soumis pour révision par les pairs (non obligatoire). Les déviations par rapport au plan initial doivent être documentées et justifiées, mais un manuscrit ne peut être rejeté en raison de résultats non-significatifs, sauf en cas de problèmes méthodologiques graves (Lakens, 2024 ; Lakens et al., 2024).

La Commission cantonale d'éthique de la recherche du canton de Genève a approuvé le protocole associé à ce projet de recherche le 10 octobre 2024 (CCER2024-00959). Des données pilotes sont en cours de collecte et seront analysées afin d'ajuster le protocole aux contraintes spécifiques de l'environnement de recherche. Le rapport sera ensuite soumis au journal avant le déploiement du protocole dès l'année 2025. La Contribution empirique n°4 prend donc la forme d'un rapport enregistré en cours de préparation. L'article a été formaté selon les normes de l'American Psychological Association (APA). Le matériel supplémentaire est disponible en Annexe 2.

Effect of Differentiated Music Exposure on Exercise-Related Affect Among Cardiac Rehabilitation Inpatients: A Registered Report of the MUSICare Project

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Author Contributions

The first draft of the manuscript was written by LF, BC and PS. All authors commented on the previous versions of the manuscript. All authors read and approved the final manuscript. LF contributed to conceptualisation, methodology, investigation, formal analysis, writing—original draft; KI contributed to conceptualisation, methodology, investigation, formal analysis, writing–review and editing; CIK contributed to conceptualisation, methodology, formal analysis, writing–review and editing; JH contributed to conceptualisation, methodology, writing–review and editing; ET contributed to conceptualisation, methodology, resources, writing–review and editing; CL contributed to conceptualisation, methodology, resources, writing–review and editing; PS conceptualisation, methodology, supervision, writing—original draft; BC contributed to conceptualisation, methodology, supervision, writing—original draft.

Abstract

Objectives. Affective variables, such as core affect, remembered pleasure, and forecasted pleasure, are key for promoting physical activity (PA) and exercise, especially in people with chronic diseases. The use of music has been shown to be a particularly cost-effective and low-friction approach to promoting positive affective valence during PA and exercise. According to the peak-end rule, it is not the averaged sum of the affective responses that matters, but rather the most intense and the final affective valences of an experience that significantly shape remembered pleasure, which in turn predicts forecasted pleasure and future activity engagement. Despite the potential benefits, interventions using music to improve exercise-related affective phenomena in people with chronic disease remain unexplored, particularly in relation to the peak-end rule. This study will aim to evaluate a proof-of-concept experimental design that combines the effects of music with the peak-end rule to improve core affective responses (valence and arousal), remembered pleasure, and forecasted pleasure during exercise sessions among cardiac rehabilitation inpatients. Additionally, we will also test its impact on exercise-related perceived exertion, heart rate, and heart rate variability.

Design. Fully counterbalanced within-subject design.

Methods. Seventy-two inpatients undergoing a 3-week cardiac rehabilitation programme will participate in four moderate-intensity continuous training (MICT) sessions under different conditions: (a) music during the first half (MFH), (b) music during the second half (MSH), (c) music during the entire session (music throughout, MT), and (d) no music (control condition). Measurements will be taken before (affective valence, forecasted pleasure), during (core affective response, rating of perceived exertion, heart rate, and heart rate variability), and after (remembered pleasure, global perceived exertion) each session. Core affective response and rating of perceived exertion will be assessed during the first and last halves of the exercise sessions. Linear mixed-effect models will be used to analyse the effects of the conditions on the pre-, during-, and post-MICT outcomes, as well as the influence of remembered pleasure on forecasted

pleasure. Mediation analyses will assess whether final affective valence mediates the relationship between conditions and remembered pleasure.

Conclusion. Findings will advance the theoretical understanding of how the differentiated use of music influences exercise-related affective variables among cardiac rehabilitation inpatients. This proof-of-concept research will pave the way for future studies, enabling the design of a randomised controlled trial to test, for example, the effects of such interventions on exercise adherence, via more positive affective response at the end of the exercise session.

Keywords: physical activity, pleasure, patients, heart rate variability, health

Introduction

Cardiovascular diseases (CVD), including coronary heart disease and cerebrovascular disease, are the leading cause of death worldwide, accounting for 17.9 million deaths annually (World Health Organization, 2023). Regular physical activity (PA) and exercise play a crucial role in the primary, secondary, and tertiary prevention of CVD (Franklin et al., 2022; Perry et al., 2023). In rehabilitation centres, exercise-based rehabilitation programmes (EBRPs) are an integral part of the comprehensive cardiac rehabilitation programmes (Bierbauer et al., 2020; Dibben et al., 2023; Richardson et al., 2019). Participation in EBRPs has been associated with numerous health benefits in this population, including reduced hospital admissions, improved quality of life, and increased physical, mental, and cognitive health (Anderson et al., 2016; Bracewell et al., 2022; Dibben et al., 2023; Haseler et al., 2019).

It is perhaps something of a paradox that only 17% to 38% of those living with CDV meet the weekly 150 minutes of moderate-to-vigorous PA (MVPA; Kotseva et al., 2016; Tang et al., 2013), and less than 27% of CDV patients adhere to EBRPs (Bracewell et al., 2022). Despite the recognised health benefits of EBRPs, patients disengage quickly after discharge from a cardiac rehabilitation programme (Bierbauer et al., 2023; Dagner et al., 2019; Steca et al., 2017). For example, only 20% of patients achieved the recommended levels of PA six months after being discharged from a cardiac rehabilitation programme (Dagner et al., 2019). Notably, as PA levels were assessed using a self-reported questionnaire, the actual figures may have been even lower if measured with device-based methods, such as accelerometer (Dyrstad et al., 2014). Because regular PA can have significant health benefits for people with cardiovascular diseases, it is important to develop interventions that increase PA in this population over the long term. Affective mechanisms may play a key role in achieving this objective.

Affective Mechanisms in Physical Activity

Affect, a collective term describing feeling states, including emotions, moods, and core affect (Niven, 2013), has taken a prominent place in recent PA-related theories (Brand & Ekkekakis, 2018; Cheval & Boisgontier, 2021; Conroy & Berry, 2017). Importantly, affective mechanisms can be considered essential in explaining why many people who intend to be physically active fail to translate their intentions into action (Cheval et al., 2024; Rhodes et al., 2022). These mechanisms encompass the interplay and manifestation of key affective variables, including core affect, remembered pleasure, and forecasted pleasure (Schiller et al., 2024; Williams & Evans, 2014). Core affect refers to a neurophysiological state that is consciously accessible as a simple primitive nonreflective feeling (Russell & Feldman Barrett; 2009). Remembered pleasure is the degree to which the PA performed is remembered as being pleasant or unpleasant (Hutchinson et al., 2023). Forecasted pleasure, on the other hand, is the extent to which people anticipate how pleasant or unpleasant a future PA will be (Hutchinson et al., 2023).

Anchored in the so-called dual-process models, repeated engagement in exercise and PA elicits distinct affective experiences (or affective responses) that can be assessed at both an automatic (i.e., rapid, requiring minimal cognitive resources and effort) and a reflective (i.e., slower, requiring a more conscious and controlled processing) level (Brand & Ekkekakis, 2018; Evans & Stanovich, 2013). Crucially, it has been argued that positive automatic and reflective affective evaluations of exercise may increase the likelihood of engaging in this behaviour in the future when the opportunity arises, whereas negative affective evaluations should decrease it (Brand & Ekkekakis, 2018; Conroy & Berry, 2017). Moreover, according to the recent Theory of Effort Minimization in Physical Activity (TEMPA; Cheval & Boisgontier, 2021; Cheval et al., 2024), positive automatic affective evaluations are expected to reduce the perceived effort associated with a given PA behaviour, thereby increasing the likelihood of engage in and repeating that behaviour. In summary, affective mechanisms are thought to play a key role in the regulation of PA behaviours, regardless of the specific dual-process models applied.

Understanding the influence of affective variables on exercise and PA behaviours has gained increasing attention in recent years, especially in the context of people with chronic diseases (Cheval et al., 2021; Fessler, Tessitore, et al., 2024; Luque-Suarez et al., 2019; Oğuz et al., 2023). For example, affective valence (i.e., pleasure-displeasure) have been suggested to play a role in shaping PA and exercise engagement (Dunton et al., 2023; Liao et al., 2017; Rhodes et al., 2023; Rhodes & Kates, 2015; Teixeira et al., 2024; Williams et al., 2016). Notably, negative affective valence experienced during PA may be particularly impactful for those with chronic diseases, where factors such as fear, pain, and discomfort associated with exercise play a critical role (Cheval et al., 2021; Goubran et al., 2024; Shelby et al., 2008). For example, fear of PA is particularly pronounced in CDV patients (Hoffmann et al., 2018), which may contribute to their low adherence to PA programmes (Goubran et al., 2024; ter Hoeve et al., 2015). In addition, negative affective experiences during PA may depend not only on the cognitive biases against this behaviour, but also on the objective physiological conditions associated with the disease, such as claudication pain (Abaraogu et al., 2018). Therefore, the development of interventions that target exercise-related affect may be particularly important in promoting PA and exercise adherence in cardiac rehabilitation patients. In this context, music can serve as a particularly cost-effective and low-friction approach to improve affective responses during exercise and PA.

Music and Exercise-Related Affect

In their narrative review, Ziv and Lindor (2011) indicated that the addition of music to an EBRP improved patients' motivation and adherence. The affect-enhancing properties of music may by be partly responsible for these findings, as studies have shown that listening to music during exercise sessions can improve patients' affective valence during PA and exercise (Calik-Kutukcu et al., 2016; Hutchinson et al., 2017). This positive affective experience may, in turn, support the sustained engagement in such behaviours (Rhodes & Kates, 2015; Teixeira et al., 2024). For example, Hutchinson et al. (2017) examined the effects of music and music videos on perceptual, affective, and physiological variables in 24 female outpatients at a diabetes exercise clinic. In this within-subject study, participants completed three 55-min moderate-intensity exercise sessions (i.e., 40%–60% heart rate [HT] reserve) that included a combination of aerobic and resistance training. During the sessions, participants were exposed to either a 60-min music playlist, a music-video playlist, or a control with no audiovisual stimuli. Results showed that both the addition of music and music-video conditions significantly improved affective valence scores compared to the control (d = 0.57 and d = 0.56, respectively). Similar findings have been reported for patients with cystic fibrosis (Calik-Kutukcu et al., 2016).

A recent meta-analysis by Terry et al. (2020) provided compelling evidence for the benefits of incorporating of music into exercise sessions to enhance affective experience. Analysing data from 139 studies showed significant positive effects on multiple indicators such as physical performance (e.g., time, distance, power; g = 0.31), oxygen consumption (g = 0.15), and the rating of perceived exertion (g = 0.22). Among these, affective valence, as measured by the Feeling Scale, had the largest standardized mean effect size (g = 0.48). The analysis also examined a set of moderators, including music preference, tempo, PA intensity, participant training status, and mode of music delivery, but found no significant moderation effects. This suggests that music positively influences affective valence during PA, regardless personal, situational, and musical characteristics. However, with a few exceptions (e.g., Calik-Kutukcu et al., 2016; Hutchinson et al., 2017), most studies on the effects of music on affective responses during exercise have been conducted in healthy participants.

Manipulating the Presentation of Music and the "Peak-End Rule"

Beyond continuous music exposure throughout an exercise session, the application of the peak-end rule (Kahneman et al., 1993)—which posits that the remembered pleasure of an experience is mainly influenced by its most intense (i.e., the "peak") and final (i.e., the "end") moments, rather than by the average affective responses throughout—may offer a novel approach to enhancing the impact of music on the affective experience of exercise (Terry et al., 2020). In addition, it is suggested that the overall trend (e.g., increasing or decreasing pleasure) of an experience also plays a crucial role in shaping how the experience is remembered (Ariely & Carmon, 2000). In turn, it is expected that the remembered pleasure associated with a given behavioural experience would, in turn, predict forecasted pleasure and future engagement in that behaviour (Fredrickson, 2000). The application of the peak-end rule to improve remembered pleasure has been effectively demonstrated in the context of exercise (Fessler, Sarrazin, et al., 2024; Hargreaves & Stych, 2013; Hutchinson et al., 2023; Hutchinson et al., 2020; Teixeira et al., 2024;

Zenko et al., 2016). For instance, studies have shown that decreasing intensity throughout an exercise session resulted in an overall increasing trend in pleasure aceoss the session, while increasing exercise intensity led to a decresing trend (Hutchinson et al., 2023; Hutchinson et al., 2020; Zenko et al., 2016). Additionally, decreasing exercise intensity significantly improved affective valence at the end of the session compared to sessions that ended with increasing intensity. This more favourable ending also led to higher levels of remembered pleasure. Furthermore, consistent with the peak-end rule, higher remembered pleasure was associated with higher forecasted pleasure for the next exercise session.

By integrating the influence of music with this *end-effect*, it is expected that placing music at the end of an exercise session will induce a positive affective trend and enhance the affective experience of participants at that moment. This positive end-of-session experience could, in turn, enhance both the remembered pleasure of the session and the forecasted pleasure of future exercise sessions. To date, only two studies have examined the effects of differentiated music exposure on affective variables during exercise (Lim, 2012; Lim et al., 2009).

Lim et al. (2009) investigated the effects of music introduced and removed at different points (i.e., *differentiated music exposure*) during a 10-km self-paced intensity cycling time trial. Eleven males were enrolled in three conditions: music played between 0–5 km, music played between 5–10km, and no music. Participant's positive affect (i.e., the extent to which a person feels enthusiastic, active, and alert; Watson et al., 1988) was measured at 0.5 km, 4.5 km, 5.5 km and at 9.5 km using the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988). Results showed that positive affect decreased at 5.5 km in both music conditions, corresponding to the period just after music was removed for the 0–5 km condition, and just after music introduction for the 5–10km condition. Interestingly, positive affect increased back to initial levels 9.5 km in the 5–10km condition. In other words, playing music during the second half of the cycling trials resulted in higher positive affect at the end of the trial. However, several limitations of this study should be noted. First, the sample size was relatively small, which may limit the generalisability of the findings. In addition, the PANAS used to assess positive affect may not have been the most suitable tool to capture the nuances of affective responses during exercise (Ekkekakis & Zenko, 2016). Finally, the study did not include a condition in which music was played throughout the session, hindering a direct comparison of the effects of introducing or removing the music stimulus.

In 2012, Lim expanded upon the previous study by adding a fourth condition, in which music was played continuously throughout the 10-km cycling time trial. This study involved 24 male students, and affective valence and arousal were measured at 2.5 km, 5 km, 7.5 km, and 10 km using the Feeling Scale (FS; Hardy & Rejeski, 1989) and the Felt Arousal Scale (FAS; Svebak & Murgatroyd, 1985), respectively. Results indicated that participants who had music introduced during the second half of the session exhibited more positive affect and higher arousal at the end of the trial compared to those who had music in the first half, continuously, or no music at all. Specifically, playing music during the second half attenuated the decline in affective valence.

Taken together, these results suggest that strategically timed music exposure can significantly influence the affective valence experienced at the end of an exercise session. However, both studies focused on healthy male adults, leaving open the question of whether similar effects would occur in patients participating in cardiac EBRP in a hospital setting.

The Present Study

To fil this knowledge gap, the primary objective of the present study will be to examine the effects of differentiated music exposure on affective valence during four moderate-intensity continuous training (MICT). Secondary objectives will be to assess the effect of this exposure on affective arousal, rating of perceived exertion, and heart rate variability responses during MICT, as well as on associated remembered pleasure, global perceived exertion, and forecasted pleasure. The study will also investigate whether affective valence at the end of MICT mediated the association between music exposure and remembered pleasure. Finally, we will examine how remembered pleasure influences subsequent forecasted pleasure. Our hypotheses, based on previous research (e.g., Lim, 2012; Hutchinson et al., 2023; Hutchinson et al., 2017) and outlines in Table 1, include the expectation that playing music during the second half of the exercise session will attenuate the decline in affective valence scores throughout the session (i.e., positive trend), compared to when no music is played during this period. Based on the peak-end rule principle, we hypothesise that more positive affective valence score at the end of the exercise session will increase remembered pleasure score, which, in turn, will positively impact forecasted pleasure for the next exercise session.

Method

Study Design and Power Analysis

The MUSICare Project is a single-centre study using a fully counterbalanced, repeated-measures and crossover design.

Due to the nature of the differentiated music exposure conditions, blinding of participants and experimenters is not feasible, although participants will remain unaware of the purpose and hypotheses of the study. The study will begin upon acceptance of the current Registered Report ("First-Participant-In") at the rehabilitation service of the Beau-Séjour Hospital of the University Hospital of Geneva (Switzerland) and will end after ("Last-Participant-Out"). Eligible patients will complete four MICT sessions, each corresponding to one of the following condition: (a) music played during the first half of the session (MFH; Minute 3–12), (b) music played during the second half of the session (MSH; Minute 13–22), (c) music played during the entire exercise session (music throughout, MT; i.e., Minute 3–22), and (d) no music (control condition). Participants will be randomly assigned by the medical staff and/or the researcher assistant to one of 24 possible sequences of the four conditions, following Williams' procedure (Williams, 1949). The randomisation will be conducted using R (v.4.2.3) and the code will be available on Zenodo. The study will follow the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) statement (Chan et al., 2013).

Table 1

Research Hypotheses

Question	Hypothesis	Rational	Analysis Plan
Does the differentiated use of music influence affective valence during MICT?	Affective valence scores will decrease from the first half (i.e., first 10 min) to the second half (i.e., last 10 min) of the MICT in each condition (H_{1a}). The change from the first half to the second half (i.e., the coefficient of the decrease) will be significantly smaller in the MSH and MT conditions when compared to the MFH and control conditions (H_{1b}). During the first half of the MICT, affective valence scores will be significantly higher in the MFH and MT conditions when compared to the MSH and control conditions (H_{1c}). During the second half of the MICT, affective valence scores will be significantly higher in the MSH and MT conditions when compared to the MFH and control conditions (H_{1d}).	H_{1a} and H_{1b} are based on Lim (2012). H_{1c} and H_{1d} are based on Lim (2012), Hutchinson et al. (2017), and Terry et al. (2020).	MEM with conditions, time points and their interaction as fixed factors and participants as a random factor will be computed. Interactions between two conditions (i.e., MFH × MSH; MFH × MT; MFH × Control; MSH × MT; MSH × Control; MT × Control) and two time points (i.e., the first and second half) will be performed to compare the slopes of affective valence (i.e., the coefficient of the decrease) from the first to the second half of the MICT across conditions. Simple effects tests will be used to examine the slopes of affective valence for each condition. Thereafter, we will compare the level of affective valence across conditions at the first time point and separately at the second time point. The models will also include a random slope for the effect of time at the level of participants. Potential covariates are age, sex, and BMI.
Does the differentiated use of music influence affective arousal during MICT?	Affective arousal scores will increase from the first to the second half of the MICT in the MSH, MT and control conditions, but will decrease in the MFH condition (H_{2a}). The change from the first to the second half (i.e., the coefficient of the increase) will be significantly smaller in the MFH and control conditions when compared to the MSH and MT conditions (H_{2b}). During the first half of the MICT, affective arousal scores will be significantly higher in the MFH and MT conditions when compared to the MSH and control conditions (H_{2c}). During the second half of the MICT, affective arousal scores will be significantly higher in the MSH and MT conditions when compared to the MFH and control conditions (H_{2d}).	H_{2a} and H_{2b} are based on Lim (2012). H_{2c} and H_{2d} are based on Lim (2012) and Terry et al. (2020).	MEM with conditions, time points and their interaction as fixed factors and participants as a random factor will be computed. Interactions between two conditions (i.e., MFH × MSH; MFH × MT; MFH × Control; MSH × MT; MSH × Control; MT × Control) and two time points (i.e., the first and second half) will be performed to compare the slopes of affective arousal (i.e., the coefficient of the decrease) from the first to the second half of the MICT across conditions. Simple effects tests will be used to examine the slopes of affective arousal for each condition. Thereafter, we will compare the level of affective arousal across conditions at the first time point and separately at the second time point. The models will also include a random slope for the effect of time at the level of participants. Potential covariates are age, sex, and BMI.

Continue

Table 1 *(Continue)*

Question	Hypothesis	Rational	Analysis Plan
Does the differentiated use of music influence the rating of perceived exertion during MICT?	RPE scores will increase from the first to the second half of the MICT in each condition (H_{3a}). During the first half of the MICT, the RPE scores will be significantly lower in the MFH and MT conditions when compared to the MSH and control conditions (H_{3b}). During the second half of the MICT, RPE scores will be significantly lower in the MSH and MT conditions when compared to the MFH and control conditions (H_{3c}). Given the limited research on the effects of differentiated music use during MICT on RPE has not been extensively studied in previous literature, we will explore the potential changes in RPE scores from the first to the second half of the exercise (i.e., the coefficient of the increase) across different conditions, without formulating any a priori hypotheses (E_1).	H_{3a} is based on Hutchinson et al. (2014). H_{3b} and H_{3c} are based on Terry et al. (2020).	MEM with conditions, time points and their interaction as fixed factors and participants as a random factor will be computed. Interactions between two conditions (i.e., MFH × MSH; MFH × MT; MFH × control; MSH × MT; MSH × control; MT × control) and two time points (i.e., the first and the second half) will be computed to compare slopes of the RPE (i.e., the coefficient of the increase) from the first to the second half of the MICT across conditions. Simple effects tests will be used to examine the slopes of the RPE for each condition. Thereafter, we will compare RPE across conditions at the first time point and separately at the second time point. The models will also include a random slope for the effect of time at the level of participants. Potential covariates are age, sex, and BMI.
Does differentiated use of music influence the global rating of perceived exertion scores when assessed immediately after MICT cool-down?	Given that the differentiated use of music during MICT on retrospective global RPE has not been extensively studied in previous literature, we will explore the potential effect without formulating any a priori hypotheses (E_2).	N.a.	MEM with associated contrasts across conditions. Conditions will be specified as fixed factor and participants as a random factor. Potential covariates are age, sex, and BMI.

Continue

Table 1 *(Continue)*

Question	Hypothesis	Rational	Analysis Plan
Does differentiated use of music influence remembered pleasure immediately following a bout of MICT?	Remembered pleasure scores will be significantly higher following the MSH and MT conditions when compared to the MFH and control conditions (H_{4a}).	H_{4a} is based on the peak-end rule principle (Fredrickson, 2000) and related empirical studies (Hargreaves & Stych, 2013; Hutchinson et al., 2023; Zenko et al., 2016).	MEM with associated contrasts across conditions. Conditions will be specified as fixed factor and participants as a random factor. Potential covariates are age, sex, and BMI.
Does affective valence reported at the end of MICT mediate the effects of condition on remembered pleasure?	The effect of condition on remembered pleasure will be mediated by the affective valence scores reported at the end of the MICT (i.e., min 22; H_{4b}).	H_{4b} is based on the peak-end rule principle (Fredrickson, 2000) and related empirical studies (Hargreaves & Stych, 2013; Hutchinson et al., 2023; Zenko et al., 2016).	Mediation model using the component approach (Yzerbyt et al., 2018). This approach involves two key steps: (1) *Path a*: whether the condition has a significant effect on the last affective valence. (2) *Path b*: whether the last affective valence significantly predicts remembered pleasure (path b). The indirect effect is considered significant if both *path a* and *path b* are statistically significant.

Continue

Table 1 *(Continue)*

Question	Hypothesis	Rational	Analysis Plan
Does affective valence reported at the beginning (i.e., 3 min) and middle (i.e., 13 min) of a MICT mediate the effects of condition on remembered pleasure?	Given that the mediating role of affective valence reported at the beginning and middle of MICT on the effects of music on remembered pleasure has not been extensively studied in previous literature, we will explore the potential effect without formulating any a priori hypotheses (E_3).	N.a.	Mediation models using the component approach (Yzerbyt et al., 2018). This approach involves two key steps: (1) *Path a*: whether the condition has a significant effect on (a) the affective valence reported at the beginning and (b) the affective valence reported at the middle of the MICT. (2) *Path b*: whether (a) the affective valence reported at the beginning and (b) the affective valence reported at the middle of the MICT significantly predict remembered pleasure (path b). The indirect effect is considered significant if both *path a* and *path b* are statistically significant.
Does remembered pleasure predict subsequent forecasted pleasure in relation to MICT?	Remembered pleasure scores will be a positive predictor of subsequent forecasted pleasure (H_5).	H_5 is based on the peak-end rule principle (Fredrickson, 2000) and related empirical studies (Hargreaves & Stych, 2013; Hutchinson et al., 2023; Zenko et al., 2016).	MEM with the effect of remembered pleasure and participants will be specified as random factors, and the models will also include a random slope for the effect of remembered pleasure at the level of participants. Potential covariates are age, sex, and BMI.
Does the differentiated use of music influence forecasted pleasure with reference to future MICT?	Given that the differentiated use of music during MICT on forecasted pleasure has not been extensively studied in previous literature, we will explore the potential effect without formulating any a priori hypotheses (E_4).	N.a.	MEM with the effect of conditions specified as a fixed factor and participants as a random factor. Potential covariates are age, sex, and BMI.

Continue

Table 1 *(Continue)*

Question	Hypothesis	Rational	Analysis Plan
Does remembered pleasure mediate the effects of condition on forecasted pleasure?	Given that the mediating role of remembered pleasure on the effects of music on forecasted pleasure has not been extensively studied in previous literature, we will explore the potential effect without formulating any a priori hypotheses (E_5).	N.a.	Mediation model using the component approach (Yzerbyt et al., 2018). This approach involves two key steps: (1) *Path a*: whether the condition has a significant effect on the remembered pleasure. (2) *Path b*: whether the remembered pleasure significantly predicts forecasted pleasure (path b). The indirect effect is considered significant if both *path a* and *path b* are statistically significant.
Does the differentiated use of music influence heart rate across MICT?	Given that the differentiated use of music during MICT on heart rate across MICT has not been extensively studied in previous literature, we will explore the potential effect without formulating any a priori hypotheses (E_6).	N.a.	MEM with the effect of conditions and time will be specified as fixed factors and participants as a random factor. The models will also include a random slope for the effect of time at the level of participants. Potential covariates are age, sex, and BMI.
Does the differentiated use of music influence heart rate variability during MICT?	Given that the differentiated use of music during MICT on heart rate variability during MICT has not been extensively studied in previous literature, we will explore the potential effect without formulating any a priori hypotheses (E_7).	N.a.	MEM with the effect of conditions and time will be specified as fixed factors and participants as a random factor. The models will also include a random slope for the effect of time at the level of participants. Potential covariates are age, sex, and BMI.

Note. *H* = hypothesis; *E* = exploration, MICT = moderate-intensity continuous training (20 min on a stationary cycle at 60–70% HRR, 60–70 rpm, excluding the warm-up and cool-down periods); first half = first half of MICT (i.e., first 10 min, first time point); second half = second half of MICT (i.e., last 10 min, second time point); MFH = music during the first half of the MICT; MSH = music during the second half of the MICT; MT = music throughout the MICT; control = no music throughout; MEM = mixed-effects model; BMI = body mass index.

The sample size calculation was based on the primary hypotheses and their interaction effects: the impact of the different conditions on affective valence at two time points (H_{1a}) and the differences in the trend of affective valence across conditions between these time points (H_{1b}). Calculations were performed using R (v.4.2.3) with the "Superpower" package (Lakens & Caldwell, 2021) for linear mixed-effects models (MEM). In fully counterbalanced designs, such as the one used in this study, results from repeated-measures ANOVA and linear MEM are expected to be in close agreement (Parma et al., 2023). Therefore, a two-way within-subjects ANOVA was utilised to estimate the required sample size (Parma et al., 2023). The expected effect size was derived from Lim's (2012) study, which closely aligns with the protocol used in this study. Current guidelines recommend conducting a safeguard power analysis (Perugini et al., 2014), which uses the lower bound of a 60% two-sided confidence interval around the effect size estimate to provide a more conservative estimate. However, Lim's (2012) study included young, healthy, and physically active participants, whereas our study focuses on deconditioned patients undergoing cardiac rehabilitation. Since the existing literature suggests that the effect of music on affective valence may be more pronounced in untrained people compared to trained individuals (Hutchinson et al., 2011; Karageorghis & Priest, 2012), we anticipate a larger effect in our study than reported by Lim (2012). Nevertheless, we retained the effect size from Lim's study for our sample size calculation to ensure a conservative estimate for our research context.

An a priori power analysis, assuming a medium effect size ($f = 0.40$), an α level of 0.05, and a power of 0.90, indicated that a minimum of 32 participants would be required for H_{1a} (4 [Conditions] x 2 [Time Points]). Required sample sizes for each comparison (H_{1b}) were as follows: 27 participants for 2 (Conditions; MFH, MSH) x 2 (Time Points; X and Y) comparison, 57 for 2 (Conditions MFH vs. MT) x 2 (Time Points; X and Y) comparison, 208 for 2 (Conditions MFH vs. control) x 2 (Time Points; X and Y) comparison, 236 for 2 (Conditions MSH vs. MT) x 2 (Time Points; X and Y) comparison, 61 for 2 (Conditions MFH vs. MSH) x 2 (Time Points; X and Y) comparison, and 236 for 2 (Conditions MT vs. control) x 2 (Time Points; X and Y) comparison. The R code for this power analysis will be available on Zenodo. Given the logistical constraints of the SMIR-BS, which accommodate a maximum of 12 patients every 3 weeks, and an anticipated recruitment rate of four participants per month, recruiting more than 200 participants would extend the study duration beyond 4 years, which would be impractical. The sample size for this study was set at 61, the closest feasible number to the 208-participant requirement. To account for potential attrition or data loss and to ensure full counterbalancing, the target sample size has been increased to 72 participants. If dropouts occur, they will be replaced to ensure 72 complete data sets are obtained.

Participants

Participants will be eligible for inclusion in the study if they meet the following criteria: (a) enrolment in the 3-week inpatient cardiac EBRP at the SMIR-BS of the Geneva University Hospital, Switzerland, (b) age between 50 and 75 years, reflecting the typical age of inpatients enrolled in the service, (c) ability to complete the study protocol without undue health risk, (d) ability of providing to provide written informed consent. Exclusion criteria include (a) the presence of any medical condition that contraindicates PA, as assessed by the participant's health status, (b) the presence of cognitive or psychological disorders (e.g., Alzheimer's disease, dementia, organic brain syndrome, or any other serious memory impairment), (c) the presence of hearing impairment without hearing aids. All inclusion and exclusion criteria will be assessed by the medical team at the Geneva University Hospital. The decision to include or exclude a participant will be made jointly by the Chief Medical Officer and the research assistant to ensure a rigorous selection process.

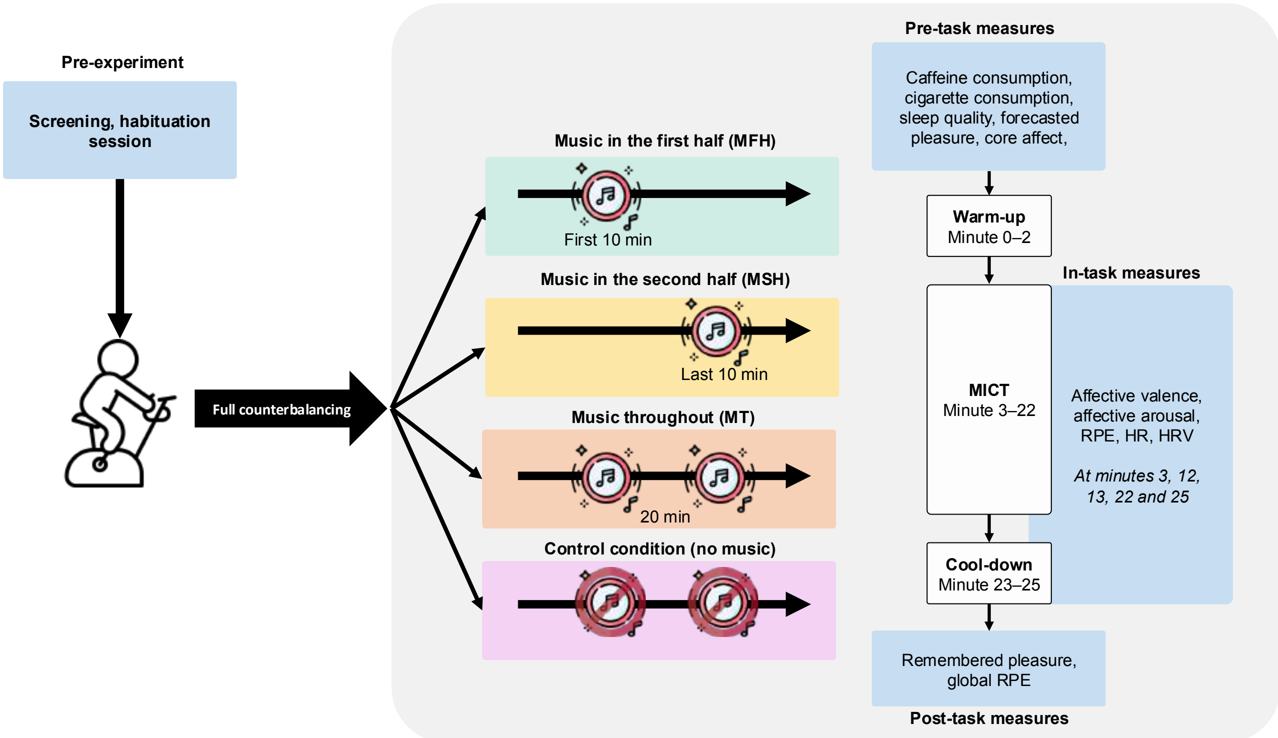
Procedure

Baseline testing

The present study has been approved by the Ethics Committee of Geneva Canton, Switzerland (reference number: 2024-00959). After recruitment and informed consent, participants will complete a questionnaire measuring demographic (i.e., date of birth, sex, socio-economic status), motivational (i.e., instrumental attitudes, motivation towards PA, task self-efficacy), and affective (i.e., affective attitudes) variables in relation to PA. In addition, participants’ preference for and tolerance of the intensity of exercise, as well as usual level of PA, will be assessed. Anthropometric data (i.e., height, weight, body mass index), treatment details (e.g., beta-blockers), and cardiac clinical conditions (e.g., myocardial infarction, coronary artery disease) will be collected from patient records at the Geneva University Hospital. The baseline testing questionnaires are detailed in Table 2. A visual overview of the study procedure is presented in Figure 1.

Figure 1

Overview of the Experimental Protocol



Note. HR = heart rate; HRV = heart rate variability; MICT = moderate-intensity continuous training; RPE = rating of perceived exertion. Each participant will individually complete four MICT sessions, each under one of the following condition: (a) with music played during the first half (MFH; Minute 3–12), (b) with music played during the second half (MSH; Minute 13–22), (c) with music played during the entire exercise session (music throughout, MT; Minute 3–22), and (d) without music (control condition). The order of the conditions will be fully counterbalanced. Icons were made using Freepik from www.flaticon.com.

Table 2

Overview of the Baseline Screening Measures

Measure	Assessment method
Participants' characteristics	Demographic (i.e., age, sex) and health (i.e., blood pressure, waist circumference, glycemia, HbA1c, lipid profile, type of cardiovascular disease, treatment, medical burden, co-morbidity, mobility test, functional independence, health-related quality of life) indicators will be collected using the patient file from the University Geneva Hospital. Anthropometric indicators will be assessed as follow: height using a stadiometer, measured to the nearest 0.1 cm; weight using a digital-balanced weighting scale to the nearest 0.1 kg; body mass index will be calculated from weight and height measurements (weight/height^2).
Socio-economic status	The socio-economic status of the participants will be assessed using a questionnaire measuring their financial health self-rating and their education level, derived from the Survey of Health, Ageing and Retirement in Europe (SHARE; see Fessler et al., 2023). The financial health self-rating refers to paying for the things that people need to live when they have little money. To measure financial health self-rating, participants will be asked to answer the following sentence: "How would you rate your current financial situation?" (1. I'm not doing well; 2. I have to be careful; 3. I am fairly comfortable; 4. I am very comfortable). To measure the education level, participants will be asked to indicate their highest level of education through the following educational level: 1. Lower than apprenticeship or vocational school, 2. Apprenticeship or vocational school*, 3. High school graduation, 4. University graduation.
Usual level of physical activity	Saltin-Grimby Physical Activity Level Scale (SGPALS; Grimby et al., 2015).
Preference for and Tolerance of the Intensity of Exercise	Preference for and Tolerance of the Intensity of Exercise Questionnaire (PRETIE-Q; Ekkekakis et al., 2005).
Instrumental attitudes towards physical activity	Instrumental attitudes towards physical activity will be measured by asking participants to answer the following question using two bipolar scales ranging from 1 (useless, harmful) to 7 (useful, beneficial): "For me, getting at least 30 minutes of moderate-to-vigorous physical activity a day, most days of the week during my free time is..." (Phipps et al., 2021).

Continue

Table 2 *(Continue)*

Measure	Assessment method
Affective attitudes toward physical activity	Affective attitudes towards physical activity will be measured by asking participants to answer the following question using two bipolar scales ranging from 1 (unpleasant, boring) to 7 (pleasant, stimulating): "For me, getting at least 30 minutes of moderate-to-vigorous physical activity a day, most days of the week during my free time is..." (Phipps et al., 2021).
Amotivation, autonomous and controlled motivation toward physical activity	Amotivation, autonomous and controlled motivation toward physical activity will be assessed using a short version of the Motivation Scale toward Health-Oriented Physical Activity (EMAPS; Boiché, Gourlan, et al., 2019). The short version of the EMAPS assess the various forms of physical activity motivation through 2-item subscales: amotivation (e.g., "Frankly, I practice PA but I do not see the point"), intrinsic motivation (e.g., "For the pleasure I experience when I practice physical activity"), identified regulation (e.g., "Because I think that physical activity will allow me to feel better"), introjected regulation (e.g., "Because I would feel bad if I did not make this effort") and external regulation (e.g., "Because some people around pressure me to do it"). Following the stem "Please indicate the extent to which each of the following statements currently corresponds to one of your reasons for being physically active", participants answered to each proposition using a Likert scale ranging from 1 (Not at all true) to 7 (Totally true). An autonomous and controlled motivation scores were computed by averaging intrinsic and identified items, and introjected and external items, respectively.
Task self-efficacy	Task self-efficacy will be assessed by asking participants to indicate their degree of confidence in their ability to cycle at a moderate intensity during 20 min, from 0% (cannot do at all) to 100%) (certain can do; Welch et al., 2010).

Note: SMIR-BS = internal medicine and rehabilitation department, HbA1c = glycated haemoglobin. *All persons who do not have finished a certified training/education after having passed the compulsory education (9 years). Persons who have passed compulsory education with or without a training time (2 years) belong to category 1. All the questionnaires will be assessed electronically using REDCap software (https://projectredcap.org/) .

Habituation Session

Before starting the first MICT, participants will undergo a 5-min habituation session (Figure 1). This session begins with a detailed explanation of the in-task scales. Participant will be then instructed to pedal on the stationary cycle for 5 min on a stationary cycle, selecting a wattage that corresponds to 60–69% of their HRR and that they feel they can sustain for 20 min. The target heart rate (HR) for the exercise session will be calculated using Karvonen's formula HRest (% of HR reserve [HRR]), with 50% for the warm-up and cool-down and 60–69% for the MICT (Arbelo et al., 2023). The max HR will be calculated as follows: (a) for patients not taking beta-blocker treatment = 206.9 - 0.67 × age (Gellish et al., 2007), (b) for patients taking beta-blocker treatment = 164 - 0.7 × age (Brawner et al., 2004). The HRR will be calculated as follows: max HR—resting HR. The selected wattage will remain the same for all MICT sessions. During the 5-min period, the in-task scales will be administered to familiarize participants with the procedure. This will be followed by a 5-min rest period before the first MICT session begins. The decision to allow participants to select their wattage based on their subjective perception at 60–69% HRR is driven by two key considerations. Firstly, most patients in our study population are unable to perform a maximal exercise test, which is the gold standard for assessing exercise capacity in cardiac patients (Glaab & Taube, 2022). However, submaximal exercise testing provides valuable functional information for those unable to perform maximal tests (Arbelo et al., 2023). Secondly, maximal exercise testing may elicit negative affective responses during the session (Ekkekakis et al., 2020). These negative experiences may create negative affective associations with the future cycling exercise sessions, potentially undermining the goals of the current experiment

Experimental and Control Conditions

Participants will engage in four bike MICT sessions, each corresponding to one of the following conditions: (a) music played during the first half (MFH; Minute 3–12), (b) music played during the second half (MSH; Minute 13–22), (c) music played during the entire exercise session (music throughout, MT; i.e., Minute 3–22), and (d) no music played (control condition). The presentation of the conditions will be presented will be fully counterbalanced to ensure that any potential order effects are minimized.

Exercise Sessions

Each of the four MICT sessions will begin with a 2-min warm-up period at 50% HRR, 50–70 revolutions per minute (rpm), followed by 20 min at 60–69% HRR (Arbelo et al., 2023), 60–70 rpm. The session concludes with a 2-min cool-down period at 50% HRR, 50–70 rpm. During each session, participants' HR and heart rate variability (HRV) will be continuously monitored using a chest-strap HR monitor (Polar H10; Polar Electro Oy, Kempele, Finland). HRV will be assessed using time-domain indices, including root mean square of successive differences (RMSSD) and standard deviation of normal-to-normal RR intervals (SDNN) (Laborde et al., 2022). These exercise sessions have been designed in collaboration with the medical team at the Geneva University Hospitals to closely resemble the standard exercise programme offered to patients. These sessions will be integrated into the patients' usual exercise group sessions to ensure patient involvement and medical supervision. Each exercise session will be separated by 24–48 hours.

Music Selection and Delivery

Music selection was guided by the Brunel Music Rating Inventory-3 (BMRI-3; Karageorghis, 2008) and the Affect Grid (Russell et al., 1989) to ensure that both the motivational and affective quality of the were carefully considered music (Supplementary Material 1). A selection panel of participants who will not take part in the experimental phase were involved (Figure S1). The panel (N = 10; five females and five males) had a similar socio-cultural background and were in the same age range as the participants in the experiment phase (Table S1; see Karageorghis & Terry, 1997). Middle-aged and older exercisers (> 50 years) often show a preference for slower tempi during exercise compared to their younger counterparts (Priest et al., 2004), reflecting reduced work rate that often accompanies aging (Karageorghis, 2017). The selection of music during exercise in this population typically considers the artist, musical style, and the release date of the tracks, consistent with the concept of age-appropriate music (Karageorghis et al., 2006). Drawn from the epoch that coincides with the formative years of the participants, the musical selection was made according to the criteria of Karageorghis et al. (2006) to ensure that the tracks are sufficiently energising and suitable for the task.

Tracks that have noticeable rallentandos (i.e., gradual slowing down of the tempo) or accelerandos (i.e., gradual speeding up of the tempo) and/or a high level of syncopation (i.e., unexpected rhythmic emphasis) were excluded from the initial selection pool of tracks that will be administered to the music-rating panel (Tables S2 and S3). According to the specificities of middle-aged and older exercisers (> 50 years) described above, the tempo range was set in the range 118–125 beats per minute (bpm). Therefore, songs were chosen from the top 100 charts of each year. The 20 top-rated tracks in accord with BMRI-3 and Affect Grid scores were included in the final playlist for each age range (50–62 years and 63–75 years; Tables S4 and S5, Figures S2, S3 and S4).

The selected playlists will be played for either 10 (i.e., MFH and MSH) or 20 (i.e., MT) minutes, depending on the condition. The music delivery will be asynchronous, meaning that there will be no conscious synchronisation of the movement rate to the rhythmic or temporal aspects of the music (i.e., the absence of conscious synchronisation of the movement rate to the rhythmic or temporal aspects of the music; Karageorghis, 2020, p. 932). To ensure a minimally disruptive environment in the collective hospital gym where the experiment will take place, headphones will be used. To prevent external distractions, such as ambient noise and conversation, participants will wear headphones even during period when music is not playing. This will include the warm-up, the second half of the MFH condition, the first half of the MSH condition, during the control condition, and the cool-down. The music playlist will last for 20 min, with the order of the tracks randomised across conditions. For the three experimental conditions, music will be played at a sound intensity range of 65–85 dBA, a level considered safe from an audiological perspective (see Alessio & Hutchinson, 1991).

Time of Measurement

Prior to each MICT session, the following variables will be assessed: (a) caffeine intake, (b) cigarette consumption, and (c) sleep quality from the previous night, (d) forecasted pleasure of the upcoming session (Empirical Valence Scale; Lishner et al., 2008), (e) core affect (FS and FAS) before engaging in the MICT. During the MICT, core affective responses and perceived exertion (RPE; Borg, 1998) will be measured at five time points: Minute 3, 12, 13, 22, and 25. Participants' remembered pleasure (Visual Analogy Scale; Zenko et al., 2016) and global perceived exertion of the MICT (session RPE; Foster et al., 2001) will be assessed 5 min after completion of the MICT. To minimise the potential for response order effect, the in-task measures will be administered in different order during the exercise sessions (i.e., FS, FAS, RPE at min 3; FAS, FS, CR-10 at min 12; RPE, FS, FAS at min 13; FS, RPE, FAS at min 22; and FAS, FS, RPE at min 25; Ejelöv & Luke, 2020; Krosnick & Alwin, 1987). Pre-task, in-task and post-task measures are detailed in Table 3 and Table 4 provides the schedule of assessment.

Table 3

Outcomes Measured and Assessment Method

Outcome	Assessment method
Primary outcome	
Affective valence during the moderate-intensity continuous training	Affective valence will be measured at five time points (Minute 3, Minute 12, Minute 13, Minute 22, and Minute 25) using the Feeling Scale (Hardy & Rejeski, 1989), a single-item bipolar rating scale using the sentence “How do you feel right now, at this moment?” with possible responses ranging from −5 (very bad) to +5 (very good) and verbal anchors at zero (neutral) and each odd number.
Secondary outcomes	
Affective arousal during the moderate-intensity continuous training	Affective arousal will be measured at five time points (Minute 3, Minute 12, Minute 13, Minute 22, and Minute 25) using the Felt Arousal Scale (Svebak & Murgatroyd, 1985), a single-item bipolar rating scale using the sentence “How aroused do you actually feel?” with possible responses ranging from 1 (low arousal) to 6 (high arousal).
Rating of perceived exertion during the moderate-intensity continuous training	Rating of perceived exertion will be measured at five time points (Minute 3, Minute 12, Minute 13, Minute 22, and Minute 25) using the using the RPE scale (Borg, 1998) ranging from 6 (None) to 20 (Maximum).
Remembered pleasure after the moderate-intensity continuous training	Remembered pleasure will be measured 5 min after each training session using a visual analogy scale presented on a Samsung Galaxy Tab ranging from −100 (very unpleasant) to +100 (very pleasant) in intervals of 1 (Zenko et al., 2016). Participants will be asked to answer the following question: “How did the exercise session make you feel?” (Hutchinson et al., 2023).
Global rating of perceived exertion after the moderate-intensity continuous training	The global rating of perceived exertion will be measured 5 min after each training session using the session RPE scale ("What was your overall level of exertion during your session?"; Foster et al., 2001) ranging from 0 (None) to 10 (Maximal).
Forecasted pleasure before the moderate-intensity continuous training	Forecasted pleasure in relation to the upcoming exercise session will be assessed before each session using a visual analogy scale. Participants will be asked to answer the following question: “How do you expect to feel during today’s training?” (Hutchinson et al., 2023) using the Empirical Valence Scale (EVS; Lishner et al., 2008) presented on a Samsung Galaxy Tab from 15 empirically spaced verbal anchors, ranging from -100 (most unpleasant imaginable) to +100 (most pleasant imaginable; Zenko et al., 2016).
Haemodynamic variables during the moderate-intensity continuous training	Heart rate (bpm) and heart rate variability will be measured throughout the training with a chest-strap HR monitors (Polar H10; Polar Electro Oy, Kempele, Finland). R-R intervals, root mean square of successive differences (RMSSD) and the standard deviation of the NN (R-R) intervals (SDNN) will be extracted as the indices of interest (Laborde et al., 2022).

Continue

Table 3 *(Continue)*

Outcome	Assessment method
Control variables	
Affective valence before the moderate-intensity continuous training	Affective valence will be measured before each training session using the Feeling Scale (Hardy & Rejeski, 1989), a single-item bipolar rating scale using the sentence "How do you feel right now, at this moment?" with possible responses ranging from −5 (very bad) to +5 (very good) and verbal anchors at zero (neutral) and each odd number.
Caffeine consumption before the moderate-intensity continuous training	Caffeine consumption will be measured before each training session. The participants will be asked to answer the following question: "How many caffeinated drinks did you drink in the 2 hours immediately before the session?"
Cigarette consumption before the moderate-intensity continuous training	Cigarette consumption will be measured before each training session. The participants will be asked to answer the following question "How many cigarettes did you smoke in the 2 hours immediately before the session?" (Cheval et al., 2022).
Sleep quality before the moderate-intensity continuous training	Sleep quality will be measured before each training session. The participants will be asked to answer the following question: "During the last night, how would you rate your sleep quality overall?" (1. Very bad, 2. Fairly bad, 3. Fairly good, 4. Very good; Buysse et al., 1989).

Note. RPE = rating of perceived exertion. All the questionnaires will be assessed electronically using REDCap software.

Table 4

Schedule of assessment

Time (day)	**-1 day**	**0**	**+2**	**+4**	**+6**
Visit	Screening and information	Habituation session 1st MICT	2nd MICT	3rd MICT	4th MICT
Written consent	+				
Inclusion and exclusion criteria	+				
Participant characteristics	+				
Motivation towards physical activity		+			+
Affective attitudes towards physical activity		+			+
PRETIE-Q		+			+
Intervention		+	+	+	+
Pre-task, in-task and post-task measures		+	+	+	+

Note. MICT = moderate-intensity continuous training; PRETIE-Q = Preference for and Tolerance of the Intensity of Exercise Questionnaire (Ekkekakis et al., 2005).

Data Analyses

Missing Data and Outliers

All data analyses will be performed using R (v.4.2.3). To handle missing data, we will first inspect potential patterns of missingness using Little's missing completely at random test (Little, 1988) and visualisation techniques (see Cheval et al., 2023 for a similar procedure). Multivariate imputation by chained equations will be applied to missing data that are either completely at random or missing at random using the "mice" R package (van Buuren & Groothuis-Oudshoorn, 2011; van Ginkel et al., 2020). The default imputation method will be employed to handle numeric, binomial, and multinomial data types, with 10 imputed datasets generated to ensure robust analysis. Sensitivity analyses with unimputed data will also be conducted.

Potential outliers will be screened in relation to each statistical model rather than the raw data (Leys et al., 2019). Univariate outliers will be identified using the median absolute deviation (MAD; Leys et al., 2013), while multivariate outliers will be assessed using the Mahalanobis-MCD distance (Leys et al., 2018) using the "performance" R package (Lüdecke et al., 2021). The use of the median in these methods provides a more robust indicator for detecting outliers compared to methods that rely on the mean (e.g., Mahalanobis distance; Leys et al., 2019). If outliers are detected, they will initially be retained in the model, following Leys et al. (2019) guidelines. The decision will be based on the similarity of the residual distributions of the model, with and without the outliers. If the distributions are similar, outliers will be kept; otherwise, they will be removed.

Main Analyses

The main analyses are detailed in Table 1 for each hypothesis. Following descriptive analyses, linear mixed-effects models (MEMs) will be computed to test (a) the effect of conditions, time and their interaction on affective valence ($H_{1a–d}$), affective arousal ($H_{2a–d}$), rating of perceived exertion ($H_{3a–c}$, E_1); (b) the effect of conditions on global perceived exertion (E_2), remembered pleasure (H_{4a}), forecasted pleasure (E_4), heart rate (E_6), heart rate variability (E_7) ; (c) the effect of remembered pleasure on forecasted pleasure (H_5). MEMs are particularly suited for longitudinal data as they effectively handle missing data and account for the nested structure of repeated observations from the same individuals (Boisgontier & Cheval, 2016; Lohse et al., 2020). The MEMs will be built and fitted using maximum likelihood estimation with the “lme4” and “lmerTest” R packages (Bates et al., 2015; Kuznetsova, 2016). P-values will be approximated using Satterthwaite’s method to estimate degrees of freedom and provide accurate p-values for fixed effects in models with complex random effects structures (Kuznetsova, 2016; Parma et al., 2023; R Core Team, 2019). Effect sizes for fixed effects will be reported using the marginal pseudo R2, computed with the “MuMIn” package (Barton, 2018).

In addition, mediation models using the component approach (Yzerbyt et al., 2018), will be computed. Specifically, these models will evaluate the potential mediation of affective valence on the relationship between conditions and remembered pleasure (H_{4b} and E_3), and the potential mediation of remembered pleasure on the link between conditions and forecasted pleasure (E_5). The component approach is expected to reduce the likelihood of Type I errors while maintaining statistical power, compared to bootstrap methodologies (e.g., single test of a mediational index) (Maltagliati et al., 2023; Yzerbyt et al., 2018).

Statistical assumptions of normality of the residuals, linearity, multicollinearity, and undue influence will be checked for all models using the “performance” R package (Lüdecke et al., 2021). The dependent variable and potential covariates will be centred around the mean with standard deviation units.

Data availability statement:

All data analysed for this Registered Report alongside the code for R software will be available on Zenodo (*URL*).

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Résumé de la Contribution empirique n°4

Ce protocole propose d'examiner l'impact d'une intervention combinant l'utilisation de **musiques motivantes** et l'application du principe du « **pic et de la fin** » sur des variables affectives, telles que l'affect fondamental, l'affect remémoré et la réponse affective anticipée lors de séances d'APA. Soixante-douze patient·es participant à un programme de réadaptation cardiovasculaire stationnaire de trois semaines seront recruté·es aux Hôpitaux Universitaires de Genève. Ces patient·es participeront à **quatre séances** de vélo stationnaire d'intensité modérée et continue, sous différentes conditions : avec de la **musique** pendant la **première moitié** de la séance, la **seconde moitié**, **tout au long** de la séance, ou **sans musique**. Les mesures seront effectuées avant, pendant, et après les séances, et incluront des variables **psychologiques** (affects fondamentaux immédiats, affect remémoré de la séance, réponse affective anticipée pour la séance suivante), **psychophysiques** (effort perçu), et **psychophysiologiques** (variabilité de la fréquence cardiaque). En complément, d'autres variables affectives et socio-cognitives telles que la motivation intrinsèque, les attitudes affectives ou encore le sentiment d'efficacité personnelle, seront également évaluées. Les playlists musicales ont été préalablement élaborées en fonction des **préférences motivationnelles et affectives** de patient·es représentatif·ves du service, qui ne participent pas au protocole expérimental.

L'analyse des résultats visera à évaluer l'impact de ce type **d'intervention** sur les **variables affectives expérientielles**, qui pourraient jouer un rôle crucial dans **l'engagement** et **l'adhésion** aux séances d'APA. Cette étude pourrait ouvrir de nouvelles perspectives pour **l'amélioration des programmes de réadaptation cardiovasculaire**, en proposant une stratégie à la fois endogène et exogène à l'activité physique, peu coûteuse et facile à mettre en œuvre.

6.3 Stratégies d'intervention digitales qui ciblent les réponses automatiques, indépendamment de l'expérience directe avec l'activité physique

Comme décrit dans le Chapitre 3, l'AHBF de Williams et Evans (2014) s'inscrit dans une approche duale, qui distingue les processus automatiques des processus réfléchis. Au cours des dernières années, l'importance de cibler les processus automatiques pour modifier les comportements de santé – notamment l'activité physique – et prévenir les maladies a gagné en reconnaissance (Larsen & Hollands, 2022 ; Marteau et al., 2012). Parmi ces processus automatiques, les tendances d'approche-évitement sont considérées comme la variable la plus proximale des comportements d'activité physique (Cheval & Boisgontier, 2021 ; Cheval, Sarrazin, & Radel, 2016 ; Conroy & Berry, 2017 ; Friese et al., 2011). Par conséquence, le développement de stratégies d'intervention ciblant les tendances d'approche-évitement envers l'activité physique pourrait donc représenter une piste prometteuse pour encourager une participation régulière à des activités physiques.

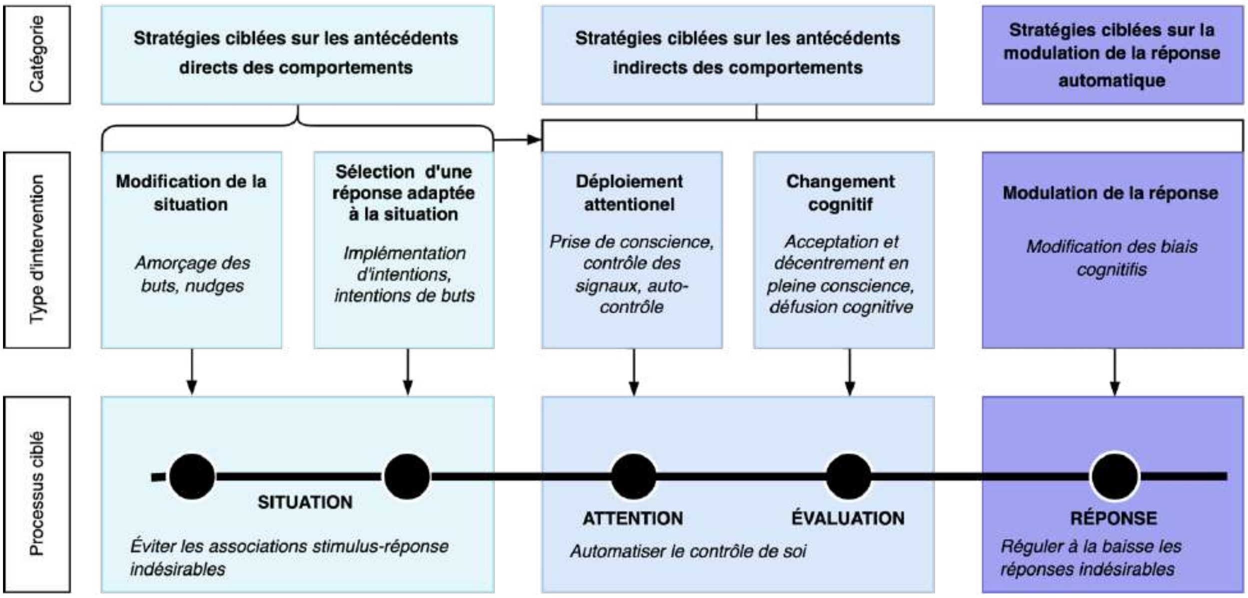
Récemment, Larsen et Holland (2022) ont récemment proposé un cadre conceptuel pour les interventions ciblant les processus automatiques liés aux comportements de santé, inspiré du modèle de régulation des émotions de Gross (1998, 2001). Ce modèle distingue trois grandes catégories de stratégies d'intervention : (a) celles qui ciblent les antécédents directs des comportements (e.g., intentions) ; (b) celles qui agissent sur les antécédents indirects (e.g., contrôle de soi) ; et (c) celles qui modulent directement la réponse automatique (e.g., tendances d'approche-évitement ; Figure 5). Dans le cadre de ce projet doctoral, nous nous concentrerons spécifiquement sur cette dernière catégorie, c'est-à-dire, les interventions visant à réduire les réponses automatiques indésirables (i.e., impulsives) par la modulation de la réponse et la modification directe des tendances d'approche-évitement (Larsen & Holland, 2022).

Les stratégies de modulation de la réponse automatique identifiées par ce modèle reposent sur des tâches dites de « modification des biais cognitifs » (CBM). Ces tâches visent à modifier directement les processus automatiques, tels que les tendances d'approche-évitement, en les orientant dans une direction particulière (e.g., approcher ou éviter un comportement ; Jones & Sharpe, 2017 ; MacLeod &

Mathews, 2012). Ces techniques peuvent également être envisagées comme des interventions complémentaires aux traitements traditionnels (Wiers et al., 2018), tels que des programmes de réadaptation cardiovasculaire (voir **Contribution n°6**). Comme nous allons l'aborder dans cette section, cette stratégie d'intervention repose principalement sur l'utilisation de supports digitaux, tels que des ordinateurs ou des tablettes tactiles, et ne nécessite pas l'expérience directe du comportement (e.g., réaliser une séance d'activité physique ; Cheval et al., 2021 ; Cheval et al., 2015 ; Cheval, Sarrazin, Pelletier, et al., 2016 ; Krieglmeyer & Deutsch, 2010 ; Radel et al., 2011). C'est pourquoi nous qualifierons ces stratégies de « stratégies d'intervention digitales ciblant les réponses automatiques, sans nécessiter d'expérience directe avec l'activité physique ».

Figure 5

Cadre conceptuel des techniques d'intervention ciblant les processus automatiques, adapté de Larsen et Hollands (2022)



Note. D'après les auteur·es, les stratégies d'intervention proposées dans ce modèle ne sont pas exhaustives.

Plusieurs tâches de CBM ont été développées dans le but de manipuler les tendances d'approche-évitement, telles que les tâches de Go/No-Go ou les tâches de réentraînement des tendances à l'action (Larsen & Holland, 2022). Les tâches Go/No-Go se concentrent sur l'inhibition des réponses motrices face à des stimuli attrayants, tels que des images liées au tabac, à l'alcool, à des aliments riches en calories ou des comportements sédentaires comme les fauteuils (Allom et al., 2016 ; Aulbach et al., 2019 ; Farajzadeh et al., 2023 ; Jones et al., 2016 ; Turton et al., 2018). Cependant, dans le domaine de l'activité physique, ces tâches ont été principalement utilisées pour évaluer le contrôle inhibiteur des individus en rapport avec l'exercice physique (e.g., Cheval et al., 2020 ; Kullmann et al., 2014), plutôt que pour réentraîner les tendances d'approche-évitement associées (Farajzadeh et al., 2023). Dans ce travail doctoral, nous nous concentrerons sur le second type de tâche – les tâches de réentraînement des tendances à l'action – qui a été plus couramment utilisé pour manipuler les tendances d'approche-évitement envers l'activité physique (Cheval et al., 2015 ; Cheval, Sarrazin, Pelletier, et al., 2016 ; Preis et al., 2021). Ces tâches peuvent être classées en deux catégories : sensorimotrices et non-sensorimotrices (Rougier et al., 2018).

Les tâches sensorimotrices sont basées sur des mouvements physiques associés à l'approche ou à l'évitement, tels que la flexion du coude. Par exemple, dans une étude de 2011, Wiers et al. ont demandé à des patient·es alcoolodépendant·es d'effectuer des mouvements d'évitement en poussant un joystick en réponse à des images d'alcool, et des mouvements d'approche en tirant un joystick en réponse à des images de boissons non alcoolisées. Ces stimulations physiques étaient conçues pour imiter les mouvements que les patient·es réalisent dans la vie réelle lorsqu'elles et ils sont confronté·es à des boissons alcoolisées. L'étude comprenait également deux groupes de contrôle (actif et passif). Les résultats ont montré que, comparativement aux groupes contrôle, les participant·es des conditions expérimentales (approche et évitement) ont non seulement inversé leur biais d'approche vers un biais d'évitement de l'alcool, mais ont également réduit leur taux de rechute de 13 % un an après leur sortie de la clinique. Ces résultats ont été répliqué par deux autres études, montrant une réduction du taux de rechute de 9 % un an après la sortie de la clinique (Eberl et al., 2013), et de 12 % deux semaines après la sortie (Manning et al., 2021), attribuable à un changement des tendances d'approche envers l'alcool.

Les tâches non-sensorimotrices, en revanche, n'impliquent pas de mouvements physiques spécifiques, mais utilisent des actions symboliques. Un exemple classique est la tâche du mannequin *(mannikin task)*, où les participant·es déplacent un avatar *vers* ou *loin* de stimuli spécifiques (e.g., l'image d'un vélo ; Cheval et al., 2015 ; Cheval, Sarrazin, Pelletier, et al., 2016 ; Krieglmeyer & Deutsch, 2010 ; Radel et al., 2011). Dans ces tâches – contrairement aux tâches sensorimotrices – il n'y a pas de contingences entre le mouvement moteur (flexion et extension) et la réponse associée (approche et évitement). Par exemple, Cheval et al. (2016) ont demandé à des étudiant·es de déplacer un avatar – censé les représenter – vers des stimuli liés à l'activité physique (approche) et de l'éloigner des stimuli associés à la sédentarité (évitement), affichés sur un écran d'ordinateur. Dans deux autres conditions, les participant·es devaient soit (a) déplacer l'avatar vers des stimuli sédentaires et loin des stimuli d'activité physique, soit (b) le déplacer de manière équitable entre les deux types de stimuli (contrôle). Les résultats ont montré que chez les participant·es les moins actif·ves physiquement, les tendances à approcher l'activité physique augmentaient dans la première condition – approche de l'activité physique et évitement des comportements sédentaires. De plus, ces participant·es ont passé plus de temps à effectuer des squats lors d'une tâche d'exercice, comparativement aux deux autres conditions.

Plus récemment, Rougier et al. (2018) ont développé un autre type de tâche qui intègre des éléments sensorimoteurs et non-sensorimoteurs : la *Visual Approach/Avoidance by the Self Task* (VAAST). Cette tâche se distingue par une scène visuelle interactive combinant divers indices visuels provenant à la fois des stimuli présentés et de l'environnement, créant ainsi l'illusion d'un déplacement complet du soi vers ou loin des stimuli. Autrement dit, en appuyant sur une touche du clavier, les participant·es ont l'impression que leur corps tout entier s'approche ou s'éloigne d'un stimulus affiché à l'écran. Cette approche immersive est conçue pour refléter plus fidèlement les dynamiques réelles d'approche-évitement (voir Chapitre 8 pour une explication détaillée de la VAAST). Un des avantages majeurs de cette tâche, comparé à la tâche classique du mannequin, est qu'elle génère des effets de « compatibilité » qui se sont avérés être plus larges et reproductibles que dans la tâche du mannequin (Aubé et al., 2019 ; Rougier et al., 2018).

Dans l'ensemble, les stratégies interventions digitales visant à modifier les tendances d'approche-évitement ont montré une certaine efficacité dans divers contextes de comportements de santé, tels que la consommation d'alcool et de tabac (Boffo et al., 2019 ; Jones & Sharpe, 2017 ; Wiers et al., 2011), les comportements alimentaires (Aulbach et al., 2019 ; Van Dessel et al., 2018) et la pratique d'activité physique en contexte de laboratoire (Cheval, Sarrazin, Pelletier, et al., 2016). Cependant, l'efficacité de ces interventions sur les comportements d'activité physique en contexte écologique nécessite des preuves plus solides et systématiques (Larsen & Hollands, 2022 ; Maltagliati, Sarrazin, et al., 2024 ; Preis et al., 2021), notamment chez les personnes atteintes de maladies chroniques (Cheval et al., 2021).

Une vidéo de la VAAST utilisée dans la Contribution n°1 et la Contribution n°6 est disponible en scannant le QR code ci-dessous ou en se rendant au lien suivant :

https://www.youtube.com/watch?v=Wj5ZUxnFkdU&ab_channel=LayanFessler

Résumé du Chapitre 6

Dans son ensemble, ce chapitre visait à répondre à la seconde question de ce travail doctoral : **Quelles sont les stratégies d'intervention qui permettent de manipuler des variables affectives ?** À travers la **Contribution n°3**, la **Contribution empirique n°4**, et la **section 6.3**, nous avons pu identifier trois types de stratégies qui semblent prometteuses : (1) les stratégies d'intervention « **endogènes** » basées sur l'expérience directe de l'activité physique, ciblant les réponses affectives, l'affect remémoré et la réponse affective anticipée ; (2) les stratégies d'intervention « **exogènes** » basées sur l'expérience directe de l'activité physique, visant les mêmes variables affectives ; et (3) les **stratégies d'intervention digitales**, qui **ciblent les réponses automatiques**, telles que les tendances d'approche-évitement, sans nécessiter d'expérience physique directe avec l'activité physique. Plus précisément, l'ajustement de facteurs **endogènes** (e.g., moduler l'intensité de l'effort à différents moments d'une séance d'APA) et **exogènes** (e.g., l'utilisation de musique) durant l'expérience d'activité physique pourrait favoriser des **expériences affectives positives** associées à ce comportement. Par ailleurs, les **stratégies d'intervention digitales** qui **ciblent les réponses automatiques** (e.g., VAAST) permettraient de moduler les **tendances automatiques à approcher et éviter l'activité physique**, indépendamment de la pratique physique elle-même.

Toutefois, le **nombre limité d'études** et les **contraintes méthodologiques** associées entravent une évaluation rigoureuse de l'efficacité de ces approches, en particulier chez les personnes atteintes de maladies chroniques. Il est donc essentiel de réaliser un **recensement exhaustif** des études visant à améliorer les niveaux d'activité physique chez cette population tout en manipulant les variables affectives associées (**<u>Contribution n°5</u>**). De plus, il apparaît nécessaire de **développer davantage d'interventions** ciblant ces variables chez les personnes atteintes de maladies chroniques, dans le but d'améliorer leur niveau d'activité physique (**Contributions <u>n°6</u>** et **<u>7</u>**).

PARTIE 3

Intervenir sur les variables affectives pour favoriser l'activité physique chez les personnes atteintes de maladies chroniques

Chapitre 7 **Intervenir sur les variables affectives pour favoriser l'activité physique des personnes atteintes de maladies chroniques : état de l'art**

7.1 Contribution n°5

Cette cinquième Contribution avait pour objectif de réaliser une revue systématique de l'efficacité des interventions visant à modifier les variables affectives et les comportements d'activité physique chez les personnes atteintes de maladies chroniques. La revue systématique a été conduite conformément aux lignes directrices PRISMA et préenregistrée sur la plateforme PROSPERO (https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42022354104). Les recherches ont été effectuées dans les bases de données suivantes : Web of Science, PubMed MEDLINE, PsycINFO, Cochrane Library, ProQuest Dissertations et Google Scholar. Initialement, 21 176 études ont été identifiées. Après suppression des doublons, 14 310 études ont été sélectionnées manuellement sur la base du titre et du résumé. Par la suite, 108 études ont été soumises à une évaluation du texte intégral. En fin de compte, 13 études ont répondu aux critères d'inclusion et ont été intégrées à la revue, incluant au total 904 adultes atteint·es de diverses maladies chroniques. Bien qu'une méta-analyse ait été initialement prévue, l'hétérogénéité substantielle entre les études en termes de conception, de mesures et de disponibilité des données n'a pas rendu ces analyses possibles. Le risque de biais et la qualité des preuves ont été évalués à l'aide des outils Risk of Bias 2 et ROBINS-I, ainsi que de l'approche GRADE.

Pour structurer la synthèse de la littérature, des thèmes et sous-thèmes ont été identifiés en s'appuyant sur l'approche de la médecine expérimentale et l'AHBF (Sheeran et al., 2017 ; Stevens et al., 2020 ; Williams & Evans). Ce processus a consisté à classer les études en quatre thèmes principaux : (1)

l'efficacité des interventions sur le comportement en matière d'activité physique (étape X de l'approche de la médecine expérimentale), (2) l'effet des interventions sur les variables affectives (étape C), (3) l'association entre les variables affectives et les comportements d'activité physique (étape B), et (4) les variables affectives en tant que médiateurs potentiels des interventions (étape D). Par la suite, des sous-groupes ont été formés selon deux critères : (a) les différents contextes de comportements d'activité physique (i.e., pendant ou après l'intervention) et (b) les catégories de variables affectives ciblées dans les études, telles que définies par l'AHBF.

Cet article est en cours de préparation pour soumission. L'article a été formaté selon les normes de l'American Medical Association (AMA). Le matériel supplémentaire est disponible en Annexe 3. Les différences entre la référence du pré-enregistrement et l'article proposé dans ce manuscrit de thèse résultent principalement de la réalisation d'une revue systématique, en lieu et place d'une méta-analyse.

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Effectiveness of Interventions Targeting Affective Variables to Improve Physical Activity in People with Chronic Disease: A Systematic Review

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Author Contributions

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Abstract

Background. Contemporary theories suggest that affective variables, such as affective responses, enjoyment, or affective associations, may improve engagement in physical activity (PA), especially in people with chronic diseases. However, we are unaware of any review of the experimental evidence on whether affective variables can cause future PA participation in people with chronic diseases.

Purpose. To review the effectiveness of interventional studies that target affective variables and PA behaviour change in people with chronic diseases.

Method. A systematic review following the PRISMA guidelines was conducted, with searches across six databases. Risk of bias and quality of evidence were assessed using the Risk of Bias 2 and ROBINS-I tools, and the GRADE approach.

Results. Thirteen studies met the inclusion criteria, with most rated as moderate in quality and presenting a high risk of bias. Eleven studies measured PA during the intervention, and four assessed PA at the end of or following the intervention (1-week to 9-month follow-up). Three studies demonstrated effectiveness in improving both affective variables and PA behaviour, three studies showed significant positive effects on affective variables alone, and three studies demonstrated effectiveness in improving PA behaviour alone. Nineteen behaviour change techniques were identified across these interventions (M = 4.18±2.89), with "action planning" being the most frequently employed.

Conclusion. The findings provide limited support for the effectiveness of interventions targeting affective variables in promoting PA engagement in people with chronic diseases. However, the paucity of high-quality studies in this area suggests that these mechanisms should not be disregarded, as further research is needed to clarify their potential impact.

PROSPERO Registration CRD42022354104.

Keywords: Exercise, noncommunicable disease, affect, intervention, health

Introduction

Chronic diseases are a global health challenge, accounting for 75% of worldwide mortality [1]. Physical activity (PA) has emerged as a critical behaviour in the prevention and management of chronic diseases [2-4]. Adherence to the PA guideline of 150 minutes of moderate-to-vigorous physical activity (MVPA) per week is estimated to prevent over 10 million deaths annually that are attributable to chronic diseases [4-6]. Although the health benefits of PA are well-known [7, 8], global levels of physical inactivity in people with chronic diseases remain alarming high [9]. For example, studies have showed that only 17% to 38% of patients with coronary artery disease self-reported meeting the PA guidelines [10, 11]. In addition, among people with health risk factors who intend to engage in PA, only about 40% successfully translate their intention into actual behaviour [12]. This significant gap between intention and action highlights the need for targeted interventions to address physical inactivity in people with chronic diseases. Current strategies for promoting PA in this population are largely informed by social-cognitive theories, which emphasize the role of cognitive processes, such as goal setting and intention formation, as key drivers of behaviour change [13, 14]. While such interventions have been shown to be somewhat effective in changing PA behaviour [15-18], meta-analyses have revealed that their impact on people's intentions is generally stronger than on their actual behaviours [19-21]. Therefore, these interventions alone may not be sufficient to bridge the intention-behaviour gap, underscoring the need to explore complementary strategies targeting additional factors that may more effectively promote PA engagement.

In recent years, there has been a growing interest in affective variables within the realm of PA theories [22-25], opening new avenues for intervention strategies to promote PA. Theoretical frameworks, such as the Affective–Reflective Theory [22], the Theory of Effort Minimisation in PA [23], the Dual-Model Framework of Automatic Affective Evaluation and PA [24], and the Affect and Health Behaviour Framework (AHBF) [25, 26], highlight the key role of affective variables in the regulation of PA behaviour. These frameworks describe how affective responses (i.e., valence and arousal), evaluations of affective experiences (e.g., implicit and explicit affective attitudes), and automatic motivational orientations (e.g., approach-avoidance tendencies) influence both the initiation and maintenance of PA [22-25]. Specifically, the AHBF integrates the affective correlates and determinants of PA into four categories: (a) the affective responses, which describe how one feels while performing or immediately after completing PA [25]; (b) the incidental affect, referring to feelings arising from situational factors unrelated to PA (e.g., anger resulting from an altercation) [27]; (c) the affect processing, which involves the automatic and reflective evaluation of previous affective responses (e.g., viewing PA as a pleasant behaviour); and (d) the affectively charged motivation, a motivational state grounded in past affective responses to PA (e.g., desire or dread towards PA) [25]. According to the AHBF, interventions targeting PA behaviour change can directly address these four categories of affective variables [28].

Current systematic reviews and meta-analyses provide initial support for the role of affective variables in regulating of PA behaviour [16, 29-34]. However, only three of these reviews specifically examined the effects of interventions on both affective variables and PA behaviour [16, 29, 30]. These studies show that targeting affective responses (e.g., affective valence), incidental affect (e.g., mood state), affect processing (e.g., affective attitudes, enjoyment, recalled pleasure), and affectively charged motivation (e.g., intrinsic motivation) can improve these variables, which in turn predict greater PA participation [16, 29]. Furthermore, Chen et al. found that incorporating behaviour change techniques (BCTs) [35], such as "prompt/cues" (e.g., phone reminders) and "social comparison" (e.g., social media groups), led to greater improvements in both affective variables and PA levels [30]. However, these reviews have primarily focused on reflective affective variables (e.g., affective attitudes, enjoyment), while overlooking automatic affective variables (e.g., affective associations, implicit attitudes) that are critical for a comprehensive understanding of PA engagement and maintenance [22-25]. This oversight limits our understanding of how interventions impact automatic processes and, in turn, PA behaviour. Moreover, these reviews have largely focused on healthy adults, leaving the potential effectiveness of such interventions for people with chronic diseases (e.g., cancer, diabetes) underexplored.

It is particularly important to address affective variables in people with chronic diseases, who often experience pain, discomfort, or fear associated with PA [36-40]. For instance, a recent meta-analysis found that individuals with chronic diseases, particularly cardiovascular diseases, are prone to kinesiophobia—

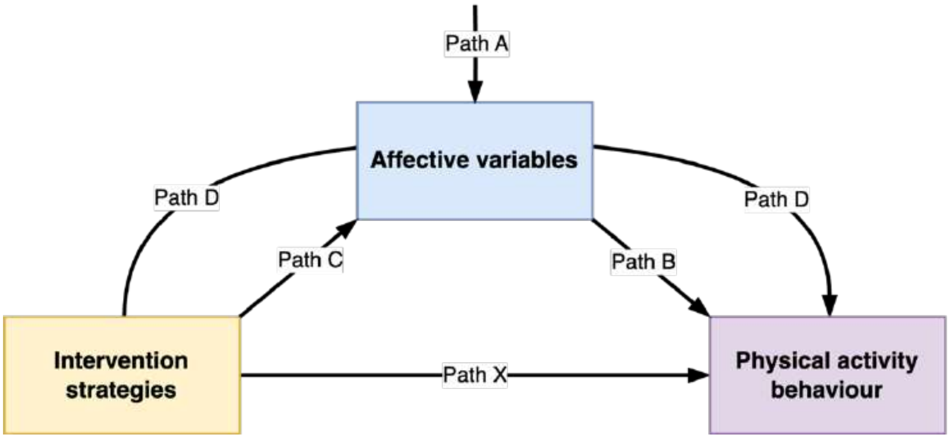
defined as an excessive and irrational fear of movement—which may result from the development of negative affective evaluations of PA [38]. Thus, improving affective variables associated with PA may be particularly effective in promoting PA engagement in people with chronic diseases. Therefore, further investigation of interventions that may enhance these affective variables in this population is warranted.

To address this knowledge gap, the aim of this preregistered study was to conduct a systematic review evaluating the effectiveness of interventions targeting affective variables to increase PA behaviors in people with chronic diseases. To guide our analysis, we adopted the experimental medicine approach [41, 42], a systematic framework that helps to identify the mediating mechanisms underlying the potential effect of an intervention on health behaviour change (Figure 1). Our systematic review was structured as follows: First, we assessed the effectiveness of interventions in changing PA behaviour (i.e., Path X). Next, we examined whether these interventions were successful in changing affective variables (i.e., the putative target; Path C) and whether changes in these affective variables led to changes in PA behaviour (i.e., Path B). Finally, we investigated evidence of mediation by determining whether the interventions influenced PA behaviour through their effects on affective variables (i.e., Path D). We also summarized the affective variables assessed in the literature (i.e., the putative targets; Path A) and the BCTs used (i.e., the active ingredients) within the general characteristics of the included studies.

Methods

To minimize bias and demonstrate adherence to a priori analysis intentions [43], this review was preregistered with the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42022354104. Procedures followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [44]. To enhance reproducibility and transparency [45], the preregistration details, PRISMA checklist, study materials, and datasets will be available on the Open Science Framework *(URL)*.

Figure 1. Experimental medicine approach to health behaviour change adapted to affective variables and physical activity behaviour



Path A represents the process of identifying the putative affective variables. Path B assesses how changes in affective variables influence changes in PA behaviour. Path C tests the effectiveness of interventions in altering affective variables. Path D examines whether interventions modify PA behaviour through their impact on affective variables. Path X tests the direct effectiveness of interventions in changing PA behaviour. Adapted from Sheeran et al. [41].

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria were established using the Population/Patient, Intervention, Comparison, and Outcome (PICO) framework [46], which provides a structured methodology for identifying key concepts for an effective search strategy (see Table S1 for the PICO of the present study).

Studies were included if they met the following criteria: (i) used any type of experimental design (e.g., randomised controlled trials, quasi-experimental design); (ii) used an intervention aimed at improving both PA/exercise (regardless of whether it targeted other health behaviours) and affective variables; (iii) included participants of any age with at least one chronic disease (e.g., cardiovascular disease, hypertension, diabetes); (iv) provided information on PA levels by any means (e.g., self-reported questionnaires, device-based measures, exercise session attendance); (v) reported at least one affective outcome as either a primary or secondary outcome, (vi) were published in English or French.

Studies were excluded based on the following criteria: (i) lack of a comparator (e.g., waitlist, control group, exercise, activity, or within-subjects comparator); (ii) primary intervention not explicitly designed to modify affective variables; or (iii) unavailability of full text through institutional access or direct correspondence with the author.

Search Strategy

A systematic literature search was conducted between September 2022 and April 2023 in six databases: Web of Science, PubMed MEDLINE, PsycINFO, Cochrane Library, and Google Scholar, and ProQuest Dissertations. To further extend our research forward and backward citation tracking of eligible articles was performed in January 2024. The search strategy used a combination of four strings of key terms that included affective variables, interventions, PA and exercise, and people with chronic diseases. Detailed descriptions of the search strings and strategies are provided in the Supplementary Material 1. The study selection process is illustrated in the PRISMA flow diagram (Figure 2).

Screening

A two-stage screening process was used to assess study eligibility. Initially, the first author (LF) reviewed titles and abstracts using Rayyan software (https://rayyan.ai/). Subsequently, LF and the second author (HS) conducted a comprehensive full-text review of eligible articles to determine their inclusion in the systematic review. The screening process achieved substantial interrater reliability (K = .62). Conflict between LF and HS were resolved through discussion.

Data Extraction and Analysis

Data extraction was performed by LF using a form adapted from Sivaramakrishnan et al. [47]. This form codes for study characteristics (e.g., author, year), participant demographics (e.g., sex, age, type of chronic diseases), PA outcomes (e.g., frequency, intensity, type), affective outcomes (e.g., enjoyment, affective valence), and method of outcome measurement (e.g., self-reported, device-based).

To evaluate the risk of bias (interrater reliability: K = .80) and the quality ratings (K = .60) of the included studies, LF conducted the initial assessment, while HS randomly checked 30% of these rating to ensure consistency [47]. The risk of bias in randomized controlled trials was assessed using the Risk of Bias 2 tool (RoB 2 [48]). This tool examines several domains, including the randomization process, deviations from the intended intervention, missing outcome data, method of outcome measurement, and selection of reported results (i.e., selectively reporting outcomes based on their direction, magnitude, or statistical significance). Based on the RoB 2 assessment, studies were classified as: "low risk" (i.e., low risk of bias in all domains); "some concerns" (raised concerns in at least one domain, but not to be a high risk of bias in any domain); "high risk" (i.e., high risk of bias in at least one domain or multiple concerns that substantially reduce confidence in the result); "no information" (i.e., insufficient data to assess risk) [48].

For non-randomized studies, the ROBINS-I tool [49] was used to examine potential confounders, participant selection, intervention classification, deviations from the intended intervention, missing data, outcome measurement, and selection of reported results. Based on the ROBINS-I criteria, studies were classified as: "low risk" (i.e., comparable to a well-performed randomised trial); "moderate risk" (i.e., sound evidence, but not directly comparable to a well-performed randomised trial); "serious risk" (i.e., some important problems); "critical risk" (i.e., too problematic to provide any useful evidence and should not be included in a synthesis); "no information" (i.e., insufficient data to assess risk) [49].

The overall quality of evidence and strength of recommendations were evaluated using the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) approach [50], with a modified checklist from Rhodes and Kates [33] (see Table S2 for more details). The checklist consists of 16 questions: 15 scored as yes (1) or no (0), and one scored as yes (2), acceptable (1), or no (0). Studies were categorized as "high quality" (score of 13-17), "fair quality" (score of 7-12), or "low quality" (score of 0 to 6) [33]. For each study, LF and HS extracted data on intervention strategies (interrater reliability; K = .65). LF and HS conducted independent coding of the different BCTs based on the taxonomy established by Michie et al. [35]. Each BCT in this taxonomy was coded as: (a) "present" (i.e., indicating certainty about its use), (b) "probably present" (i.e., indicating uncertainty about its use), or (c) "non-BCT strategy" (i.e., intervention strategies not included in the BCT taxonomy).

To structure the synthesis of the literature, themes and sub-themes were identified based on the experimental medicine approach [41] and the AHBF [25, 26]. This process involved categorisation studies into four main themes: (1) effectiveness of interventions on PA behaviour (Path X, Figure 1), (2) effectiveness of interventions on affective variables (Path C), (3) significant associations between affective variables and PA behaviour (Path B), and (4) affective variables as potential mediators of the interventions (Path D). Subgroups were then created based on two criteria: (a) the different contexts of PA behaviour (i.e., during the intervention period or at the end/ following the intervention period); and (b) the specific affective variables targeted in the studies, as defined by the AHBF model.

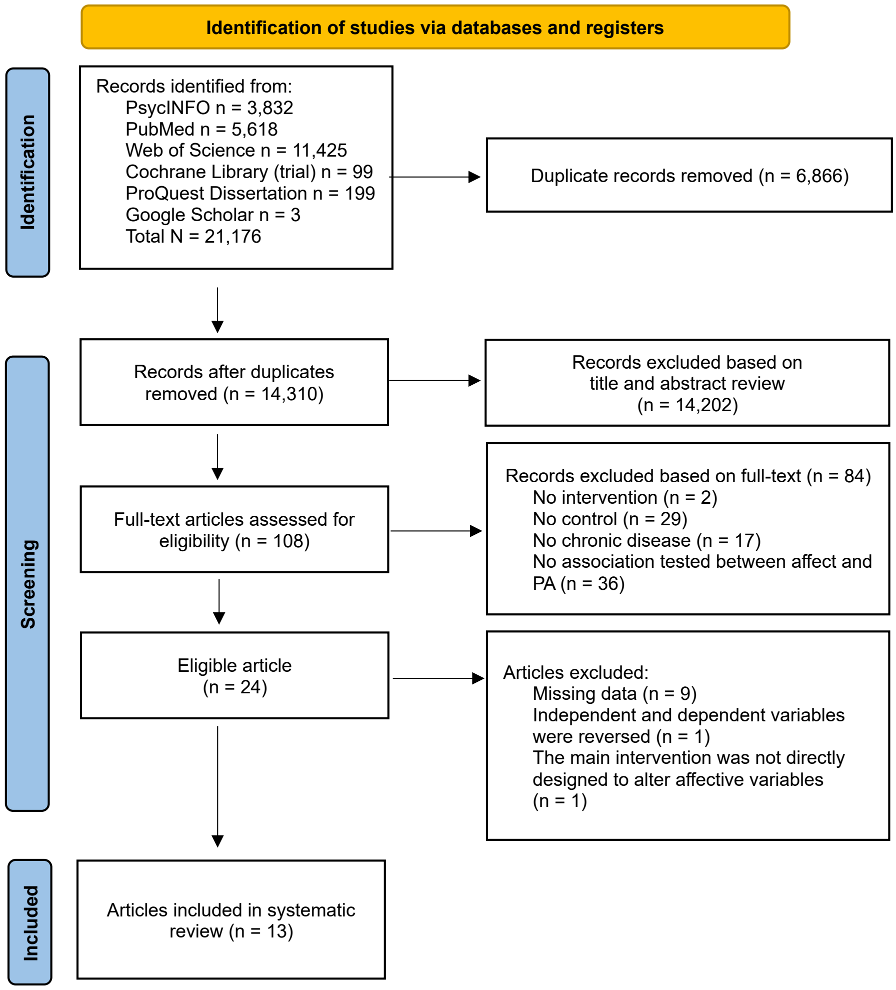
Results

A total of 21,176 records were identified using the search strategy. After removing duplicates (n = 6,866), 14,202 references were excluded based on title and abstract screening. Then, 84 references were screened but not retrieved for further analysis. Finally, 13 studies met the inclusion criteria and were included in the review (Figure 2).

Deviations from Preregistered Protocol

Several protocol deviations were identified. Initially, our search strategy included seven databases: Web of Science, PubMed, PsycINFO, Cochrane Library, SPORTDiscus, Google Scholar, and ProQuest Dissertations. However, due to the large number of records identified (21,176; see Figure 2) and the large number of duplicates encountered (6,866), we decided to exclude the SPORTDiscus database. Additionally, modifications were made to the originally specified intervention characteristics. The original protocol aimed to include only interventions explicitly designed to improve PA behaviour by targeting affective variables (e.g., affective responses, remembered pleasure, implicit attitudes, approach-avoidance tendencies). However, due to the limited number of studies that met these specific criteria, we expanded our inclusion criteria to include interventions in which PA behaviour and affective variables were primary or secondary outcomes, even if they were not explicitly designed to alter affective variables. Moreover, although a meta-analysis was initially planned, substantial heterogeneity among the included studies in terms of design, outcome measures, and data availability, necessitated a shift to a systematic review instead [51]. Finally, the initial inclusion criteria stated that studies must either provide sufficient information in the published paper to estimate an effect size for PA or exercise outcomes or allow for such information to be obtained through direct correspondence with the authors (i.e., two email requests/reminders spaced 14 days apart). However, this criterion was ultimately not applied due to our inability to conduct a meta-analysis based on the available data.

Figure 2. PRISMA flow diagram of study selection



General Study Characteristics

General study characteristics are detailed in Table 1. Of the 13 interventional studies included in this review, 11 were randomised controlled trials [52-62], while two were non-randomised studies (i.e., a pre-post within-subject design and a quasi-experimental between-subject design) [63, 64]. Together, these studies included a total of 904 participants, with a mean age of 52.58 (±11.92) years and a mean body mass index of 30.24 (±3.60) kg/m². 64% of the participants were female. Participants presented with a variety of chronic diseases, the most common being obesity (n = 7), followed by type 2 diabetes (n = 4) and cardiovascular disease (n = 3). Other conditions included asthma, chronic obstructive pulmonary disease, other pulmonary diseases, hyperlipidemia, hypertension, minor mental illness, multiple sclerosis, musculoskeletal pain, locomotor disorders, Parkinson's disease, polycystic ovarian syndrome, sleep apnea, stage 0–3 breast cancer, type 1 diabetes, and other conditions (Table 1).

Physical Activity Behaviour Measured

PA behaviour was measured in two different contexts: (1) PA behaviour recorded during the intervention period (lifestyle PA or exercise; n = 11) and (2) PA behaviour at the end or following the intervention period (n = 4; Table 1). Measurements methods included self-reported measures (n = 7) and device-based measures such as accelerometer or pedometer (n = 6), and records of exercise adherence during the study (n = 5; Table 1).

Affective Variables Measured

Table 1 lists the specific affective variables assessed in each study, organised according to the AHBF [25, 26].

Affective Responses

Affective responses refer to core affect, which includes both affective valence (i.e., pleasure-displeasure) and affective arousal (i.e., activation-deactivation) [25]. However, the studies included in this review only measured affective valence in relation to PA using the Feeling Scale [65] (n = 2).

Affect Processing

Implicit affective attitudes towards PA—defined as the immediate affective evaluation triggered by PA [25]—were assessed in three studies [52, 61, 63] using the using the Implicit Association Test [66]. Affective associations—defined as associations in memory between PA and previously experienced affective responses to PA [25]—were assessed in one study [60] using the following item: "When you think about being physically active, how do you feel?" [67, 68]. This item was followed by five positive (happy, delighted, joy, excited, and proud) and five negative (disgusted, annoyed, sad, irritated, and bored) affective words. Participants responded to each affective word on a separate Likert-type scale, anchored from 1 (not at all) to 5 (extremely). Affective attitudes towards PA—defined as evaluations of PA based on an aggregation of different anticipated potential affective responses (e.g., pleasure) [26]—were assessed in two studies. The first one used the following item: "For you, practicing PA (e.g., taking a brisk walk) is something…" [52]. The second one used the following item: "Would you say that being physically active is something…" [63]. In both studies, participants responded on two 7-point bipolar scales, ranging from 1 (unpleasant) to 7 (pleasant) and from 1 (boring) to 7 (fun). Exercise enjoyment—defined as the perception of great pleasure and happiness towards exercise [69]—was assessed in eight studies [53-59, 64]. Among them, five [53, 56-59] used the Physical Activity Enjoyment Scale (PACES [70]), one [54] used a subscale of the Intrinsic Motivation Inventory (IMI [71]), one [64] used a modified visual analogic scale rating how negative or positive the exercise experience was, and one [55] used a single 7-point Likert scale item asking participants how much they had enjoyed their exercise session, ranging from 1 (not at all) to 7 (very much). Remembered pleasure—defined as the global retrospective evaluation of pleasure or displeasure associated with PA [72]—was measured in one study [63] using the Global Affective Evaluation item [73].

Affectively Charged Motivation

Intrinsic motivation towards PA—defined as engaging in PA behaviour for the pursuit of its own pleasure [74]—was measured in one study [54] using the IMI.

Incidental Affect

No incidental affect variable was measured.

Theoretical Framework

Table 1 shows the specific theoretical framework used the studies reviewed. Of the 13 studies included in this review, five used a single theoretical framework, five used multiple theories, and three did not refer to a theoretical framework. Social Cognitive Theory [75] was mobilised in three studies, primarily to examine the association between self-efficacy and affective responses [40, 76]. The Affective–Reflective Theory of physical inactivity and exercise [22] and the conceptual dual-model of automatic affective evaluation and PA [24] were employed in two studies. The Transtheoretical Model [77] in two studies and the Self-Determination Theory [74] were applied in two studies. Other models and theories used in one study include the Theory of Effort Minimisation in PA [23], the Reflective-Impulsive Model in one study [78], the Associative-Propositional Evaluation Model [79], the AHBF [26], the Hedonic Theory [80], and the Health Action Process Approach [61].

Table 1. Overview of Studies Included in the Review

Authors	Participants	Duration of intervention and follow-up	Theory	Affective variables measured	PA behaviour measured	Outcomes	Study quality (/17)
Chevance et al., 2019	*N* = 79 M_{age} = 61.84 years; 47% female; M_{BMI} = 31.09 kg/m² Physically inactive Patients with COPD, sleep apnea, asthma, other France	**Intervention** 5 days **Follow-up** N.a.	Affective-Reflective Theory of physical inactivity and exercise Conceptual dual model of automatic affective evaluation and PA Associative-Propositional Evaluation Model	Explicit (*2-item questionnaire*) and implicit (*IAT*) affective attitudes toward PA Explicit affective attitudes toward sedentary behaviour (*2-item questionnaire*)	Device-based LTPA and MVPA (*ActiGraph GT3X+)* PA behaviour during the intervention period (lifestyle PA)	**Path B** (N.a.) **Path C** No significant differences between groups in implicit affective attitudes, and explicit affective attitudes **Path D** (N.a.) **Path X** No significant differences between groups in PA	High (14)
Fessler et al., 2024	*N* = 7 M_{age} = 72.00 years; 43% female; M_{BMI} = 22.80 kg/m² Physically active Patients with Parkinson's disease Switzerland	**Intervention** 8 weeks **Follow-up** N.a.	Affective-Reflective Theory of physical inactivity and exercise Conceptual dual model of automatic affective evaluation and PA Theory of Effort Minimisation in PA	Explicit (*2-item questionnaire*) and implicit (*IAT*) affective attitudes toward PA Remembered pleasure (*GAE*) of the exercise session	Device-based MVPA (*ActiGraph GT3X*) Self-reported MVPA (*IPAQ-SF*) PA behaviour during the intervention period (lifestyle PA)	**Path B** (N.a.) **Path C** No significant differences between the two conditions in implicit affective attitudes, and remembered pleasure Significant and positive association between the intervention condition and explicit affective attitudes (b = 1.00, *p* =.022) **Path D** (N.a.) **Path X** No significant differences between conditions in PA	Moderate (12)

Continue

Table 1 *(Continue)*

Authors	Participants	Duration of intervention and follow-up	Theory	Affective variables measured	PA behaviour measured	Outcomes	Study quality (/17)
Gilbertson et al., 2019	*N* = 29 M_{age} = 72.00 years; 100% female; M_{BMI} = 37.87 kg/m² Physically inactive Patients with prediabetes, obesity United States of America	**Intervention** 16 weeks **Follow-up** *(N.a.)*	N.a.	Exercise enjoyment (*PACES*)	Exercise adherence (*number of sessions attended out of 48*) PA behaviour during the intervention period (exercise)	**Path B** *(N.a.)* **Path C** No significant difference between groups in exercise enjoyment Exercise enjoyment score was improved by 9.15 points (± 3.37; *p* = .041) in the MICT group only from baseline to 8 weeks, and by 10.77 points (± 14.19; *p* = .021) from baseline to 16 weeks, but not from 8 weeks to 16 weeks (1.62 ± 3.33; *p* = .114), with no significant differences between groups **Path D** *(N.a.)* **Path X** No significant difference between groups in exercise adherence and exercise enjoyment	Moderate (12)
Hagberg et al., 2009 *(continue)*	*N* = 120 M_{age} = 49.74 years; 33% female; M_{BMI} = 29.88 kg/m² PA experience not described Patients with cardiovascular disease, type 2 diabetes, musculoskeletal pain and locomotor disorder, minor mental illness Sweden	**Intervention** 3 months **Follow-up** Months 6 and 12	N.a.	Expected exercise enjoyment (baseline, *1-item VAS*) Exercise enjoyment (3-, 6-, and 12-month follow-up, *1-item VAS*)	Exercise level (*1-item questionnaire*) PA behaviour following the intervention protocol (12-month follow-up)	**Path B** Significant baseline correlation between expected enjoyment and exercise level in control group only (*r* =.46, *p* <.01) Significant correlation between exercise enjoyment and exercise level for control (*r* =.43, *p* =.01), intervention (*r* =.33, *p* =.01) at 12 months Significant correlation between change in exercise enjoyment and exercise level for control group only (*r* =.50, *p* <.01)	Moderate (9)

Continue

Table 1 *(Continue)*

Authors	Participants	Duration of intervention and follow-up	Theory	Affective variables measured	PA behaviour measured	Outcomes	Study quality (/17)
Hagberg et al., 2009 *(continue)*	*N* = 120 M_{age} = 49.74 years; 33% female; M_{BMI} = 29.88 kg/m^2 PA experience not described Patients with cardiovascular disease, type 2 diabetes, musculoskeletal pain and locomotor disorder, minor mental illness Sweden	**Intervention** 3 months **Follow-up** Months 6 and 12	N.a.	Expected exercise enjoyment (baseline, *1-item VAS*) Exercise enjoyment (3-, 6-, and 12-month follow-up, *1-item VAS*)	Exercise level (*1-item questionnaire*) PA behaviour following the intervention protocol (12-month follow-up)	**Path C** Higher exercise enjoyment in intervention group at baseline, 3-, 6-, and 12-month follow-up (*ps* < .05) At 12 months, exercise enjoyment was 25% higher in the intervention group (*p* <.01) Exercise level significantly increased in the intervention group only (*p* <.01) **Path D** No significant differences in exercise level when controlling for exercise enjoyment (*p* >.05) **Path X** Higher odds of exercising 2-3 times/week in intervention group (OR = 3.75, *p* =.01)	Moderate (9)
Höchsmann et al., 2019 *(continue)*	*N* = 36 M_{age} = 57.00 years; 47% female; M_{BMI} = 32.00 kg/m^2 Physically inactive Patients with type 2 diabetes, obesity Switzerland	**Intervention** 24 weeks **Follow-up** *(N.a.)*	Self-Determination Theory	Intrinsic motivation toward PA (*IMI*) Interest/enjoyment (*a subscale of the IMI, considered as the true self-report measure of intrinsic motivation*)	PA adherence *(% of all in-game workout completed*) Device-based daily steps (*mobile phone*) PA behaviour during the intervention period (exercise and lifestyle PA)	**Path B** Significant positive association between total in-game training (minutes) and change in IMI total score (b = 0.003, *p* =.01, R^2 = 0.34) **Path C** Intrinsic motivation (IMI total score) significantly increased in intervention group (p <.001). Adjusted difference of 8.15 points between groups (*p* =.03) Interest/enjoyment significantly increased in intervention group (*p* <.001). Adjusted difference of 2.03 points (*p* =.049)	

Continue

Table 1 *(Continue)*

Authors	Participants	Duration of intervention and follow-up	Theory	Affective variables measured	PA behaviour measured	Outcomes	Study quality (/17)
Höchsmann et al., 2019 *(continue)*	*N* = 36 M_{age} = 57.00 years; 47% female; M_{BMI} = 32.00 kg/m² Physically inactive Patients with type 2 diabetes, obesity Switzerland	**Intervention** 24 weeks **Follow-up** *(N.a.)*	Self-Determination Theory	Intrinsic motivation toward PA (*IMI*) Interest/enjoyment (*a subscale of the IMI, considered as the true self-report measure of intrinsic motivation*)	PA adherence *(% of all in-game workout completed)* Device-based daily steps (*mobile phone*) PA behaviour during the intervention period (exercise and lifestyle PA)	**Path D** *(N.a.)* **Path X** Significant increase in daily steps in the intervention group 82.6% of all in-game workout reminders led to a completed work out on the same day	High (14)
Kiel et al., 2022	*N* = 64 M_{age} = 28.58 years; 100% female; M_{BMI} = 30.52 kg/m² PA experience not described Women with polycystic ovary syndrome, obesity Norway, Australia	**Intervention** 12 months **Follow-up** *(N.a.)*	N.a.	Exercise enjoyment (*PACES*)	Device-based PA (*Sensewear Armband*) Self-reported PA (*HUNT 1 questionnaire*) Adherence to the HIIT programme (*number of sessions attended*) PA behaviour during the intervention period (exercise, week 16) PA behaviour during the intervention period (lifestyle PA, week 52)	**Path B** *(N.a.)* **Path C** No between-group differences in exercise enjoyment **Path D** *(N.a.)* **Path X** No between-group or within-group differences in daily energy expenditure/step count No differences in time spent sedentary or doing light, moderate, or vigorous PA at any time point No difference in adherence to the HIIT programme	High (14)

Continue

Table 1 *(Continue)*

Authors	Participants	Duration of intervention and follow-up	Theory	Affective variables measured	PA behaviour measured	Outcomes	Study quality (/17)
McAuley et al., 2007	*N* = 26 M_{age} = 43.46 years; 88% female BMI not described Physically inactive Patients with multiple sclerosis, pulmonary disease, hypertension, hyperlipidemia, diabetes United States of America	**Intervention** 12 weeks **Follow-up** *(N.a.)*	Social Cognitive Theory	Affective valence (*FS*) Exercise enjoyment (*1-item questionnaire*)	Exercise adherence (*number of sessions attended out of 36*) PA behaviour during the intervention period (exercise)	**Path B** Significant correlation between exercise adherence and exercise enjoyment **Path C** Non-significant effect for the intervention condition on affective valence and exercise enjoyment (*p* =.07) **Path D** *(N.a.)* **Path X** Non-significant effect of the intervention on adherence	Moderate (12)
Pinto et al., 2015	*N* = 130 M_{age} = 63.60 years; 21% female; M_{BMI} = 29.10 kg/m² Physically active Patients with cardiovascular disease, type 2 diabetes, obesity United States of America	**Intervention** 12 months **Follow-up** *(N.a.)*	Social Cognitive Theory Transtheoretical Model	Exercise enjoyment (*PACES*)	Self-reported PA (*7 Day PAR*) PA behaviour at the end of the intervention protocol (month 12)	**Path B** No association between exercise enjoyment and PA behaviour **Path C** No difference in exercise enjoyment between groups **Path D** No mediation effect of exercise enjoyment **Path X** *(N.a.)*	Moderate (12)

Continue

Table 1 *(Continue)*

Authors	Participants	Duration of intervention and follow-up	Theory	Affective variables measured	PA behaviour measured	Outcomes	Study quality (/17)
Pinto et al., 2023	*N* = 161 M_{age} = 57.33 years; 100% female BMI not described Physically active Patients with stage 0–3 breast cancer United States of America	**Intervention** 9 months **Follow-up** Months 9 and 12	Social Cognitive Theory Transtheoretical Model	Exercise enjoyment (*PACES*)	Device-based MVPA (*Actigraph GT3X*) Self-reported MVPA (*7 Day PAR*) PA behaviour during the intervention period (lifestyle PA) PA behaviour at the end and following the intervention protocol (months 9 and 12)	**Path B** Increase in enjoyment from baseline to 6 months was significantly associated with MVPA at 9 months for RPM Increase in enjoyment from baseline to 9 months was significantly associated with MVPA at 9 months for RPP **Path C** Significant exercise enjoyment improvement from baseline to 3, 6, 9, and 12 months in each group No significant effect of intervention on enjoyment of exercise at any time point **Path D** Increase in enjoyment from baseline to 12 months significantly mediated the effect of RPM on MVPA at 12 months **Path X** PA levels increased in both groups at 3 months (no difference) RPM and RPP reported significantly greater MVPA (≥ 14.03 min/week) compared to RP at 6, 9, and 12 months RPM reported an additional 13.08 min/week of self-reported MVPA compared to RPP at 9 months	Moderate (12)

Continue

Table 1 *(Continue)*

Authors	Participants	Duration of intervention and follow-up	Theory	Affective variables measured	PA behaviour measured	Outcomes	Study quality (/17)
Poon et al., 2022	*N* = 42 M_{age} = 41.35 years; 0% female; M_{BMI} = 26.44 kg/m^2 Physically inactive Males with obesity[a] China	**Intervention** 16 weeks **Follow-up** *(N.a.)*	N.a.	Exercise enjoyment (*PACES*)	Exercise adherence (*% of prescribed session attended*) PA behaviour recorded during the intervention period (exercise)	**Path B** *(N.a.)* **Path C** No significant differences for enjoyment between groups **Path D** *(N.a.)* **Path X** No significant differences for adherence between groups	Moderate (12)
Van Wasshenova et al., 2023	*N* = 67 M_{age} = 67.51 years; 40% female; M_{BMI} = 31.81 kg/m^2 PA experience not described Patients with cardiovascular disease, obesity United States of America	**Intervention** 1 day **Follow-up** At weeks 1 and 3	Affect and Health Behaviour Framework	Automatic affective association toward PA (*5-item questionnaire*)	Self-reported PA (*PA log*) PA behaviour during the intervention period (lifestyle PA) PA behaviour following the intervention protocol (1 and 3 weeks after the end)	**Path B** *(N.a.)* **Path C** *(N.a.)* **Path D** No mediation of positive affective associations **Path X** No significant effect of the intervention on PA	Moderate (11)

Continue

Table 1 *(Continue)*

Authors	Participants	Duration of intervention and follow-up	Theory	Affective variables measured	PA behaviour measured	Outcomes	Study quality (/17)
Wilczynska et al., 2019	*N* = 84 M_{age} = 44.70 years; 70% female; M_{BMI} = 25–40 kg/m^2 Physically inactive Adults diagnosed with, or at risk of type 2 diabetes, obesity Australia	**Intervention** 20 weeks **Follow-up** *(N.a.)*	Social Cognitive Theory Health Action Process Approach	Implicit affective attitudes toward PA (*IAT*)	Device-based steps (*Yamax, model: Digi-Walker Electronic Pedometer*) PA behaviour during the intervention period (lifestyle PA)	**Path B** No significant association between implicit affective attitudes and PA **Path C** No significant effect of intervention on implicit affective attitudes **Path D** No significant mediation of implicit attitudes **Path X** Significant effect of the intervention on steps (mean difference between groups = 1330, 95% CI = 59; 2600, *d* = 0.67, *p* =.043)	High (13)
Williams et al., 2016 *(continue)*	*N* = 59 M_{age} = 47.70 years; 88% female; M_{BMI} = 31.90 kg/m^2 Overweight or obese adults United States of America	**Intervention** 6 months **Follow-up** *(N.a.)*	Self-Determination Theory Hedonic Theory	Affective valence (*FS*)	Self-reported exercise behaviour (handheld electronic diaries) PA behaviour during the intervention period (exercise)	**Path B** Effects of affective valence during (b = 0.47, SE = 0.25, f^2 = 0.04)[b], immediately after (b = 0.23, SE = 0.19, f^2 = 0.02), and 15 min after (b = 0.15, SE = 0.31, f^2 = 0.01) the exercise sessions on duration/latency of next exercise session **Path C** Effects of self-paced vs. prescribed exercise condition on affective valence during (a = 0.20, SE = 0.28, f^2 = 0.02) immediately after (a = 0.21, SE = 0.32, f^2 = 0.02), and 15 min after (a = 0.27, SE = 0.60, f^2 = 0.01) the exercise sessions	Moderate (10)

Continue

Table 1 *(Continue)*

Authors	Participants	Duration of intervention and follow-up	Theory	Affective variables measured	PA behaviour measured	Outcomes	Study quality (/17)
Williams et al., 2016 *(continue)*	N = 59 M_{age} = 47.70 years; 88% female; M_{BMI} = 31.90 kg/m^2 Overwieght or obese adults United States of America	**Intervention** 6 months **Follow-up** *(N.a.)*	Self-Determination Theory Hedonic Theory	Affective valence (*FS*)	Self-reported exercise behaviour (handheld electronic diaries) PA behaviour during the intervention period (exercise)	**Path D** Effects of self-paced exercise on next session through affective valence during (ab = 0.11, SE = 0.06, f^2 = 0.10), immediately after (ab = 0.01, SE = 0.06, f^2 = 0.001), and 15 min after (ab = 0.09, SE = 0.12, f^2 = 0.01) previous exercise session **Path X** Small-to-medium effect of self-paced vs. prescribed exercise condition on duration/latency of the next session (c = 1.56, SE = 0.45, f^2 = 0.08)	Moderate (10)

BMI, body mass index; COPD, chronic obstructive pulmonary disease; FS, Feeling Scale; GAE, Global Affective Evaluation; HIIT, high-intensity interval training; HUNT 1, the first health survey of the Trøndelag Health Study (1984–1986); IMI, Intrinsic Motivation Inventory; IPAQ-SF, International Physical Activity Questionnaire Short Form; MICT, moderate-intensity continuous training; MVPA, moderate-to-vigorous physical activity; PACES, Physical Activity Enjoyment Scale; PA, physical activity; PAR, Physical Activity Recall; RP, Reach Plus; RPP, Reach Plus Phone; RPM, Reach Plus Message; VAS, Visual Analogue Scale. Path B refers to the relationship between affective variables and PA behaviour. Path C refers to the effect of the intervention on affective variables. Path D refers to the testing of affective variables as potential intervention mediators. Path X refers to the effect of the intervention on PA behaviour. [a]BMI > 25.0 kg/m^2 according to the standard for the Asian population [96]; [b]As this was a proof-of-concept study, null-hypothesis significance testing was not the intended goal. Instead, the authors interpret clinically meaningful effect sizes regard- less of their statistical significance in terms of *p*-value.

Behaviour Change Techniques

Table 2 outlines the specific BCT employed in the reviewed studies.

Behaviour Change Techniques Present

A total of 19 unique BCTs were identified across the 13 studies included in this review, with an average of 3.54 (±3.07) BCT per study. The most commonly reported BCTs were "action planning" (n = 6), "social support (unspecified)" (n = 5), and "goal setting (behavioural)" (n = 5).

Behaviour Change Techniques Probably Present

In addition, seven unique BCTs were identified as probably present, with an average of 1.00 (±1.00) per study. The most commonly identified probable BCTs were "instruction on how to perform a behaviour" (n = 3), "self-reward" (n = 3), "behavioural practice/rehearsal" (n = 2), and "self-monitoring of behaviour" (n = 2).

Non-BCT Strategies

Two interventions were identified as non-BCT strategies, with a mean of 0.31 (±0.48) per study. These strategies include "exercise intensity and manipulation regimen" (n = 3) and "acceptance and commitment therapy" (n = 1).

Risk of Bias and Study Quality

Details results of the risk of bias and study quality assessment are available in the OSF repository (URL). The risk of bias analysis showed that seven studies were classified as having a high risk of bias (see Figure S1). This was mainly due to participants and intervention providers being aware of their assigned intervention (n = 7). Additionally, three studies were classified as having "some concerns" regarding bias, particularly related to missing outcome data, measurement of the outcome (i.e., low quality measurement method), selective reporting of results, and lack of adjustment for potential confounders. Three studies had a low risk of bias.

Regarding study quality, nine studies were classified as moderate quality and four as high quality (Table 2). The moderate quality rating was mainly due to a lack of information on participants' baseline characteristics (e.g., PA levels), loss to follow-up, insufficient statistical power, and inadequate handling of missing data.

Table 2. Intervention Strategies

Authors	Dependent variable	Intervention strategy	BCT
Chevance et al., 2019	Implicit and explicit affective attitudes towards PA and SB PA behaviour	Patients in a pulmonary rehabilitation programme were exposed, over four days in their bedrooms, to posters depicting older adults either: (a) engaging in PA, or (b) being sedentary while having fun Each poster included a pleasant adjective The control group had no posters in their bedrooms	7.8 Associative learning
Fessler et al., 2024	Remembered pleasure, implicit and explicit affective attitudes towards PA PA behaviour	Patients were enrolled in an eight-week within-subject study with weekly moderate-intensity exercise sessions, where the first four weeks served as a control, and the last four weeks included an additional 9 minutes of lower-intensity exercise at the end of each session (intervention)	4.1 Instruction on how to perform a behaviour 7.5 Remove aversive stimulus
Gilbertson et al., 2019	Exercise enjoyment Exercise adherence	Patients were enrolled in three weekly supervised sessions of either: (a) INT (4–10 bouts of 30-second maximal sprints with 4-minute active recovery), or (b) MICT (30–60 minutes at 45–55% HRR), combined with a diabetes prevention programme The diabetes prevention programme included (a) 16 individual education sessions on diet, exercise and behaviour modification; (b) individualized support to aid participants losing body weight and increasing activity level	Exercise intensity and regimen manipulation [b] 1.1 Goal setting (behaviour) 1.2 Problem solving [a] 1.4 Action planning 2.3 Self-monitoring of behaviour [a] 2.7 Feedback on outcome(s) of behaviour [a] 3.1 Social support (unspecified) 4.1 Instruction on how to perform a behaviour 5.1 Information about health consequences

Continue

Table 2. *(Continue)*

Authors	Dependent variable	Intervention strategy	BCT
Hagberg et al., 2009	Expected exercise enjoyment Exercise enjoyment PA behaviour	Intervention group received an initial consultation about health problems, lifestyle, and life situation. Together with the patients, three weekly group-based exercise sessions were planned over 3 months, followed by support to plan exercise sessions for the next 9 months Control group received the usual primary health care	1.4 Action planning 3.2 Social support (practical) 5.1 Information about health consequences
Höchsmann et al., 2019	Intrinsic motivation towards PA Interest/enjoyment towards PA Exercise adherence PA behaviour	Intervention group received a mobile app incorporating a storyline, virtual rewards, goal setting, action planning, feedback on performance, prompts and cues, and individualized exercises Control group received one-time lifestyle counseling and a structured exercise plan for autonomous implementation.	1.1 Goal setting (behaviour) 1.4 Action planning 2.7 Feedback on outcome(s) of behaviour 10.10 Reward (outcome)
Kiel et al., 2022	Exercise enjoyment Exercise adherence PA behaviour	Participants were enrolled in three weekly exercise sessions of either: (a) a LV-HIT protocol (ten 1-minute maximal intensity work-bouts and 1-minute recovery periods), or (b) a HV-HIT protocol (four 4-minute work-bouts at 90-95% HRmax and 3-minute recovery periods) Control group received information on PA guidelines without exercise sessions	2.2 Feedback on behaviour [a] 4.1 Instruction on how to perform a behaviour [a] Exercise intensity and regimen manipulation [b]
McAuley et al., 2007	Exercise affective valence Exercise enjoyment Exercise adherence	All patients received bi-weekly workshops incorporated into a 12-week PA programme Intervention group received workshops designed to improve self-efficacy towards PA, including (a) the importance of realistic, challenging, and attainable goals; (b) common barriers to initiation and maintenance of exercise and strategies for overcoming these barriers; (c) monitoring of performance feedback; (d) strategies to promote realistic outcome expectations; (e) importance of social support and networks within and outside the exercise environment; and (f) formation of "buddy groups" Control group received standard care workshops, included (a) general benefits associated with increased PA; (b) exercise-related injuries and strategies for preventing and treating such injuries; (c) the contribution of proper nutrition to good health; (d) health allergies and strategies for minimising the severity of attacks; and (e) importance of managing blood pressure and cholesterol	1.2 Problem solving 2.4 Self-monitoring of outcome(s) of behaviour 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behaviour

Continue

Table 2. *(Continue)*

Authors	Dependent variable	Intervention strategy	BCT
Pinto et al., 2015	Exercise enjoyment PA behaviour	All patients received an exercise prescription and brief counselling calls from an interventionist, focusing on the health benefits of exercise adherence Intervention group (Maintenance Counselling Group) received tailored motivational calls promoting aerobic exercise adherence through goal setting, plan development, reinforcement, discussions of the pros and cons of regular exercise, information on a variety of enjoyable activities, and encouragement to seek support from family and/or friends Control group (Contact Control Group) received an equal number of contacts from the interventionist at the same intervals, with the focus solely on the health benefits of exercise adherence	1.1. Goal setting (behaviour) 1.2 Problem solving 1.4. Action planning 3.1 Social support (unspecified) 5.6 Information about emotional consequences 9.2 Pros and cons 10.9 Self-reward [a]
Pinto et al., 2023	Exercise enjoyment PA behaviour	Participants were randomised into three groups: (a) RP group: 3 months of physical activity (PA) counselling (see Pinto et al., 2015, "Maintenance Counselling Group"), PA logs, a pedometer, and feedback reports with weekly calls over 12 weeks (b) RPP group: the same as the RP group, but with additional monthly calls from months 4 to 9 following the initial 3-month counselling period (c) RPM group: the same as the RP group, but with weekly motivational messages via email or text from months 4 to 9 after the initial 3-month counselling period. The messages were tailored to motivate, prompt, and reinforce continued PA	***All groups*** 1.1. Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 2.3 Self-monitoring of behaviour 2.7 Feedback on outcome(s) of behaviour 3.1 Social support (unspecified) 5.6 Information about emotional consequences 9.2 Pros and cons 10.1 Material incentive (behaviour) 10.9 Self-reward [a] ***RPM group only*** 7.1 Prompts/cues
Poon et al., 2022	Exercise enjoyment Exercise adherence	Patients were enrolled in three weekly supervised sessions of either: (a) HIIT, consisting of twelve 1-minute running bouts at 80-90% HRmax, with 1-minute walking recovery periods; (b) MICT, involving 40 minutes of brisk walking at 65-70% HRmax per session; (c) an alternating group (HIIT-MICT), which alternated between HIIT and MICT protocols across sessions; or (d) a control group, which received no specific exercise intervention, but followed a standardised warm-up and cool-down at 50% HRmax	4.1 Instruction on how to perform a behaviour [a] 8.1 Behavioural practice/rehearsal [a] Exercise intensity and regimen manipulation [b]

Continue

Table 2. *(Continue)*

Authors	Dependent variable	Intervention strategy	BCT
Van Wasshenova et al., 2023	Affective association towards PA PA behaviour	Intervention group received a 60-min individual session aimed at improving positive affective associations towards PA through a semi-structured guided interview based on ACT principles, focusing on identifying personal values and their connection to PA, with participants creating visual representations to reinforce these associations for future reference Control group received standard health education, providing information on topics such as healthy eating and reducing risk factors of heart disease	***Intervention group only*** Acceptance and Commitment Therapy (acceptance, cognitive defusion, being present, self as context, committed action, and values) [b] ***Control group only*** 2.3 Self-monitoring of behaviour [a] 5.1 Information about health consequences
Wilczynska et al., 2019	Implicit affective attitudes towards PA PA behaviour	Intervention group participated in a 20-week eCoFit programme consisting of two phases: Phase 1 (initiation; weeks 1–10) included integrated face-to-face sessions combining cognitive mentoring with a psychologist (i.e., overcoming barriers and increasing motivation) and supervised outdoor PA sessions with practical education, alongside the use of the eCoFit smartphone app tailored for location-specific workouts, goal-setting and self-monitoring, and cognitive-behavioural task to increase motivation, overcome barriers, and develop positive PA behaviour, and links to social media Phase 2 (maintenance; weeks 11–20) focused exclusively on the use of the eCoFit smartphone app Control group was placed on a waiting list	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 2.3 Self-monitoring of behaviour 2.7 Feedback on outcome(s) of behaviour 3.1 Social support (unspecified) 4.1 Instruction on how to perform a behaviour 10.3 Non-specific reward 10.9 Self-reward [a]
Williams et al., 2016	Affective valence PA behaviour	Participants were randomly assigned to either: (a) a self-paced exercise group (instructed to walk at a pace achieving a heart rate range of 64–76% of HRmax), or (b) a prescribed moderate intensity exercise group (instructed to choose their own walking pace, not exceeding 76% of age-predicted HRmax), within identical 6-month print-based exercise promotion programs All participants were instructed to target one 30- to 60-min walking session at least 5 days per week, and to indicate each time they began and ended a session All participants were reminded of the exercise prescription throughout the study	2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform a behaviour [a] 7.1 Prompts/cues 8.1 Behavioural practice/rehearsal [a]

ACT, Acceptance and Commitment Therapy; HIIT, high-intensity interval training; HRmax, maximum heart rate; HRR, heart rate reserve; HV-HIT, high-volume high-intensity interval training; HUNT 1, the first health survey of the Trøndelag Health Study (1984–1986); INT, instructed run sprint interval training; LV-HIT, low-volume high-intensity interval training; MICT, moderate-intensity continuous training; PA, physical activity; RP, Reach Plus; RPP, Reach Plus Phone; RPM, Reach Plus Message. [a] Probably present. [b] Non-BCT strategy.

Effect of Interventions on Physical Activity Behaviour (Path X)

Physical Activity Behaviour Measured During the Intervention Period

Significant Effect. Of the 11 studies that measures PA during the intervention, only two reported a significant effect of the intervention on PA behaviour during this period [58, 61] (Table 1). Pinto et al. [58] evaluated the effects of three motivational counselling protocols (Reach Plus, RP; Reach Plus Phone, RPP; Reach Plus Message, RPM; see Table 2 for details on the intervention protocol) on moderate-to-vigorous PA (MVPA) in 161 females with breast cancer over a 9-month period (Table 1). Ten BCTs were present and one probably present (Table 2). MVPA levels were assessed at baseline, and at 3, 6, and 9 months using both device-based and self-reported measures (Table 1). At 3 months, device-based results showed an increase in MVPA of 79.39 min/week from baseline, but no significant differences between groups (p = .48). At 6 months, MVPA levels were significantly higher in RP compared to RPM (b = 49.17, f^2 = .20, SE = 6.40, p = .02) and RPP (b = 40.17, f^2 = .19, SE = 4.51, p = .02). However, no significant differences were found between RPM and RPP. At 9 months, RPM had significantly higher MVPA levels than RP (b = 31.50, SE = 6.89, f^2 = .18, p = .03), although the difference between RPP and RP did not reach significance (b = 15.10, SE = 4.55, f^2 = .09, p = .06). Self-reported data showed an increase in MVPA of 167.92 min/week from baseline to 3 months, with no significant differences between groups (p > .05). At 6 months, RPM (f^2 = .12, p = .03) and RPP (f^2 = .16, p = .03) had significantly higher MVPA levels compared to RP, although no differences were observed between RPM and RPP (p = .83). At 9 months, both RPM and RPP had significantly higher MVPA levels than RP (RPM: f^2 = .11, p = .04; RPP: f^2 = .21, p = .05), with RPM also outperforming RPP (p = .04).

Wilczynska et al. [61] evaluated the effects of a 20-week mobile-app eCoFit programme (see Table 2 for intervention details) on PA behaviour in 84 adults at risk for or diagnosed with type 2 diabetes or obesity. The control group was placed on a waiting list. PA behaviour was assessed using pedometer over a 7-day period at baseline and again at 10 and 20 weeks during the intervention period. Results showed that participants significantly increased their daily steps from baseline to 10 weeks, with a mean increase of 1,330 steps (95%CI = 59; 2600, d = 0.67, p =.043). However, no significant changes were observed between baseline and 20 weeks.

In contrast to the other studies, Williams et al. [62] did not report statistical significance and focused on the effect sizes only. Consequently, a direct comparison of the effects of this intervention on affective variables and physical activity levels with those of studies showing statistically significant effects cannot be made. Their study examined self-paced intensity versus prescribed moderate-intensity exercise programmes over a 6-month period in 56 overweight or obese adults (Tables 1 and 2). PA behaviour was measured using self-reported electronic diaries in which participants recorded that start and end time of their exercise sessions. Two distinct BCTs were present and two were probably present (Table 2). Results showed a small-to-moderate effects of the intervention on exercise duration/latency (i.e., longer exercise sessions and a reduction in the time between sessions; c = 1.56, SE = 0.45, f^2 = 0.08). These results suggest that a self-paced exercise, relative to a prescribed moderate intensity exercise, may lead to more exercise frequency/duration.

Nonsignificant Effect. Of the 11 studies that measured PA during the intervention period, nine report no statistically significant effect on PA behaviour [52-56, 59, 60, 62, 63]. Across these studies, 12 distinct BCTs were present and four probably present (Table 2). The most commonly used BCTs included "instruction on how to perform a behaviour" (n = 5) and "self-monitoring of behaviour" (n = 3). Additionally, two non-BCT strategies were identified: "exercise intensity and regiment manipulation" (n = 3) and "acceptance and commitment therapy" (ACT, n = 1).

Physical Activity Behaviour at the End/Following the Intervention Period

Significant Effect. Of the four studies that measures PA at the end or after the intervention period, two reported a significant effect of the intervention on PA behaviour during this period [58, 64]. Hagberg et al. [64] investigated the effect of a 3-month intervention consisting of 3 weekly group-based exercise sessions followed by 9 months of exercise planning support on self-reported exercise levels among 120 patients with various chronic diseases (Table 1). This intervention was compared with a control group that received only brief exercise advice (see Table 2 for details on the protocol). Three BCTs were present: "action planning", "social support (practical), and "information about health consequences". Exercise frequency, defined as the frequency of participation in exercise sessions to improve or maintain fitness, health, or well-being, were assessed at baseline and again after a 9-month follow-up period (i.e., at 12 months from the start of the intervention; Table 1). Results showed a significant increase in exercise levels in the intervention group (p < .01), with participants reporting increases from baseline to 12 months: never (17% to 8%), sometimes (40% to 11%), 1–2 times/week (16% to 40%), 3–5 times/week (25% to 35%), and >5 times/week (2% to 3%). Furthermore, the intervention significantly increased the odds of exercising two to three times per week compared to not exercising (OR = 3.75, 95%CI = 1.33; 10.56, *p* = .01), although the odds of exercising more than three times per did not reach statical significance (OR = 2.44, 95% CI = 0.93; 6.37, *p* = .07).

Pinto et al. [58] assessed weekly MVPA levels at 12 months following the intervention period (Table 1). Device-based results showed a significant increase in weekly MVPA levels in all groups from baseline to 12 months (*ps* < .01). Moreover, self-reported MVPA levels indicate that both the RPM (*p* = .04) and RPP (*p* = .05) groups had significantly higher weekly MVPA levels than the RP group at 12 months, with no significant differences between RPM and RPP.

Nonsignificant Effect. Of the four studies that assessed PA at the end or after the intervention period, two found no statistically significant effect of the intervention on PA behaviour at this time [57, 60]. Across these studies, 11 distinct BCTs were used, with "self-reward" (*n* = 2), "action planning" (*n* = 2), "goal setting (behavioural)" (*n* = 2), "problem solving" (*n* = 2), and "social support (unspecified)" (*n* = 2) being the most commonly implemented (Table 2).

In summary, three studies (23%) showed a significant and positive effect of the intervention on PA behaviour [58, 61, 64]. Effect sizes ranged from f^2 = .11 [58] to f^2 = .20 (reported as d = 0.67 in the study [61]) for PA behaviour during the intervention period [58, 61], and an OR of 3.75 for exercising two to three times per week compared to no exercise three months after the intervention [64]. These studies used 12 BCTs to increase PA behaviour during the intervention period [58], and 13 BCTs to improve PA behaviour after the intervention period [58, 64] (Table 3). The mean number of BCTs used in studies with significant intervention effects (*M* = 7.67 ± 4.16) was higher than in without significant intervention effects on PA behaviour (*M* = 3.60 ± 2.32). "Action planning" was the only BCT applied in the two trials that reported improvements in PA behaviour after the intervention. However, these studies showed considerable heterogeneity in terms of PA behaviour (lifestyle PA vs. exercise), PA measurement methods (device-based vs. self-reported), and population characteristics (e.g., 100% vs. 33% female participants, cancer vs. minor mental illness; Table 1).

Effects of Interventions on Affective Variables (Path C)

Affective Responses

Of the two studies that measured affective responses during exercise [55, 62], neither found a significant effect of the intervention (Table 1). Six distinct BCTs were present and two were probably present (Table 2). Although Williams et al. [62] did not report statistical significance, they examined the effect of their intervention on affective valence, measured using the Feeling Scale [65], at 10-minute intervals during the exercise sessions, as well as immediately after and 15 minutes post-exercise. Results showed a small effect of the self-paced exercise condition compared to the prescribed exercise condition (reference group) on affective valence during exercise (a = 0.20, SE = 0.28, f^2 = 0.02) and immediately postexercise (a = 0.21, SE = 0.32, f^2 = 0.02). However, the effect on affective valence 15 min postexercise was almost negligible (a = 0.27, SE = 0.60, f^2 = 0.01). Across all time points, the self-paced condition resulted in higher affective valence scores compared to the prescribed exercise condition.

Affect Processing

Significant Effect. Of the 12 studies that measured affect processing, four reported a significant effect of intervention on these affective variables [54, 60, 63, 64]. Fessler et al. [63] conducted an eight-week within-subject early-phase study of weekly moderate-intensity exercise sessions with seven physically active Parkinson's disease patients. The first four weeks served as a control period, while the last four weeks included an additional nine minutes of lower-intensity exercise at the end of each session (intervention). Remembered pleasure of the exercise session was assessed at the end of each session, and implicit and explicit affective attitudes towards PA were measured at baseline, 4 weeks, and 8 weeks using self-reported questionnaires and IAT (Table 1). Two BCTs were present: "instruction on how to perform a behaviour," and "remove aversive stimulus". Results showed a significant positive effect of the intervention on explicit affective attitudes towards PA (b = 1.00, 95%CI = 0.36; 1.64, R^2 = .37, *p* =.022), but a non-significant effect of the intervention on implicit affective attitudes (b = 0.19, 95% CI = -0.41; 0.79, *p* =.564) and remembered pleasure (b = 0.04, 95%CI = -1.44; 1.51, *p* = .963).

Van Wasshenova et al. [60] investigated the effect of a single 60-min individual semi-structured guided interview, based on Acceptance and Commitment Therapy principles, on the self-reported affective associations towards PA in 84 adults diagnosed with or at risk of type 2 diabetes and obesity, compared to a control group that received standard health education (Table 2). Affective associations were assessed at three time points (Table 1): baseline, 1-week after the intervention, and 3 weeks after the intervention. Two BCTs were probably present: "information about health consequences" and "self-monitoring of behaviour" (Table 2). Results showed a significant negative correlation between groups and positive affective associations at baseline (*r* = -.27, *p* <.05), 1 week (*r* = -.35, *p* <.01), and 3 weeks (*r* = -.44, *p* <.01). Additionally, there was a significant negative effect of the group on overall positive affective associations (t = -3.1, *p* =.003). However, it should be noted that the study does not specify which group was used as the reference in the statistical analyses, and we failed to obtain this information with the corresponding authors of this paper after two reminders. Therefore, this limits our ability to interpret the effect of the intervention.

Two studies found significant effects of the intervention on exercise enjoyment [54, 64]. Hagberg et al. [64] showed that expected enjoyment for the first exercise session of the intervention (baseline) was significantly higher in the intervention group compared to the control group (*Mean difference* = 7.9, 95%CI = 0.9; *d* = .40, 14.9, *p* =.03). Furthermore, exercise enjoyment score was significantly higher in intervention group compared to the control group at 3 (*Mean difference* = 16.5, 95%CI = 9.2; *d* = 0.85, 23.8, *p* <.01), 6 (*Mean difference* = 11.2, 95%CI = 3.0; 19.3, *d* = 0.53, *p* =.01), and 12 months (*Mean difference* = 14.6, 95%CI = 5.8; 23.4, *d* = 0.62, *p* <.01). Exercise enjoyment increased significantly from baseline to 3 and 6 months in the intervention group only (*p* <01).

Höchsmann et al. [54] investigated the effect of a mobile app incorporating a storyline, virtual rewards, individualised exercises, and daily PA promotion on exercise interest/enjoyment towards PA on 36 patients with type 2 diabetes and obesity, compared to a control group receiving one-time lifestyle counselling and a structured exercise plan (Tables 1 and 2). Exercise interest/enjoyment was measured at baseline and after the 24-week intervention using a subscale of the IMI [71]. Four BCTs were employed (Table 2). Pre-post intervention results showed that exercise interest/enjoyment scores increased by 2.00 points (± 1.94; *p* < .001) in the intervention group only, resulting in a mean score of 2.03 points higher than the control group (95% CI = 0.04; 4.09, d = 0.73, *p* = .049).

Nonsignificant Effect. Of the 12 studies that measured affect processing, eight did not report a significant effect of intervention on affect variables [52, 53, 55-59, 61]. Across these eight studies, 11 distinct BCTs were present and seven were probably present. "Social support (unspecified)" (*n* = 5), "problem solving" (*n* = 5), "action planning" (*n* = 4), and "goal setting (behaviour)" (*n* = 4) being the most frequently used (Table 2). Additionally, one non-BCT strategies was identified, namely "exercise intensity and regiment manipulation" (*n* = 3).

Affectively Charged Motivation

Only Höchsmann et al. [54] examined the effect of their intervention on an affectively charged motivational variable, specifically intrinsic motivation towards PA (Tables 1 and 2). Intrinsic motivation was assessed at baseline and after the 24-week mobile app-based intervention using the total score of the IMI [71]. Pre- and post-intervention results showed that intrinsic motivation scores increased by 6.39 points (±4.19; *p* < .001) in the intervention group and decreased by 1.94 points in the control group (±16.46, *p* = .620), resulting in 8.15 points more than the control group (95%CI = 0.90; 15.39, *d* = 0.70, *p* = .030).

In summary, four studies (i.e., 31%) showed a significant effect of the intervention on affective variables [54, 60, 63, 64]. Across these studies, a total of nine distinct BCTs were used to enhance affective variables (Table 3). The mean number of BCTs employed in these studies with significant effects (*M* = 2.33

± 0.58) was lower than in the studies without significant effects of the intervention on affective variables (*M* = 5.2 ± 3.36). "Action planning" (*n* = 2) and "information about health consequences" (*n* = 2) were the only BCTs applied in more than one study. Despite these findings, the studies showed considerable heterogeneity regarding affective variables (i.e., four distinct affective variables), measurement methods (e.g., two different scales for assessing exercise enjoyment), and population characteristics (e.g., metabolic vs. neurodegenerative diseases; Table 1).

Relationship Between Affective Variables and Physical Activity Behaviour (Path B)

Affective Responses

Two studies assessed affective responses during PA behaviour [55, 62], but neither found a significant relationship between affective responses and PA behaviour (Table 1). Six distinct BCTs were present and two were probably present (Table 2). Although they did not report statistical significance, Williams et al. [62], showed a small-to-medium effects of affective valence on exercise duration/latency between daily exercise sessions (b = 0.47, SE = 0.25, f^2 = 0.04). In addition, small effects of postexercise affective valence on duration/latency of next session (b = 0.23, SE = 0.19, f^2 = 0.02). These results suggest that more positive affective valence to individual exercise sessions would result in shorter latencies to and longer durations of subsequent exercise sessions. However, the effect of affective valence 15 min postexercise on duration and latency of next exercise session was almost negligible (b = 0.15, SE = 0.31, f^2 = 0.01).

Affect Processing

Significant Effect. 12 studies measured affect processing, with four reporting a significant relationship between affect processing variables and PA behaviour [55, 58, 60, 64]. Of these, three studies found a significant association between exercise enjoyment and PA behaviour. Hagberg et al. [64] found a significant and positive baseline correlation between expected enjoyment and exercise levels in the control group only (*r* =.46, *p* <.01). Furthermore, a significant positive correlation between exercise enjoyment and exercise levels at 12 months for both for the control (*r* =.43, *p* =.01) and the groups (*r* =.33, *p* =.01).

McAuley et al. [55] investigated the effect of a 12-week PA programme that included bi-weekly workshops aimed at enhancing self-efficacy, compared with standard care workshops, on exercise enjoyment and adherence in 26 patients with multiple chronic diseases (see Tables 1 and 2). Exercise enjoyment was assessed after each session using a self-reported questionnaire, while exercise adherence was defined as the number of sessions attended out of a total of 36 (Table 1). Four BCTs were employed (Table 2). Results showed a significant positive correlation between the mean exercise enjoyment score and exercise adherence during the intervention period ($r = .47$, $p < .05$).

Pinto et al. [58] assessed exercise enjoyment at baseline, and at 3, 6, 9, and 12 months after the intervention commencement, using the PACES (see Tables 1 and 2). The results indicated that the increase in enjoyment from baseline to 6 months was significantly associated with weekly device-based MVPA levels at 6 months for the RPM group compared to the RP group (b = 1.42, SE = 0.66, $p < .05$). This suggests that, within the RPM group, each unit increase in enjoyment from baseline to 6 months corresponded to an increase of 1.42 min per week in MVPA at 6 months. Additionally, the results showed that the increase in enjoyment from baseline to 9 and 12 months was significantly associated with weekly device-based MVPA levels at 9 and 12 months for the RPP group compared to the RPM group (b = 2.19, SE = 1.04, $p < .05$; b = 1.71, SE = 0.97, $p < .05$, respectively). This indicates that, within the RPP group, each unit increase in enjoyment from baseline to 9 and 12 months corresponded to an increase of 2.19 min and 1.71 min per week in MVPA at 9 and 12 months, respectively.

Finally, Van Wasshenova et al. [60] assessed affective associations towards PA and PA behaviour 3 weeks after the participants had completed their cardiac rehabilitation using self-reported questionnaires (Table 1). The results indicated that positive affective associations were associated to higher levels of PA ($t = -2.22$, $p = .03$). Of note, the study does not provide the effect size for this association and fails to clarify why a positive relationship between these variables resulted in a negative coefficient—typically indicative of a negative association—thereby limiting our ability to fully interpret these findings.

Nonsignificant Effect. Of the 12 studies that measured affect processing, eight did not report a significant relationship between affect processing variables and PA behaviour [52-57, 59, 63]. Across these studies, 14 distinct BCTs were present and four were probably present. "Instruction on how to perform a behaviour" (*n* = 3), "problem solving" (*n* = 3), "action planning" (*n* = 3), "goal setting (behaviour)" (*n* = 3), "social support (unspecified)" (*n* = 3) being the most frequently used (Table 2). Additionally, one non-BCT strategies was identified, namely "exercise intensity and regiment manipulation" (*n* = 3).

Affectively Charged Motivation

Only Höchsmann et al. [54] assessed an affectively charged motivational variable, specifically intrinsic motivation towards PA (Tables 1 and 2). Results showed a significant positive association between total in-game training (minutes) and change in intrinsic motivation from baseline and after the 24-week mobile app-based intervention (b = 0.003, R^2 = 0.34, p =.01) (Table 2).

In summary, four studies (31%) reported a significant association between affective variables and PA behaviour [55, 58, 60, 64]. Across these studies, 13 distinct BCTs were employed, one of which was probably present (Table 3). The mean number of BCTs employed in these studies (M = 5.00 ± 4.08) was superior to studies where affective variables were not significantly associated with PA behaviour (M = 4.33 ± 2.96). "Action planning" (*n* = 2), "goal setting (behaviour)" (*n* = 2), "feedback on outcome(s) of behaviour" (*n* = 2), and "self-monitoring of behaviour" (*n* = 2) were applied in more than one study. However, these studies exhibited considerable heterogeneity regarding affective variables (i.e., four distinct affective variables), measurement methods (e.g., three different scales for assessing exercise enjoyment), and population characteristics (e.g., metabolic vs. neurodegenerative diseases; Table 1).

Affective Variables as Potential Intervention Mediators (Path D)

Affective Responses

Of the two studies that assessed affective responses during PA behaviour [55, 62], neither found a significant mediating effect of affective responses on the effect of the intervention on PA behaviour (Table 1). However, although non reporting statistical significance, Williams et al. [62], reported medium indirect effects of self-paced exercise on the latency and duration of subsequent exercise sessions, mediated by affective valence during the previous session (ab = 0.11, SE = 0.06, f^2 = 0.10). These results suggest that the self-paced condition may induced more positive affective valence during individual exercise sessions, which, in turn, led to shorter latency to and longer duration of subsequent exercise sessions. However, the indirect effect through affective valence immediately post-exercise and at 15 minutes post-exercise was negligible (ab = 0.01, SE = 0.06, f^2 = 0.001; ab = 0.09, SE = 0.12, f^2 = 0.01, respectively).

Affect Processing

Significant Effect. Of the 12 studies that assessed affect processing, two found a significant mediating effect of affect processing on the impact of the intervention on PA behaviour [58, 64]. Pinto et al. [58] showed that the RPM participants experienced greater improvement in enjoyment over 12 months compared to RPP, and these improvements were positively associated to increases in min/week of self-reported MVPA at 12 months (ref. RPM; ab = -3.63, 95% CI= -28.23; -3.54). The article asserts that device-based analyses (i.e., accelerometer) yielded comparable results; however, the data were not available in the paper. We contacted the authors for the data but did not receive a response. The RPM group was the only condition employing the "prompt/cues" BCT (Table 2).

Hagberg et al. [64] found a significant correlation between exercise enjoyment and exercise levels both at baseline and 12 months (Path B, Table 1). Moreover, the intervention significantly increased the likelihood of exercising two to three times per week compared to not exercising (OR = 3.75, 95% CI = 1.33; 10.56, p = .01; Path C). Although no formal mediation analysis was performed, when controlling for exercise enjoyment, the results were no longer significant (OR = 2.78, 95% CI = 0.85; 9.06, p = .09), suggesting a mediation effect (Path C).

Nonsignificant Effect. Of the 12 studies that measured affect processing, 10 did not report a significant mediating effect of affect processing on the impact of the intervention on PA behaviour [52-57, 59-61, 63]. Across these studies, 19 distinct BCTs were employed, four of which were probably present. "Instruction on how to perform a behaviour" (n = 5), "problem solving" (n = 4), "action planning" (n = 4), "goal setting (behaviour)" (n = 4), "social support (unspecified)" (n = 4) being the most frequently used (Table 2). Additionally, two non-BCT strategies were identified: "exercise intensity and regiment manipulation" (n = 3) and "acceptance and commitment therapy" (ACT, n = 1).

Affectively Charged Motivation

Only Höchsmann et al. [54] assessed an affectively charged motivational variable, specifically intrinsic motivation towards PA (Tables 1 and 2). Although no formal mediation analysis was performed, results showed a significant positive association between total in-game training (minutes) and change in intrinsic motivation (b = 0.003, p =.01, R^2 = 0.34; Path B), and a significant positive effect of the intervention on intrinsic motivation score (+6.39 points, p <.001; Path C), suggesting a potential mediation effect (Path D, Table 1).

In summary, one study (8%) reported a positive significant formal mediating effect of affective variables on the impact of the intervention on PA behaviour (i.e., directly tested) [58], and two studies (15%) a positive non-formal mediating effect (i.e., not directly tested) [54, 64]. Due to insufficient reporting of results, we were unable to calculate effect sizes for the observed mediation patterns. Across these studies, 14 distinct BCTs were employed, one of which was probably present (Table 3). The mean number of BCTs employed in these studies (M = 7.00 ± 5.66) was superior to studies with nonsignificant mediation effect (M = 4.09 ± 2.75). "Action planning" (n = 3), "goal setting (behaviour)" (n = 2), and "feedback on outcome(s) of behaviour" (n = 2), were applied in more than one study. However, these studies exhibited heterogeneity regarding PA behaviour (i.e., lifestyle PA vs. exercise), affective variables (i.e., two distinct affective variables), measurement methods (e.g., device-based PA vs. self-reported, two different scales for assessing exercise enjoyment; Table 1).

Discussion

Main Findings

This preregistered study aimed to systematically review the effectiveness of interventions on affective variables and PA behaviour in people with chronic diseases. Thirteen studies met the inclusion criteria. Among these, five (38%) were grounded in a single theoretical framework, five (38%) utilised multiple theories, and three (23%) did not explicitly employ any theoretical framework. Overall, three studies (23%) reported a significant positive effect of interventions on PA behaviour, four studies (31%) showed significant effects on affective variables, four studies (31%) identified associations between affective variables and PA behaviour, and three studies (23%) suggested a possible mediation of affective variables in the effect of interventions on PA behaviour change. However, the majority of these studies exhibited moderate-to-high risks of bias and were of poor quality, raising concerns about the reliability of these findings. Additionally, the interventions primarily employed "action planning," a BCT not specifically designed to target affective variables.

Path X: Effect of Interventions on Physical Activity Behaviour Change

Three studies (23%) showed a significant positive effect of interventions on PA behaviour, incorporating active ingredients like cognitive mentoring, group-based sessions, and motivational counselling [58, 61, 64]. Each study demonstrated improvements in PA levels—both device-based and self-reported—across various populations, including adults at risk for type 2 diabetes, breast cancer, and obesity. Despite the significant results, two studies (Pinto et al. [58] and Wilczynska et al. [61]) exhibited a high risk of bias, while two studies (Hagberg et al. [64] and Pinto et al. [58]) were rated as moderate risk, indicating that these results should be considered when interpreting the results. The remaining studies with non-significant findings generally relied on interventions that probably did not include BCTs (Table 2) [53, 56, 59, 60, 62]. Consequently, the absence of BCTs when targeting PA behaviour change can limit the overall effectiveness of an intervention [81], as these techniques are crucial for addressing psychological and motivational barriers and fostering sustained engagement in PA [82].

Path C: Effect of Interventions on Affective Variables

Four studies (31%) reported a significant effect of the intervention on affective variables [54, 60, 63, 64]. However, these studies exhibited distinct characteristics with no common features. Fessler et al. [63] improved affective attitudes towards PA in adults with Parkinson's disease through low-intensity exercises at the end of weekly sessions. Van Wasshenova et al. [60] employed a single 60-minute Acceptance and Commitment Therapy session, resulting in decreased positive affective associations among adults at risk for type 2 diabetes and obesity. Hagberg et al. [64] implemented a comprehensive intervention with group-based exercise sessions, enhancing self-reported exercise enjoyment in adults with various chronic diseases. Höchsmann et al. [54] used a 24-week mobile app intervention, which improved exercise enjoyment and intrinsic motivation among patients with type 2 diabetes and obesity. Overall, while all studies demonstrated positive effects on affective variables, they lacked common characteristics in terms of intervention types and participant profiles (see Tables 1 and 2). Furthermore, the moderate risk of bias of these four studies [54, 60, 63, 64]—stemming from insufficient information on missing data treatment, confounding factors, participant representativeness, compliance, and baseline physical activity status—casts doubt on the reliability of these findings. With the exception of a few studies [52, 60], the remaining studies with non-significant findings generally relied on interventions that lacked specific techniques to enhance affective variables. For instance, while motivational counselling may be effective for promoting intrinsic motivation or PA behaviour change [83, 84], it often falls short in improving affective variables related to PA [83, 84], such as exercise enjoyment [57, 58] or affective valence [55].

Path B: Relationship Between Affective Variables and Physical Activity Behaviour

Four studies (31%) reported a significant association between affective variables and PA behaviour [55, 58, 60, 64], identifying positive correlations between exercise enjoyment and both exercise adherence and daily MVPA levels, as well as between positive affective associations and daily PA. These findings are consistent with previous systematic reviews and meta-analyses in healthy samples, which suggest a positive association between enjoyment and PA behaviour in youth [85] and adults [32]. Additionally, non-significant results from McAuley et al. [55], which showed that affective responses following exercise sessions were not associated to exercise adherence, correspond with previous experimental and observational studies [33]. For instance, Rhodes and Kates' systematic review [33] reported that only affective responses experienced during PA, rather than after, were significantly associated with PA behaviour. However, despite these significant results, concerns arise regarding the reliability of the reported associations due to high and moderate risks of bias in Pinto et al. [58] and McAuley et al. [55], as well as moderate quality issues in Van Wasshenova et al. [60] and Hagberg et al. [64]. These concerns stem from insufficient participant representativeness, compliance data, and details on initial PA status and exercise dosage, which ultimately limit the confidence in these findings.

Path D: Affective Variables as Potential Mediator of Physical Activity Interventions

Among the five studies that conducted formal mediation analyses (i.e., directly tested) [57, 58, 60-62], only one reported a significant mediating effect of exercise enjoyment on the relationship between the intervention and self-reported exercise behaviour [58]. Additionally, two studies suggested potential non-formal (i.e., not directly tested) mediating effects of exercise enjoyment and intrinsic motivation on physical activity behaviour [54, 64]. Interestingly, Pinto et al. [58] demonstrated a significant mediating effect compared to a similar previous study [57]. This finding may be attributed to the improved intervention design in the 2023 study [58], which included prolonged regular feedback and additional weekly tailored motivational messages designed to motivate, prompt and reinforce continued PA. Thus, it is possible that continuous motivational messages and prompts may increase enjoyment of exercise [86], which in turn may favor PA engagement [16, 32, 85]. Despite significant findings, both Pinto et al. [58] and Hagberg et al. [64] exhibited risks of bias and moderate quality, limiting the reliability of conclusions regarding the moderating role of affective variables on the effectiveness of PA behaviour interventions in people with chronic diseases.

Behaviour Change Techniques Across Interventions

Overall, studies demonstrating significant effects of interventions on PA behaviour employed twice as many BCTs compared to those reporting non-significant effects (Table 2), with "action planning" consistently featured across these studies. These findings align with previous systematic reviews indicating that this BCT is a frequently used and effective BCT for improving PA behaviour in individuals with chronic diseases [87-89]. For instance, Willett et al. [87] identified "action planning" as one of the most frequently employed BCTs in interventions targeting PA behaviour in patients with lower limb osteoarthritis. In contrast, studies reporting significant effects on affective variables utilised fewer BCTs than those showing non-significant effects. Notably, no BCT was common across all these studies, with only "action planning" appearing in more than one study [54, 64] (Table 2). These results differ from a prior meta-analysis that found "prompt/cues" and "social comparison" to be moderators of intervention effectiveness on affective variables [86]. Furthermore, "action planning" was the only BCT consistently employed across all three studies, supporting earlier systematic reviews that emphasise its effectiveness in enhancing PA behaviour among people with chronic diseases [87-89].

Comparisons with other studies are challenging, as the only meta-analysis examining the mediating effects of affective variables in PA behaviour change interventions aggregated various types of affective variables in its analyses (e.g., affective responses, affective attitudes, and remembered pleasure) [90]. Nonetheless, at least two factors may elucidate the effect of "action planning" on enjoyment and intrinsic motivation in individuals with chronic diseases. First, this BCT could assist participants in selecting optimal conditions for engaging in PA, such as more enjoyable times, locations, or exercise partners, thereby fostering a pleasant experience [91]. These elements collectively contribute to a more enjoyable experience and enhanced motivation to engage in PA. Second, a recent literature review highlighted the positive impact of action planning on self-efficacy regarding PA [92]. It has been suggested that self-efficacy may influence certain affective variables in individuals with chronic diseases, such as their immediate affective responses to PA [40]. Thus, it is plausible that "action planning" may impact PA enjoyment through its influence on self-efficacy.

Limitations, Strengths and Future Research Directions

This review presents several limitations that warrant consideration. First, the low number of studies and the significant heterogeneity regarding the BCTs employed, population characteristics, PA behaviours, affective variables, and methods of outcome measurement across the studies prevented us from performing the planned meta-analysis. Second, the initial stage of the screening process was conducted solely by LF, who reviewed the titles and abstracts of the studies. This approach may have increased the risk of excluding articles that could have been relevant to the review [96]. To mitigate this concern in future research, it would be beneficial to involve multiple reviewers in the entire screening process, ensuring a more comprehensive and unbiased selection of studies [96]. Third, the considerable heterogeneity in terminology used across the literature to describe affective variables—such as the terms "automatic affective valuation" [22] and "automatic affective evaluation" [24] being employed interchangeably for "implicit affective attitudes"—may have hindered our ability to comprehensively identify all the targeted affective variables in our research. Overall, these limitations leave a clear gap in the extant literature in identifying affective mediators of PA behaviour change interventions in people with chronic diseases. In line with recent editorials [28, 42, 97], we recommend that future interventions focus on the potential mediating role of affective variables—such as affective responses, affect processing, affectively charged motivation, and incidental affect—particularly in populations with chronic conditions.

Nevertheless, this review also possesses several strengths. First, the study employed a rigorous methodology, including preregistration and transparent methods, adhering to gold standards for systematic reviews, which significantly enhances the validity of the findings and ensures the reliability of the conclusions drawn [44]. Second, the review successfully targeted a diverse array of affective variables rather than focusing on just one at a time. This comprehensive approach allows for a more holistic analysis of the mechanisms through which affective factors influence PA, providing valuable insights into the interplay of these variables [25, 28]. Lastly, while affective variables have recently been proposed as crucial elements in regulating PA behaviour, particularly in people with chronic diseases [36-40], this study represents the first systematic review specifically examining the effectiveness of interventions designed to promote PA and affective variables within this population.

Conclusion

This systematic review identifies that, of the 13 studies examined, only three demonstrated the mediating role of affective variables in interventions aimed at improving PA levels in people with chronic diseases. While these findings underscore the potential effectiveness of such interventions, the variability in methodological quality among the studies complicates the ability to draw definitive conclusions. Moreover, it is important to note that the BCTs commonly employed were not specifically designed to target affective variables. This indicates a need for interventions that mobilised tailored BCTs to effectively enhance affective variables related to PA.

Compliance with Ethical Standards

Authors' Statement of Conflict of Interest and Adherence to Ethical Standards Authors Layan Fessler, Hamsini Sivaramakrishnan, Philippe Sarrazin, Nikos Ntoumanis, Silvio Maltagliati, and Boris Cheval declare that they have no conflict of interest. All procedures, including the - informed consent process, were conducted in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000.

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Transparency Statement

The study was preregistered with PROSPERO (CRD42023422213). The analysis plan was registered prior to beginning data collection at PROSPERO (CRD42022354104). De-identified data and materials from this study are available in OSF repository (*URL*). There is not analytic code associated with this study.

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Résumé des résultats principaux de la Contribution n°5

Cette cinquième Contribution révèle que, sur **21 176 études identifiées** dans la littérature scientifique, seules **13** ont testé l'effet d'une intervention visant à améliorer certaines variables affectives et l'activité physique chez des personnes atteintes de maladies chroniques. Dix-neuf techniques de changement de comportement ont été identifiées dans ces interventions, la « planification du comportement » étant la plus fréquemment utilisée.

Parmi les 13, seulement **trois études** ont rapporté un **effet significatif et positif** des interventions sur les **niveaux d'activité physique** chez des adultes atteint·es de maladies chroniques (étape X de l'approche de la médecine expérimentale). De plus, **trois études** ont montré un **effet significatif et positif** des interventions sur les **variables affectives**, telles que les attitudes affectives, le plaisir et la motivation intrinsèque (étape C). Parmi ces études, l'une a également rapporté une **association significative et positive** entre le **plaisir** lié à l'activité physique et les **comportements d'activité physique** (étape B). Enfin, trois études ont suggéré un **effet médiateur positif** du **plaisir** et de la **motivation intrinsèque** sur l'impact des interventions sur les comportements d'activité physique (étape D). Malgré ces résultats prometteurs, la majorité de ces études présentaient des **risques de biais modérés à élevés** et étaient de **mauvaise qualité**, ce qui soulève des préoccupations quant à la fiabilité de ces résultats. De plus, les interventions mobilisaient principalement la stratégie de « planification d'action », une technique de changement de comportement qui n'est **pas spécifiquement conçue pour cibler les variables affectives**.

En conclusion, ces résultats n'apportent que des preuves limitées quant à l'efficacité des interventions ciblant les variables affectives dans la promotion de l'activité physique chez les personnes souffrant de maladies chroniques. Toutefois, le manque d'études rigoureuses dans ce domaine souligne la nécessité de recherches supplémentaires pour mieux évaluer l'impact potentiel de ces mécanismes sur la promotion de l'activité physique chez cette population.

Chapitre 8 **Stratégies d’intervention pour favoriser l’activité physique des personnes atteintes de maladies chroniques**

Comme discuté dans la Contribution n°5, bien que l'intervention sur les variables affectives pour améliorer les comportements d'activité physique chez les personnes atteintes de maladies chroniques semble prometteuse sur le plan théorique, la littérature actuelle manque d’études empiriques pour tester cette approche. Il est donc essentiel d'évaluer leur efficacité potentielle afin de mieux comprendre leur impact et d'optimiser les stratégies d'intervention. Comme nous l’avons décrit dans le Chapitre 6, il est possible de distinguer trois type de stratégies d’intervention ciblant les variables affectives : (1) les stratégies d’intervention « endogènes » basées sur l’expérience directe de l’activité physique, ciblant les réponses affectives, l’affect remémoré et la réponse affective anticipée ; (2) les stratégies d’intervention « exogènes » basées sur l’expérience directe de l’activité physique, visant les mêmes variables affectives ; et (3) les stratégies d’intervention digitales, qui ciblent les réponses automatiques, telles que les tendances d’approche-évitement, sans nécessiter d’expérience physique directe avec l’activité physique. L’originalité de cette dernière réside dans sa capacité à créer artificiellement des associations affectives positives avec l'activité physique, sans nécessiter d’expérience physique directe avec l'activité physique. Ainsi, il serait possible de réentraîner les tendances d’approche-évitement envers l’activité physique d’une personne via des tâches répétitives, sur ordinateur ou tablette.

8.1 Contribution n°6 : stratégie d'intervention digitale ciblant la réponse automatique

Cette sixième Contribution avait pour objectif initial de tester l'effet d'une stratégie d'intervention digitale ciblant les tendances d'approche-évitement en lien avec les niveaux d'activité physique quotidiens chez des patient·es participant à un programme de réadaptation cardiovasculaire ambulatoire. Cependant, en raison d'un taux de participation et de complétion très faible après un an et demi de recrutement (moins de 5 % de l'échantillon prévu), l'hypothèse principale n'a pas pu être testée. Par conséquent, l'étude s'est recentrée sur la rédaction d'un article d'opinion discutant des défis inhérents à ce type d'intervention et des solutions potentielles pour y faire face. Dans cette partie, nous commencerons par présenter une synthèse en français du protocole de l'intervention initiale (le protocole IMPACT), suivie de la Contribution n°6.

L'article de la Contribution n°6 est en cours de préparation pour soumission. L'article a été formaté selon les normes de l'American Medical Association (AMA). Le matériel supplémentaire est disponible en <u>Annexe 4</u>. Le protocole IMPACT a été publié dans le journal *BMJ Open* et accessible gratuitement.

Référence du protocole IMPACT : Cheval, B., Finckh, A., Maltagliati, S., **Fessler, L.,** Cullati, S., Sander, D., Friese, M., Wiers, R.W., Boisgontier, M.P. Courvoisier, D., & Luthy, C. (2021). A cognitive-bias intervention to improve physical activity in patients following a rehabilitation program: protocol for the randomized controlled IMPACT trial. *BMJ Open, 11*, Article e053845. http://dx.doi.org/10.1136/bmjopen-2021-053845

BMJ Open

Cognitive-bias modification intervention to improve physical activity in patients following a rehabilitation programme: protocol for the randomised controlled IMPACT trial

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ABSTRACT

Introduction Being physically active is associated with a wide range of health benefits in patients. However, many patients do not engage in the recommended levels of physical activity (PA). To date, interventions promoting PA in patients mainly rely on providing knowledge about the benefits associated with PA to develop their motivation to be active. Yet, these interventions focusing on changing patients' conscious goals have proven to be rather ineffective in changing behaviours. Recent research on automatic factors (eg, automatic approach tendencies) may provide additional targets for interventions. However, the implementation and evaluation of intervention designed to change these automatic bases of PA are rare. Consequently, little is known about whether and how interventions that target automatically activated processes towards PA can be effective in changing PA behaviours. The Improving Physical Activity (IMPACT) trial proposes to fill this knowledge gap by investigating the effect of a cognitive-bias modification intervention aiming to modify the automatic approach towards exercise-related stimuli on PA among patients.

Methods and analysis The IMPACT trial is a single-centre, placebo (sham controlled), triple-blinded, phase 3 randomised controlled trial that will recruit 308 patients enrolled in a rehabilitation programme in the Division of General Medical Rehabilitation at the University Hospital of Geneva (Switzerland) and intends to follow up them for up to 1 year after intervention. Immediately after starting a rehabilitation programme, patients will be randomised (1:1 ratio) to receive either the cognitive-bias modification intervention consisting of a 12-session training programme performed over 3 weeks or a control condition (placebo). The cognitive-bias modification intervention aims to improve PA levels through a change in automatic approach tendencies towards PA and sedentary behaviours. The primary outcome is the sum of accelerometer-based time spent in light-intensity, moderate-intensity and vigorous-intensity PA over 1 week after the cognitive-bias modification intervention (in minutes per week). Secondary outcomes are related to changes in (1) automatic approach tendencies and self-reported motivation to be active, (2) physical health and (3) mental health. Sedentary behaviours and self-reported PA will also be examined. The main time point of the analysis will be the week after the end of the intervention. These outcomes will also be assessed during the rehabilitation programme, as well as 1, 3, 6 and 12 months after the intervention for secondary analyses.

Ethics and dissemination The study will be conducted in accordance with the Declaration of Helsinki. This trial was approved by the Ethics Committee of Geneva Canton, Switzerland (reference number: CCER2019-02257). All participants will give an informed consent to participate in the study. Results will be published in relevant scientific journals and be disseminated in international conferences.

Trial registration details The clinical trial was registered at the German clinical trials register (reference number: DRKS00023617); Pre-results.

Strengths and limitations of this study

- ► The randomised controlled Improving Physical Activity trial will test the effects of an intervention based on cognitive-bias modification to improve physical activity among patients following a rehabilitation programme.
- ► Physical activity, sedentary behaviours, physical health and mental health will be measured at multiple time points over 1 year.
- ► The findings from this well-powered study will provide evidence-based recommendations for clinical interventions aiming to promote physical activity among patients in rehabilitation.
- ► The reliance of a single-centre trial and the selection bias due to lost to follow-up and the volunteer participation are keys limitations that may reduce our ability to generalise the results to other populations.

INTRODUCTION

The health benefits of physical activity (PA) are well established and extensive. PA can

Introduction

Les bénéfices de l'activité physique (AP) pour la santé sont largement établis et incluent la réduction des risques de maladies chroniques telles que les maladies cardiovasculaires, les cancers, l'hypertension, le diabète, l'obésité, et la dépression.[1-9] En outre, sa pratique améliore la qualité de vie, la santé mentale et la fonction physique, en particulier chez les patient·es souffrant de maladies chroniques.8, 10-13 Ces avantages ont conduit à considérer l'AP comme un véritable « remède miracle » 9. Cependant, malgré ces bienfaits, une grande partie de la population, y compris les patient·es atteint·es de maladies chroniques, reste largement inactif·ve.[14-16]

Les professionnel·les de santé ont un rôle unique à jouer dans la promotion de l'AP auprès de leurs patient·es.8 Notamment, les interventions actuelles visent principalement à fournir des informations rationnelles sur les bénéfices de l'AP et à aider les patient·es à établir des objectifs atteignables et à identifier les obstacles à surmonter.[8] Ces stratégies sont fondées sur les théories socio-cognitives, qui postulent que la modification des objectifs conscients et réfléchis entraîne des changements de comportement.[17-21] Bien que ces approches soient efficaces pour influencer les intentions envers l'AP, elles ont souvent un impact limité sur les comportements réels.[22, 23] Il est donc nécessaire de mettre au point de nouvelles interventions ciblant des mécanismes alternatifs.

Les recherches récentes suggèrent que cibler les mécanismes automatiques pourrait offrir de nouvelles pistes d'intervention.[24-28] Par exemple, des études montrent que chez les personnes physiquement actives, les stimuli associés à l'AP attirent l'attention,[29-32] déclenchent des réactions affectives positives[33-36] et activent des tendances d'approche envers l'AP.[37-40] Ces mécanismes automatiques facilitent alors la traduction des objectifs conscients (e.g., être actif·ve physiquement) en comportements d'AP concrets.[38, 41] Chez les patient·es, ces mécanismes peuvent être négativement biaisés par la douleur, la peur ou l'inconfort liés à certains exercices, pouvant expliquer une faible tendance automatique à approcher de l'AP.[42] Ce déséquilibre entre les mécanisme automatiques (e.g., tendances d'approche-évitement) et réfléchis (e.g., intentions) pourrait alors être particulièrement prononcé chez cette population, justifiant ainsi des interventions spécifiques visant à modifier ces mécanismes automatiques.

La « modification des biais cognitifs » (CBM) apparaît alors comme une intervention prometteuse, déjà utilisée avec succès dans le traitement des addictions.[43,44] La CBM consiste à réentraîner les tendances d'approche ou d'évitement automatiques envers certains stimuli à travers des tâches informatisées.[45] Par exemple, des études sur l'alcoolisme ont utilisé cette méthode pour réduire les tendances d'approche envers les images d'alcool, avec des résultats montrant une diminution des taux de rechute de 9 % à 13 % un an après le traitement. [45-48] La CBM a également été appliquée à d'autres troubles comme le tabagisme, l'anxiété sociale et les comportements alimentaires.[49-53] Toutefois, son efficacité clinique a été critiquée, notamment dans les domaines de l'anxiété et de la dépression.[54-59]

À ce jour, seule une poignée d'études ont utilisé la CBM pour modifier les mécanismes automatiques liés à l'AP.[60-63] Notamment, une seule étude a examiné l'impact d'une brève intervention CBM sur les tendances d'approche-évitement envers l'AP chez des jeunes adultes en bonne santé.[63] Les résultats ont montré que les participant·es entrainé·es à approcher des stimuli liés à l'AP passaient plus de temps à faire de l'exercice – dans un contexte de laboratoire – par rapport aux groupes témoins. Ces résultats suggèrent qu'une seule session de CBM pourrait avoir un effet bénéfique sur les comportements d'AP en laboratoire. Toutefois, il reste à déterminer si ces effets se généralisent aux comportements de la vie quotidienne, et si la CBM peut être bénéfique pour les populations de patient·es, qui pourraient tirer un avantage particulier de cette approche.

Objectifs

En résumé, bien que des recherches récentes mettent en lumière l'importance de cibler les mécanismes automatiques liés à l'AP, l'efficacité des interventions visant à modifier ces mécanismes dans le but de favoriser les comportements d'AP reste insuffisamment explorée. Par conséquent, l'objectif principal de l'étude *Improving Physical Activity* (IMPACT) est d'examiner l'efficacité d'une intervention de CBM visant les tendances d'approche envers des stimuli liés à l'AP chez des patient·es d'un programme de réadaptation cardiovasculaire. Cette intervention sera menée dans le cadre d'un essai contrôlé randomisé de phase 3, en triple aveugle, avec un groupe placebo. Les objectifs secondaires consistent à évaluer l'effet de cette intervention de CBM sur les changements des (1) tendances d'approche automatiques envers l'activité physique et la motivation auto-rapportée à être physiquement actif·ve, (2) la santé physique et (3) la santé mentale. Nous émettons l'hypothèse que l'intervention CBM sera associée à des niveaux plus élevés d'AP (pré-intervention vs 1 semaine après l'intervention) (H_1). De plus, nous supposons que l'intervention CBM augmentera les tendances d'approche automatiques envers l'AP (H_{2a}), mais réduira les tendances d'approche automatiques envers les comportements sédentaires (H_{2b}). Enfin, nous prévoyons que l'intervention CBM améliorera la santé physique et mentale des patient·es (H_3). Toutes ces hypothèses seront également testées au cours du programme de réadaptation ainsi qu'à 1, 3, 6 et 12 mois après l'intervention (analyses secondaires).

Procédure

L'étude IMPACT est un essai contrôlé randomisé de phase 3, mené sur un seul site clinique et en triple aveugle. Il débutera en janvier 2022 et se terminera en janvier 2024, dans le service 3DK de la Division de Réhabilitation Médicale Générale des Hôpitaux Universitaires de Genève. Ce service prend en charge des patient·es après hospitalisation pour diverses raisons médicales, offrant un traitement multidisciplinaire, mais sans se concentrer spécifiquement sur l'engagement des patient·es dans l'AP. Les patient·es éligibles seront aléatoirement assigné·es à l'un des deux groupes : intervention CBM ou condition de contrôle actif (placebo), selon un rapport 1:1 (Figures 1). L'étude respecte les recommandations des Standard Protocol Items : Recommendations for Interventional Trials.[64]

Critères d'éligibilité

Les participant·es remplissant tous les critères d'inclusion sont éligibles pour l'étude. La présence de critères d'exclusion entraînera l'exclusion du·de la participant·e. Les critères d'inclusion sont les suivants : (a) patient·es pris·es en charge dans l'unité 3DK de la Division de Réadaptation Médicale Générale ; (b) âgé·es de 18 ans ou plus ; (c) capables de respecter le protocole de l'étude ; (d) aptes à fournir un consentement écrit pour participer à l'étude. Les participant·es seront exclu·es si elles et ils présentent une contre-indication à l'AP en raison de leur état de santé.

Recrutement et consentement à la participation

Tous·tes les patient·es entrant dans le programme de réhabilitation au service 3DK des Hôpitaux Universitaires de Genève, entre janvier 2022 et janvier 2024, seront contacté·es lors de leur première consultation avec le·la médecin chef·fe. Une feuille d'information détaillant l'objectif de l'étude IMPACT sera remise, suivie d'une explication par les investigateur·trices concernant la nature de l'étude, ses objectifs, les procédures, ainsi que les risques et bénéfices potentiels. La participation est entièrement volontaire, et les participant·es pourront se retirer à tout moment sans impact sur leurs soins. Des informations sur la possibilité d'examen des dossiers médicaux par des personnes autorisées seront également fournies pour garantir la transparence et la confidentialité. Les participant·es auront 24 heures pour lire les documents d'information et de consentement, après quoi le consentement formel sera requis avant toute procédure de l'étude. Un premier questionnaire sera ensuite complété pour évaluer les critères d'exclusion et d'inclusion, administré électroniquement via le logiciel REDCap (https://www.project-redcap.org/), et les attentes des patient·es vis-à-vis de l'intervention seront également mesurées. La Figure 1 présente une vue globale du protocole.

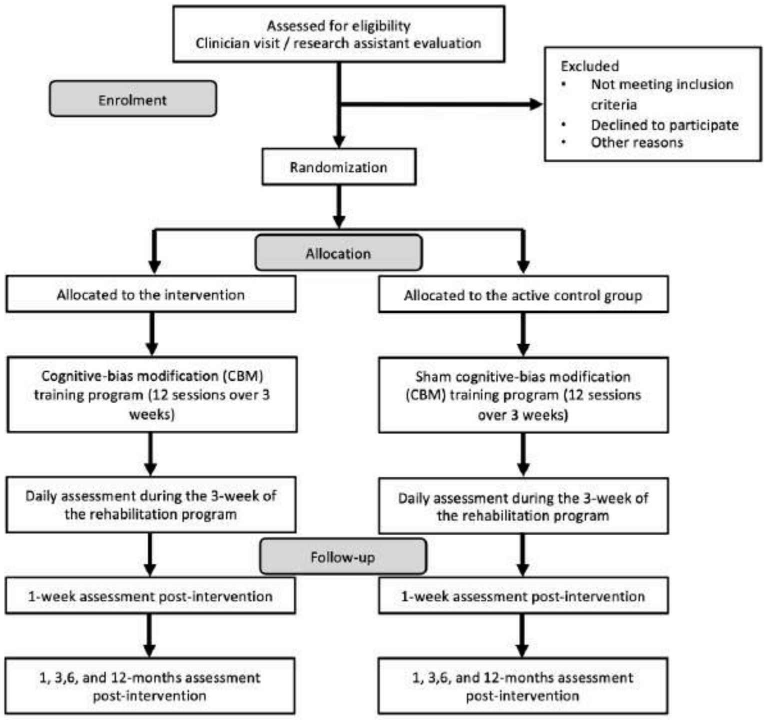
Taille de l'échantillon

Le calcul de la taille d'échantillon est détaillé dans Cheval et al. (2021). Un minimum de 252 patient·es (126 par groupe) serait nécessaire pour démontrer l'efficacité de l'intervention sur l'AP mesurée par appareil pendant la semaine suivant l'intervention, avec une probabilité d'erreur de type I <5% et une probabilité d'erreur de type II <10%. Nous anticipons une perte de suivi de 10 % à 20 % une semaine après l'intervention, et une perte de 30 % à 40 % sur un an. Ainsi, un minimum de 352 patient·es sera recruté.

Adhésion des patient·es à l'essai IMPACT

L'adhésion des patient·es au programme d'entraînement sera enregistrée dans un formulaire de rapport de cas électronique via REDCap,[67] en documentant si les sessions prévues sont complétées et les raisons en cas de non-complétion. Pour assurer un suivi complet des participant·es à 1, 3, 6 et 12 mois après l'intervention, un·e assistant·e de recherche contactera les participant·es par téléphone deux semaines avant chaque mesure de suivi. En cas d'absence de réponse, jusqu'à deux appels supplémentaires seront effectués. Si aucune réponse n'est obtenue, cette mesure sera considérée comme manquante. Les patient·es avec des données manquantes pour une vague seront recontacté·es lors des vagues suivantes.

Figure 1. Protocole de l'étude IMPACT



Interventions dans l'étude de réhabilitation cardiovasculaire

Tous·tes les patient·es nouvellement admis·es assistenterons à une réunion sur les bienfaits de l'AP pour la santé. Les assistant·es de recherche appliquerons la méthode « Demander-Évaluer-Conseiller » *(Ask-Assess-Advise)*[8] pour favoriser les changements de comportement liés à l'AP. De plus, chaque patient·e recevra une montre de suivi Polar, offrant un retour personnalisé sur leur activité physique et leurs comportements sédentaires pour renforcer leur motivation à être actif·ves. Cette approche permettra également d'évaluer les effets supplémentaires de l'intervention de CBM.

Groupe d'intervention

Les participant·es suiveront un programme de 12 session réparti sur 3 semaines (4 sessions par semaine), utilisant une version adaptée de la *« Visual-Approach/Avoidance-by-the-Self Task »* (VAAST)[68]. Contrairement à une étude précédente qui s'appuyait sur une tâche de CBM d'instructions explicites[63] (e.g., « approchez les images représentant des comportements d'AP »), les participant·es de l'étude IMPACT devront réagir à des images de comportements actifs ou sédentaires selon leur format (i.e., portrait ou paysage ; e.g., « approchez les images en format portrait ») en appuyant sur des touches pour s'approcher ou s'éloigner des images (Figure 2). Ce type de tâche évite de fournir des instructions explicites, ce qui permet de passer de la simple mesure des tendances d'approche-évitement à leur manipulation, sans que les participant·es n'en aient conscience. Les patient·es devront approcher 90 % des images d'AP et éviter 90 % des images sédentaires, rendant l'entraînement moins évident. Chaque session comprendra 144 essais d'une durée totale d'environ 10 minutes, suivie d'une évaluation de 96 essais pour mesurer les tendances automatiques d'approche et d'évitement.

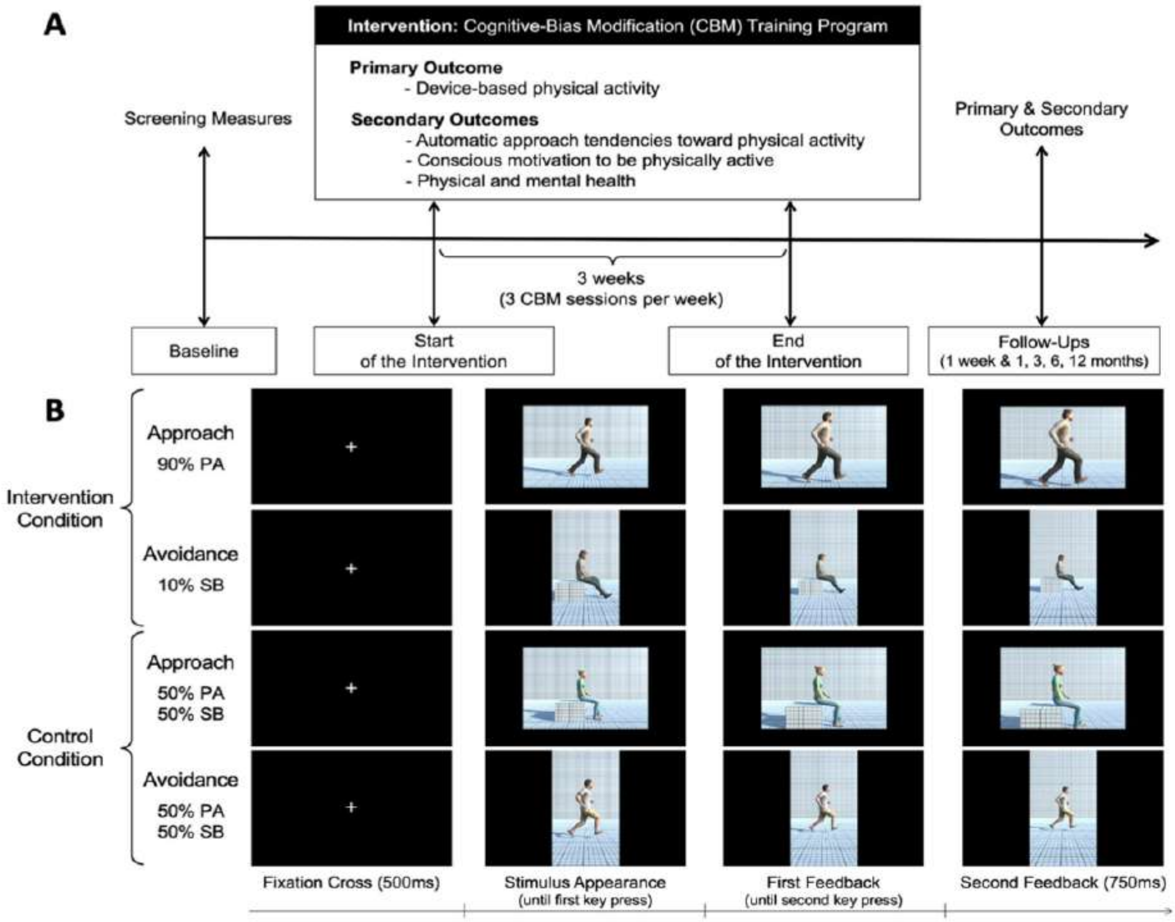
Groupe contrôle

Dans le groupe placebo, les participant·es ne seront pas spécifiquement entrainé·es à approcher les comportements actifs ou à éviter les comportements sédentaires. Les sessions contiendront également 144 essais, mais le nombre de réponses d'approche et d'évitement pour les comportements actifs et sédentaires sera égal. L'utilisation d'un placebo permettra de s'assurer que les effets observés sont liés au contenu spécifique de l'entraînement et non à une simple exposition répétée à des stimuli liés à l'AP ou aux comportements sédentaires.

Résultat principal

Le résultat principal sera la somme du temps passé à pratiquer des AP de faible, modérée et élevée intensité mesurée par accéléromètre (Actigraph GT3X+; Pensacola, USA) sur une semaine après l'intervention de CBM, exprimée en minutes par semaine. De plus, les participant·es seront invités à porter l'accéléromètre pendant une semaine aux mois 1, 3, 6 et 12 après l'intervention. Les données seront incluses si le temps de port est d'au moins 10 heures par jour et si au moins 4 jours remplissent ces conditions.[68, 69]

Figure 2. Conception de l'étude et tâche de modification des biais cognitifs (CBM)



Note : (A) Conception de l'étude. (B) Illustration de la tâche de CBM. Dans la tâche de CBM, les participant·es sont invité·es à s'approcher ou à éviter l'image apparaissant sur l'écran en fonction de son format (i.e., portrait ou paysage, contrebalancé entre les participant·es). Les participant·es doivent s'approcher de l'image dans les conditions d'approche et éviter l'image dans les conditions d'évitement. PA, activité physique ; SB, comportement sédentaire.

Résultats secondaires

Les résultats secondaires incluront les changements dans (1) les tendances d'approche-évitement et la motivation auto- déclarée à être actif·ve physiquement, (2) la santé physique et (3) la santé mentale. Les comportements sédentaires et l'AP auto-déclarée seront également examinés.

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Anatomy of a Failure: Can a Cognitive-Bias Modification Intervention Improve Daily Physical Activity in Patients Following a Cardiac Rehabilitation Programme?

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Abstract

Objectives. Regular physical activity (PA) is crucial for the rehabilitation of cardiac patients. However, many exhibits low levels of PA. In January 2022, we launched the Improving Physical Activity (IMPACT) trial, a randomised controlled trial at the University Hospital of Geneva. The trial aimed to promote PA (i.e., primary hypothesis) in cardiac patients by improving automatic approach tendencies towards exercise-related stimuli using a cognitive bias modification (CBM) intervention. However, over the course of 2 years, we encountered significant challenges in patient recruitment and adherence, compromising the trial's success. This report presents evidence of low engagement and adherence in the IMPACT trial, explores potential reasons for these challenges, and suggests strategies to improve these key prerequisites for the success of such interventions.

Results. Of the 352 patients initially needed, only 68 patients or 19% of the planned sample were enrolled. Among these, 35 were assigned to the intervention group and 33 to the placebo group. Adherence, defined as the completion of at least 3 CBM sessions over 6 weeks, was 71% in the intervention group and 55% in the placebo group. This resulted in adherence by only 25 patients in the intervention group and 18 in the placebo group. Additionally, only 10 patients in the intervention group and seven in the placebo group participated in accelerometer-based PA measurements during the week following discharge. This represents ~25% of adherent patients and a mere 5% of the planned sample size. One possible explanation for the low adherence is that some patients found the task tedious and pointless.

Conclusion. The IMPACT trial's inability to recruit and retain sufficient participants prevented the evaluation of its effectiveness in promoting PA among cardiac patients. This failure underscores the need to address issues such as patient perception of task relevance and engagement in future studies. Recommendations for enhancing patient recruitment and adherence to PA interventions are discussed, aiming to improve the effectiveness of rehabilitation programmes.

Keywords: Exercise, automatic processes, dual-model theory, cardiovascular disease, approach-avoidance tendencies

Introduction

The Importance of Promoting Physical Activity Among Patients

Promoting physical activity (PA) in patients is critical, as regular PA is associated with significant health benefits, including reduced risk of mortality, lower recurrent cardiac events and hospitalizations, and improved quality of life.[1-3] Despite these benefits, many patients exhibit low levels of PA, and previous interventions have failed to produce sustained behavioural changes.[4-6] Therefore, designing, implementing to promote PA, and evaluating innovative interventions is essential. Recent research has suggested that targeting the automatic precursors of PA, such as automatic approach tendencies, may offer a promising avenue for enhancing intervention effectiveness.[7] However, to our knowledge, no rigorous randomised controlled trials have been conducted to assess the effectiveness of these interventions in patient populations. The Improving Physical Activity (IMPACT) trial was developed to address this gap in the literature.[8]

The Improving Physical Activity Trial

The protocol of the IMPACT trial, the full rationale, and the planned analyses are described in detail elsewhere.[8] In brief, the IMPACT trial was designed to directly target approach-avoidance tendencies toward exercise-related stimuli using a cognitive-bias modification (CBM) intervention for patients enrolled in a cardiac rehabilitation programme. The CBM intervention took place at the University Hospital of Geneva. It initially consisted of a training programme of 12 sessions over 3 weeks (i.e., an average of four sessions per week) using a Visual Approach/Avoidance by the Self Task (VAAST[9]). However, due to changes in the hospital unit, the participant pool was reoriented to focus on ambulatory patients with a cardiac rehabilitation programme duration of 6 weeks. Consequently, the intervention was adjusted to 12 sessions over six weeks (i.e., two sessions per week). In the VAAST, patients responded to the format (i.e., portrait vs landscape format) of images depicting PA or sedentary behaviours by pressing a button on a touchscreen tablet to move forward or backward in the image, thereby approaching or avoiding the images. Patients were instructed to approach the image when it appeared in a portrait format and to avoid the image when it appeared in a landscape format, with the rule counterbalanced across participants.

In the intervention group, patients received training in which 90% of images depicting PA were presented in the approach format (and 10% in the avoidance format), while 90% of images depicting sedentary behaviours were presented in the avoidance format (and 10% in the approach format). In contrast, the comparator group (placebo; sham controlled) approached and avoided PA and sedentary behaviours equally often (50% in the approach format and 50% in the avoidance format), so they were not specifically trained to approach PA and to avoid sedentary behaviours compared to patients in the intervention group. At the end of the 6 weeks of rehabilitation, patients were asked to wear an accelerometer over 1 week to measure time spent in moderate-to-vigorous PA, which serves as the primary outcome of the IMPACT trial.

The primary objective of the IMPACT was to examine the effectiveness of this CBM intervention on PA levels in patients following a rehabilitation programme. The main hypothesis was that the CBM intervention group would show higher levels of PA during the week following rehabilitation discharge compared to the placebo intervention group.

The Acknowledgement of a Failure

Although CBM interventions have shown some efficacy in addressing other health-related behaviours, such as alcohol use, smoking, and dietary behaviors,[10-14] the IMPACT trial faced significant challenges. In particular, difficulties in recruitment and adherence to the CBM intervention hindered its success. Due to the low number of patients who adhered to the protocol and wore an accelerometer for 1 week (i.e., N = 17, less than 5% of the planned sample), the hypothesis could not be adequately tested. Therefore, the main objective of the present article is to report on the low patient engagement and adherence to this type of intervention in patients, explore reasons for this, and suggest strategies to improve adherence to such protocols.

Methods

In this Methods section, we describe only the key indicators used to demonstrate that the IMPACT trial failed to enrol and retain a sufficient number of patients.

Measures

Inclusion Rate. The inclusion rate was defined as the difference between the number of patients who attended the first meeting with the research assistant and the number of participants who agreed to participate in the IMPACT trial.

CBM Training Adherence Rate. The adherence rate to the CBM intervention was defined as the percentage of patients enrolled in the IMPACT trial who completed the minimum number of training sessions (i.e., three) over the six weeks.

PA Adherence Rate. PA adherence was defined as the percentage of patients with sufficient adherence to CBM training who completed PA measures in the week following the rehabilitation programme.

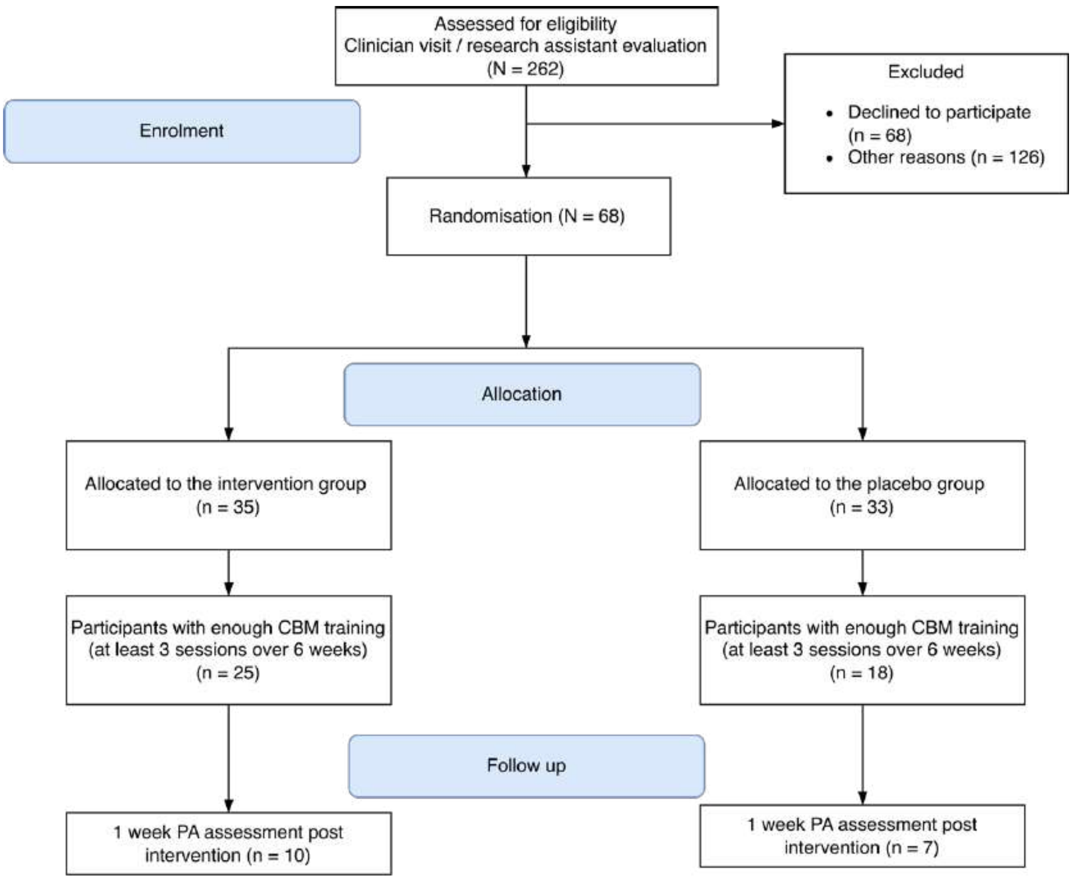
For each of the 3 indicators, we compared the sample size achieved to the planned sample size of 352 to test our primary hypothesis. This was done to estimate the gap between the planned and actual sample sizes. In addition, although the intervention and placebo groups were designed to ensure their equivalence (i.e., the only difference is based on the 90/10 versus 50/50 ratio of approach and avoidance PA and sedentary behaviour in the task), we also describe the results for all of these indicators separately by group.

Patients' Spontaneous Opinions About the Task. Research assistants were asked to note any patient complaints about the IMPACT protocol, with particular attention to the evaluation of the approach-avoidance training task.

Results

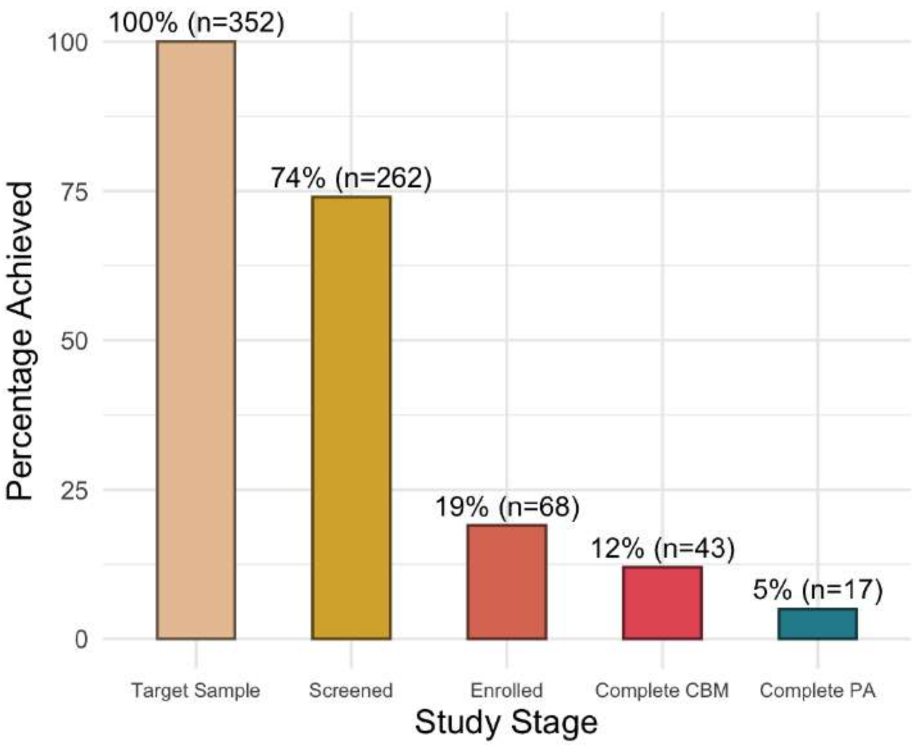
In terms of enrolment, out of the 262 patients who attended the initial meeting over the first 18 months after the trial launch, 68 patients (26%) agreed to participate in the IMPACT study. Regarding adherence to the CBM training, 43 out of the 68 patients who started the protocol (63%) completed the minimum required three training sessions over six weeks. When it came to adherence to the accelerometer-measured PA, 17 of the 43 patients (40%) who completed the CBM training wore the accelerometers correctly to provide usable data (i.e., ≥4 days in which the wear time is ≥10 waking hours per day over the week[15,16]). As a result, relative to the planned sample size of 352 patients, we reached 19% (n = 68) of the targeted enrolment, 12% (n = 43) for adherence to the CBM training, and a mere 5% (n = 17) for collecting PA data in the week following discharge from the rehabilitation programme (see Figures 1 and 2).

Figure 1. Flowchart of the Study



Abbreviations: CBM, cognitive bias modification; PA, physical activity.

Figure 2. Study Progress Metrics



Abbreviations: Target sample, the intended sample size for the IMPACT trial; Screened, patients who were screened and found eligible for the study; Enrolled, patients who were enrolled in the study; Complete CBM, participants who completed the minimum required CBM training (i.e., three sessions); Complete PA, participants who provided complete physical activity data during the week following discharge from the rehabilitation programme.

We now present the results stratified by group (placebo and intervention). 35 patients (51.5%) were randomised in the intervention group. Regarding adherence to the CBM training, 25 out of the 35 patients who started the protocol (71%) completed the minimum required three training sessions over six weeks. When it came to adherence to the accelerometer-measured PA, only 10 of the 25 patients who completed the CBM training (40%) wore the accelerometers correctly to provide usable data. As a result, relative to the planned sample size of 176 patients per group, the intervention group reached 20% (n = 35) of the targeted enrolment, 14% (n = 25) for adherence to the CBM training, and a mere 6% (n = 10) for collecting PA data in the week following discharge from the rehabilitation

33 patients (48.5%) were randomised in the placebo sham controlled group. Regarding adherence to the CBM training, 18 out of the 33 patients who started the protocol (55%) completed the minimum

required three training sessions over six weeks. When it came to adherence to the accelerometer-measured PA, 7 of the 18 patients who completed the CBM training (39%) wore the accelerometers correctly to provide usable data. As a result, relative to the planned sample size of 176 patients per group, the placebo group only reached 19% (n = 33) of the targeted enrolment, 10% (n = 18) for adherence to the CBM training, and a mere 4% (n = 7) for collecting PA data in the week following discharge from the rehabilitation

Additional analyses were performed to examine the power achieved with a final sample of 17 patients (n = 10 patients in the intervention group and n = 7 in the placebo group). For a two-tails t-test, an alpha of 0.05, an effect size of d = 0.35, and a total sample size of 17, we can expect an achieved power of 10% (Figure S1).

Finally, research assistants reported several complaints from patients regarding the task. Many expressed skepticisms about its effectiveness, questioning, *"I really don't see how this task can help me to be more active."* Additional feedback highlighted issues of boredom and disinterest, with comments such as, "*It's long and boring," "I'm not interested in doing anything on a tablet,"* and *"The images are depressing; it would be nicer with more colour."*

Discussion

Despite the well-documented health benefits of PA, many patients struggle to meet recommended levels, and current interventions often fall short in effectiveness.[4-6,17] Recent interventions have begun to focus on automatic processes, such as the tendency to approach or avoid exercise-related stimuli, to enhance PA promotion in both the general population and patients.[7,8,18,19] However, there is a lack of rigorous RCTs to test the efficacy of these new approaches. To fill this gap, we initiated the IMPACT RCT in January 2022, with the aim of evaluating the effect of a CBM intervention on modifying automatic approach tendencies towards exercise-related stimuli and increasing PA among patients.[8]

Unfortunately, eighteen months into the trial, we faced significant challenges that ultimately led to its failure. In this discussion, we will outline the extremely low rates of patient engagement and adherence observed, explore the potential reasons for these difficulties, and offer recommendations for future studies to improve patient engagement and adherence to PA interventions (see Table 1 for a summary). We also highlight the specificity of PA behaviours and conclude by emphasizing the importance of acknowledging and addressing research failures. Sharing these lessons with the scientific community is essential to preventing repeated mistakes and developing more effective interventions.

Difficulty with Patient Enrolment: Reasons and Recommendations for Future Studies

The first major challenge we faced was patient recruitment and it is a critical factor in the success of clinical trials.[20] In clinical research, three out of ten studies are abandoned due to insufficient recruitment,[21] and a clinician survey identified it as the most significant difficulty in conducting clinical research.[22] Our initial goal was to recruit a sample of 352 patients to adequately test our primary hypothesis. This number included 252 patients, with a buffer to account for a potential loss to follow-up of 10-20% at 1-week post-intervention. To maintain sufficient statistical power for the one-year follow-up, we also anticipated a dropout rate of 30-40%, resulting in a planned sample size of 352. However, 18 months into the study, we were only able to recruit 68 patients, which was only 19% of the expected sample size. This significant shortfall meant that, even before considering adherence issues, we lacked the statistical power necessary to accurately test our hypothesis.

One explanation for the difficulties in enrolling participants may be that patients perceived the protocol as a research initiative that was not an integral part of their care programme. Because the protocol was not seamlessly integrated into patients' daily routines, it may have seemed less important to them, discouraging participation. Many patients expressed reluctance to take on additional tasks during their rehabilitation, which was likely due to the high level of commitment required by the protocol, including completing questionnaires and attending two training sessions per week.

Table 1. Potential Reasons for Failure and Recommendations for Future Studies

Issue	Reasons	Recommendations
Difficulty with patient enrolment	Protocol perceived as separate from care, high commitment burden.	Integrate the protocol as a central part of rehabilitation.
	Research assistants not fully integrated in the hospital unit.	Ensure research assistants are fully embedded in the healthcare team.
	Inconsistent research assistant availability.	Align training sessions with patient schedules to minimise perceived burden.
	Logistical issues with tablets.	Ensure regular maintenance for all equipment.
Difficulty with patient adherence	Patients perceived the task as useless and boring.	Enhance the perceived value of the task by linking it clearly to PA behaviour and reducing its monotony.
	Lack of perceived connection between the task and its impact on PA behaviour.	Integrate more engaging and intrinsically motivating tasks, such as gamification or consequence-based interventions (e.g., ABC training[27]).
	Task was lengthy, monotonous, repetitive and of low subjective value.	Explore low-friction, automated interventions that minimise participant burden (e.g., Heartphone app[25]).
	Skepticism about the effectiveness of digital interventions.	Employ emerging technologies like virtual reality to create more appealing interventions.
PA as a unique health behaviour	Engaging participants in approach-avoidance interventions may be more challenging for PA compared to behaviours like smoking cessation or dietary restraint.	Develop strategies that seamlessly fit into patients' routines and leverage PA's unique aspects to improve adherence and engagement.
	PA is an adoptive behaviour without clear endpoint, which may lead to reduced motivation.	Implement interventions during actual exercise sessions to associate physical effort with immediate positive affective responses.
	PA requires lifelong engagement and significant effort, differing from abstention-based behaviours.	Explore manipulating internal and/or external components of PA, such as intensity or music.

Abbreviations: ABC, Antecedents Behaviours Consequences; PA, physical activity.

Moreover, the research assistants were not fully integrated into the healthcare team (e.g., did not attend the weekly seminars), which may have created a separation between them and the healthcare professionals responsible for patient care. This separation may have influenced how patients perceived the study's importance and reduced their willingness to incorporate it into their rehabilitation schedules. Additionally, some patients were sceptical about the effectiveness of the intervention and were put off by its digital format, particularly the use of touchscreen tablets. For those who were interested in participating, the limited availability of tablets (only eight in total) posed a logistical challenge, as all devices were sometimes in use when potential participants were available. Furthermore, the research assistants were not always present in the department, making it difficult to maintain consistent communication and support for patients. Collectively, these factors contributed to patients' reluctance to fully commit to the protocol.

Recommendations for potential improvements in enrolment capacity are primarily based on the characteristics identified above. To optimise patient enrolment, we suggest that future studies integrate the protocol as a central, albeit optional, component of the patient's rehabilitation healthcare. It is essential that healthcare professionals working with the patients, such as physicians, sports therapists, and nurses are more actively engaged in the study protocol. Research assistants should be fully integrated into the healthcare team and recognised as essential members by both the healthcare professionals and the patients. Therefore, we speculate that this seamless integration of the protocol and research assistants within the care unit may be essential. For example, ensuring that all training sessions are well integrated into patients' schedules can help reduce the perception of additional burden. The protocol should be presented in such a way that patients feel that participation requires minimal effort and time.

Difficulty with Patient Adherence: Reasons and Recommendations for Future Studies

The second difficulty we encountered was patient adherence to the CBM intervention. Of the 68 patients enrolled in the study, only 43 completed the six weeks of training, and only 17 provided valid accelerometer data for the week following the rehabilitation programme. This lack of adherence, combined with the low enrolment resulted in a severely underpowered study, with an estimated power of 10% instead of the planned 90%.

One possible explanation for this difficulty is that patients found the task to be useless and boring. Some participants reported that they did not understand how completing the task could affect their PA behaviour. This lack of perceived relevance likely decreased their motivation to engage in the task and maintain participation over the six-week period. Additionally, patients frequently expressed that the task felt long and monotonous. The subjective low value of the task likely contributed to reduced patient engagement throughout the rehabilitation period.[23] To increase adherence to training sessions, it is critical to ensure that the subjective value of the task outweighs its associated costs by addressing concerns of boredom and perceived lack of relevance.

Regarding perceived uselessness, it is important to acknowledge that novel interventions, such as those using virtual approaches to PA and avoidance of sedentary behaviour, may be seen as ineffective in promoting behaviour change. This perception may arise from a general underestimation of the impact of conditioning procedures on behaviour, coupled with an overestimation of the ability of individuals to consciously self-regulate and control their actions.[7,24] Addressing this issue is particularly challenging because one of the key advantages of such interventions is their ability to influence behaviour without requiring participants to be fully understand or be aware of the underlying mechanisms.[7]

Perceived boredom can be attributed to at least two key factors: the repetitive nature of the task and the lack of intrinsically engaging content. While reducing the number of repetitions is challenging—especially since they have already been minimised to ensure an adequate dose of intervention—alternative strategies could be explored. For example, the Heartphone mobile application, developed by Conroy and Kim,[25] is an example of such strategy. This app pairs images of PA with positive affective stimuli whenever users interact with their smartphone, fostering an automatic association between PA and positive feelings. This method offers frequent exposure to intervention content without placing additional burden on participants.

To further mitigate boredom, it is important to recognise that highly repetitive tasks can be disengaging, even for short periods of time.[26] One promising solution is to incorporate more intrinsically motivating tasks. For example, the Antecedents Behaviours Consequences (ABC) training task involves participants moving an avatar away from unhealthy choices (e.g., fatty foods, cigarettes, alcohol) and towards healthier alternatives, while participants receiving positive feedback on personally relevant outcomes such as weight loss or improved health.[27] The gamified nature of this task enhances its intrinsic value compared to traditional approach-avoidance tasks.[28] Recent applications of ABC training in PA contexts have shown promise.[18] Additionally, emerging technologies such as virtual reality offer opportunities to create more engaging and intrinsically motivating tasks.[29,30] Consequently, exploring tasks that naturally resonate with participants and leverage automatic responses to exercise-related stimuli represents a valuable avenue for future research.

Physical Activity as a Unique Health Behaviour?

Interestingly, the challenge of engaging and retaining participants in approach-avoidance interventions is less pronounced in trials targeting other health-related behaviours, such as smoking cessation, alcohol reduction, or dietary restraint.[10-14] This discrepancy may be attributed to the unique characteristics of PA compared with other health behaviours. Unlike behaviours that require participants to reduce or eliminate something—such as smoking, drinking, or consuming unhealthy food—PA is an adoptive behaviour that does not have a clear point of failure if not performed at a specific time; it can be resumed at a later point. This inherent flexibility may cause participants to view PA as less urgent, which could diminish their motivation or interest in maintaining consistent engagement.[31,32] Furthermore, PA requires an ongoing, lifelong commitment and substantial effort (at least 150 minutes per week), which is fundamentally different from behaviours that focus on abstaining from undesired actions.[23] For example, trial information about time commitment has been identified by a Cochrane review as a factor influencing patient participation to randomized trials in health care.[33]

Given the unique nature of PA, it is worth considering whether tasks designed to manipulate automatic responses to PA can be as effective as those targeting other health-related behaviours. We believe that interventions integrated into actual exercise sessions may be particularly promising. Such interventions could help individuals associate physical effort with immediate positive affective responses. In support of this notion, recent research has examined how altering the internal and/or external PA environment can enhance positive affective experiences.[34–40] For example, an early-phase study by Fessler et al.[37] investigated whether decreasing exercise intensity at the end of a session could improve participants' remembered pleasure, affective attitudes towards PA, and actual PA behaviours in patients with Parkinson's disease. The findings indicated that reducing intensity at the end of the session improved affective attitudes, although it did not significantly affect remembered pleasure or accelerometer-measured PA. This study is consistent with broader research demonstrating that manipulating the slope of effort intensity during exercise can foster more positive affective experiences.[34–36]

Such interventions may be particularly promising because they can be seamlessly integrated into patients' routines with minimal disruption. The primary focus would be on developing positive affective experiences during PA, thereby promoting favourable automatic responses towards PA behaviour.[41–43] Although, as noted above, the effectiveness of CBM interventions can be enhanced by reducing the burdensome nature of tasks, limiting repetition, and fostering intrinsic motivation, we believe that interventions that directly involve PA behaviours offer a significant opportunity to promote PA among patients. By emphasizing the creation of immediate, positive experiences during PA, these interventions can leverage the unique aspects of PA to increase patient adherence and long-term engagement.[38] This approach addresses the unique challenges and opportunities associated with PA, distinguishes it from other health-related behaviours, and employs innovative, experience-based strategies to optimize outcomes.

Conclusion

Given the critical need to promote PA among patients, who, like the general population, are predominantly physically inactive, the development and evaluation of innovative interventions are essential. The IMPACT trial aimed to test an intervention designed to influence automatic approach-avoidance tendencies towards exercise-related cues, an approach that has been shown to be effective for other health-related behaviours. Unfortunately, the trial faced significant challenges, primarily due to the very low levels of enrolment and adherence to the protocol, which hindered our ability to accurately assess the efficacy of the intervention. In this report, we have examined possible reasons for the low enrolment and adherence rates and have provided recommendations for future trials aimed at promoting PA among patients. Despite the disappointing results of the trial, this report is valuable in identifying potential pitfalls and guiding future research efforts. Our findings highlight the need for interventions that are not only theoretically sound, but also practically engaging and feasible for patients. Future research should prioritise the development of PA interventions that fit seamlessly into patients' lives, increase intrinsic motivation, and provide immediate positive experiences. By learning from our experiences, future studies can better address the challenges of patient engagement and adherence, ultimately advancing effective PA promotion strategies in healthcare settings.

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Availability of Data and Materials

Deidentified data, data management, analysis codes and research materials will be made publicly available on Zenodo (*URL*).

Ethics Approval and Consent to Participate

The present study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Geneva Canton, Switzerland (reference number: CCER2019-02257). Prior to participation in the study, all participants signed an informed consent form.

Consent for Publication

Consent for Publication declaration: not applicable.

Competing Interests

The authors have no conflicts of interest relevant to this article to disclose.

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Résumé des résultats principaux de la Contribution n°6

L'essai contrôlé randomisé IMPACT, lancé en janvier 2022, visait à évaluer l'effet d'une **stratégie d'intervention digitale** qui cible les **tendances d'approche-évitement envers l'activité physique**, sur les niveaux d'activité physique et les tendances d'approche-évitement chez des patient·es en réadaptation cardiovasculaire ambulatoire. Cependant, après deux ans de récolte de données, l'étude a échoué en raison d'un **faible taux de recrutement et d'adhésion** des participant·es. En effet, seulement 19% (n = 68) de l'échantillon prévu a été recruté, 12% (n = 43) ont complété le nombre requis de séances de CBM, et 5% (n = 17) ont fourni des données d'activité physique valides, compromettant ainsi la puissance statistique nécessaire pour tester l'hypothèse principale (i.e., effet de l'intervention sur l'activité physique).

Quatre raisons principales pourraient expliquer le manque d'engagement et d'adhésion au protocole de recherche : (1) la **charge additionnelle** du protocole interventionnel sur la prise en charge hospitalière classique ; (2) la perception de la tâche de CBM comme étant **ennuyeuse** ; (3) un **scepticisme** quant à l'efficacité de la tâche ; (4) un **manque de lien perçu** entre la tâche de CBM et l'activité physique. Pour pallier ces obstacles, nous avons formulé quatre recommandations : (1) **impliquer** de manière plus active le personnel hospitalier dans le protocole d'étude afin d'intégrer les tâches de CBM directement dans l'emploi du temps des patient·es ; (2) intégrer des tâches plus **engageantes et intrinsèquement motivantes**, via notamment la **gamification** ou l'utilisation de la **réalité virtuelle** ; (3) mettre en évidence les **conséquences** de chaque action effectuée dans la tâche, par exemple, l'amélioration de la vitalité après avoir adopté un comportement d'activité physique ; (4) établir un **lien clair** entre la tâche de CBM et les comportements d'activité physique.

8.2 Contribution empirique n°7 : stratégie d'intervention endogène

Cette septième Contribution empirique avait pour objectif de tester l'effet de la manipulation de l'intensité de l'effort à la fin de séances d'APA – une stratégie d'intervention endogène – sur l'affect remémoré associé à ces séances et sur les niveaux d'activité physique quotidiens chez des patient·es atteint·es de la maladie de Parkinson. Cette stratégie repose sur le principe du « pic et de la fin », et principalement son effet de « fin » (Fredrickson, 2000), selon lequel le dernier moment affectif d'une expérience peut influencer l'affect remémoré de cette expérience et, en retour, la probabilité de la répéter. L'impact de l'intervention sur les attitudes affectives et les évaluations affectives automatiques liées à l'activité physique a également été examiné.

Initialement, cette étude devait se dérouler sous la forme d'un essai contrôlé randomisé, comprenant un groupe expérimental et un groupe de contrôle, pour un total de 160 participant·es. Cependant, en raison des difficultés liées à la pandémie de COVID-19, nous n'avons pas pu recruter le nombre prévu de participant·es. Une étude préliminaire a donc été conduite, adaptant la procédure expérimentale et le plan d'analyse à la taille réduite de l'échantillon (N = 7). Les patient·es ont participé à une étude intra-sujets de huit semaines, incluant une séance d'APA hebdomadaire. Au cours des quatre premières semaines, les participant·es ont réalisé quatre séances d'APA à intensité modérée, tout au long de la séance (40 minutes, condition contrôle). Les quatre dernières semaines ont inclus neuf minutes d'exercices de faible intensité ajoutées à la fin de chaque séance (49 minutes, condition expérimentale). Les séances d'APA ont été élaborées en collaboration avec l'équipe médicale de la clinique. L'affect remémoré des séances d'APA a été évalué à la fin de chaque séance par questionnaire auto-rapporté. Les attitudes affectives et les évaluations affectives automatiques envers l'activité physique ont été mesurées avant le début de la première semaine, à la fin de la condition de contrôle et à la fin de la condition expérimentale par questionnaire auto-rapporté et via une tâche numérique de temps de réaction. L'activité physique quotidienne au cours des huit semaines a été mesurée par des accéléromètres et questionnaires auto-rapportés. Les données ont été analysées à l'aide de modèles linéaires à effets mixtes.

Il est important de noter que certaines terminologies employées dans cette contribution peuvent différer de celles utilisées dans ce travail doctoral. Les termes « attitudes affectives implicites » *(implicit affective attitudes)* et « évaluation affective globale de la session » *(global affective evaluation of the session)* mentionnés dans cet article correspondent aux « évaluations affectives automatiques » et à l'« affect remémoré » utilisés tout au long de ce manuscrit, respectivement.

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ARTICLE

All's well that ends well: an early-phase study testing lower end-session exercise intensity to promote physical activity in patients with Parkinson's disease

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Abstract – Decreasing the intensity of exercise at the end of a session has been associated with greater post-exercise pleasure and enjoyment. Here, we investigated whether this manipulation can enhance affective attitudes toward physical activity (PA) and promote PA in patients with Parkinson's disease (PD). Seven patients (72.9 ± 5.6 years, 3 women) were included in an eight-week within-subject study consisting of weekly exercise sessions. The first four weeks were used as a control condition. In the last four weeks, 9 minutes of lower-intensity exercise were added at the end of each session (experimental condition). Results of the linear mixed-effects models showed that the addition of lower-intensity exercise improved the explicit affective attitudes toward PA ($b = 1.00$, 95%CI = 0.36 to 1.64, $P = 0.022$). We found no evidence of an effect on implicit affective attitudes ($P = 0.564$), accelerometer-based PA ($P = 0.417$) and self-reported measures of PA ($P = 0.122$). Although not significant, self-reported PA per day was 36 minutes longer in the experimental than in the control condition. The findings of this early-phase study may suggest that reducing the intensity of an exercise at the end of the exercise sessions enhanced explicit affective attitudes toward PA in patients with PD. Yet, future well-powered and randomized studies are needed to provide more robust evidence.

Keywords: Parkinson's disease, physical activity, effort, affects, peak-end rule

Résumé – Tout est bien qui finit bien : une étude préliminaire testant l'efficacité d'une baisse d'intensité en fin de séance d'exercice pour promouvoir l'activité physique chez des patients atteints de la maladie de Parkinson. La diminution de l'intensité de l'exercice à la fin d'une séance a été associée à un plus grand plaisir après l'exercice. Ici, nous avons cherché à savoir si cette manipulation pouvait améliorer les attitudes affectives à l'égard de l'activité physique (AP) et promouvoir l'AP chez les patients atteints de la maladie de Parkinson. Sept patients (72,9 ± 5,6 ans, 3 femmes) ont été inclus dans une étude intra-sujet de huit semaines comprenant des séances d'exercice hebdomadaires. Les quatre premières semaines ont été utilisées comme condition de contrôle. Au cours des quatre dernières semaines, dix minutes d'exercices de moindre intensité ont été ajoutées à la fin de chaque séance (condition expérimentale). Les résultats des modèles linéaires à effets mixtes ont montré que l'ajout d'exercices de faible intensité a amélioré les attitudes affectives explicites à l'égard de l'AP ($b = 1,00$, 95 % IC = 0,36 à 1,64, $p = 0,022$). Nous n'avons trouvé aucune preuve d'un effet sur les attitudes affectives implicites ($p = 0,564$), l'AP basée sur des accéléromètres ($p = 0,417$) et sur les mesures d'AP autodéclarées ($p = 0,122$). Bien que cela ne soit pas significatif, l'AP journalière autodéclarée était supérieure de 36 minutes dans la condition expérimentale par rapport à la condition contrôle. Les résultats de cette étude préliminaire peuvent suggérer que la réduction de l'intensité d'un exercice à la fin des séances d'exercice améliore les attitudes affectives explicites à l'égard de l'AP chez les patients atteints de la maladie de Parkinson. Cependant, de futures études randomisées et de puissance suffisante sont nécessaires pour fournir des preuves plus solides.

Mots clés : maladie de Parkinson, activité physique, effort, affects, règle du pic et de la fin

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1. Introduction

Parkinson disease (PD) is the second most common neurogenerative disorder worldwide affecting 2–3% of the population aged 65 years or older (Connolly & Lang, 2014; Poewe et al., 2017). This chronic disorder is characterized by motor and non-motor symptoms including tremor, rigidity, slowness of movement, cognitive impairment, mood and affective disorders, as well as depressive symptoms (Chaudhuri, Healy, & Schapira, 2006: Obeso et al., 2017). Accumulating evidence suggests that patients with PD can benefit from physical activity (PA) (Chen, Zhang, Schwarzschild, Hernan, & Ascherio, 2005: Speelman et al., 2011). For example, PA can improve motor performance (Goodwin, Richards, Taylor, Taylor, & Campbell, 2008), cognitive function (Murray, Sacheli, Eng, & Stoessl, 2014), quality of life (van Uem et al., 2018), and depressive symptoms (van Uem et al., 2018). Despite such benefits, many patients with PD do not engage in the recommended levels of PA and are typically less active that the general population (Cavanaugh et al., 2015; Pradhan & Kelly, 2019). Developing interventions promoting PA in this population is thus warranted.

1.1. The theory of effort minimization in PA

Interventions promoting PA in patients with PD are mostly grounded in the dominant socio-cognitive theories (Ellis & Motl, 2013; Krishnamurthi, Fleury, Belyea, Shill, & Abbas, 2020: Speelman, van Nimwegen, Bloem, & Munneke, 2014: van Nimwegen et al., 2013). In short, these theories focus on the reflective precursors of action and argue that changing people's conscious cognitions (e.g., attitudes, intention, self-efficacy, goals) should lead to substantial change in their behaviors (Ajzen, 1991; Bandura, 1997; Prochaska & DiClemente, 1982: Sheeran, Gollwitzer, & Bargh, 2013). Although these interventions have proven to be effective to change PA behavior to some extent (Gourlan et al., 2016), meta-analyses also indicate that these interventions are more effective in changing intentions than actual behavior (Rhodes, Boudreau, Josefsson, & Ivarsson, 2021). Likewise, automatic processes have recently gained traction to shed lights on this intention-behavior gap (Brand & Ekkekakis, 2018; Cheval & Boisgontier, 2021; Conroy & Berry, 2017; Larsen & Hollands, 2022). Notably, an automatic attraction toward effort minimization has recently been proposed to account for the difficulties of the dominant socio-cognitive theories to explain failures in turning intentions to be physically active into behavior (Cheval & Boisgontier, 2021).

Based on a neuropsychological approach to physical effort (Bernacer et al., 2019; Klein-Flügge, Kennerley, Friston, & Bestmann, 2016) anchored in an evolutionary perspective (Cheval, Radel et al., 2018; Lieberman, 2015), the Theory of Effort Minimization in PA (TEMPA; Cheval & Boisgontier, 2021) argues that humans have evolved an automatic attraction toward physical effort minimization, which restrains the engagement in PA. In line with TEMPA, findings of previous research suggested that avoiding stimuli related to effort minimization requires higher inhibitory control than approaching these stimuli (Cheval et al., 2021; Cheval et al., 2020; Cheval, Tipura et al., 2018). Other results showed that the ability to overcome the automatic attraction to effort minimization is essential to the engagement in PA (Bernacer et al., 2019; Cheval, Sarrazin, Isoard-Gautheur, Radel, & Friese, 2015; Cheval, Tipura et al., 2018).

In line with the dual-process models of PA (Brand & Ekkekakis, 2018; Cheval, Radel et al., 2018; Conroy & Berry, 2017), TEMPA argues that the affective evaluation of PA is instrumental to the regulation of this behavior. Specifically, positive affective evaluations (e.g., pleasure) experienced during PA are believed to favor initiation and continuation of PA behavior. Conversely, negative affective evaluations (e.g., displeasure) experienced during PA are believed to hinder initiation and continuation of PA behaviors. In line with these theories, studies showed that affective responses to exercise predict future engagement in PA (Rhodes, McEwan, & Rebar, 2019; Williams & Bohlen, 2019).

According to TEMPA, the lack of engagement in PA results from an inability to overcome the perception of physical effort, an inability that might be particularly pronounced among patients with PD. For example, behavioral apathy, which is often observed in patients with PD, may reflect an inability to accurately perceive physical effort or an altered sensitivity to this effort (Bonnelle, Manohar, Behrens, & Husain, 2016). TEMPA posits that the affective value of PA moderates the perception of effort. Higher positive affective evaluations may reduce the perception of effort associated to a given behavior and, in turn, favor the initiation and continuation of PA behavior. In sum, developing positive affective evaluation of PA through the reduction of the perception of effort may promote PA (Cheval & Boisgontier, 2021).

1.2. The peak-end rule in exercise

Interventions that manipulate the affective evaluation of exercise to promote PA are rare (Conroy & Kim, 2020; Williams, Rhodes, & Conner, 2019), but recent studies have developed such interventions drawing on the peak- end rule (Hargreaves & Stych, 2013; Hutchinson, Zenko, Santich, & Dalton, 2020; Zenko, Ekkekakis, & Ariely, 2016). This rule is based on two mechanisms underlying the affective evaluation of PA. The first mechanism refers to the link between effort intensity and affective evaluation. Higher intensity PA (i.e., above the ventilatory threshold) reduces pleasure and increases displeasure (Ekkekakis, Parfitt, & Petruzzello, 2011). The second mechanism postulates that the global evaluation of an experience mainly depends on the affects experienced during the most intense affective moment of the experience (i.e., « peak ») and at the end of the experience (i.e., « end ») (Fredrickson, 2000; Kahneman, Fredrickson, Schreiber, & Redelmeier, 1993). Combining these two mechanisms, studies have investigated how the dynamic of effort intensity during an exercise session impacts the global affective evaluation of the session. The hypothesis is that lower effort intensity at the end of the session results in a more positive affective remembered experience, which favors a more positive global affective evaluation of PA (i.e., generalization of a specific experience to PA in general).

To the best of our knowledge, only four studies have directly manipulated the dynamics of effort intensity during exercise (Brewer, Manos, McDevitt, Cornelius, & Van Raalte, 2000; Hutchinson et al., 2023; Hutchinson et al., 2020; Zenko et al., 2016). In their study, Zenko et al. (2016) randomly assigned 46 healthy adults into a 15-min exercise session on a recumbent bike either in an increasing or decreasing-intensity condition. Results showed that the decreasing-intensity condition was associated with greater post-exercise pleasure, enjoyment, remembered pleasure (i.e., affective memories of the session), and forecasted pleasure (i.e., anticipation of the affect in a future session). Using a single session or six repeated sessions of resistance training circuit, Hutchinson et al. (2020, 2023) observed similar effects on the remembered and forecasted pleasure, but not on the explicit and implicit affective attitudes toward PA. Finally, Brewer et al. (2000) showed that adding a 5-min period of reduced exertion at the end of a 15-min stationary bicycle session was perceived as less aversive than a 15-minute session alone. In sum, these studies showed that manipulating the dynamic of effort intensity influences the affective evaluation of an exercise session, but evidence that this manipulation can generalize to the global affective evaluation of PA is lacking. Likewise, whether the manipulation of effort can impact subsequent PA behavior remains unknown.

The aim of the present study was to assess whether manipulating the intensity of effort at the end of exercise sessions enhances affective evaluation of PA and promotes daily-life PA behaviors in patients with PD. Based on TEMPA (Cheval & Boisgontier, 2021) and on the peak- end rule (Fredrickson, 2000; Kahneman et al., 1993), we hypothesized that a weekly session for 4 weeks ending with a 9-min bout of light-intensity exercise would result in more positive explicit and implicit affective evaluations of PA compared with a weekly session for 4 weeks without the final 9-min bout (H_1). We also hypothesized that self- reported and accelerometer-based daily-life PA would be higher during the four weeks with than without the final 9- min light-intensity bout (H_2).

2. Materials and methods

Study preregistration, material, and data can be found at https://zenodo.org/record/4742001#.ZAr-FsGZMQM and https://aspredicted.org/see_one.php .

2.1. Deviation from the ethics protocol

In the ethics protocol, we stated that we would use a randomized controlled trial, including an experimental and a control group using a between-subject design. Because of difficulties in patients' recruitment, we changed this strategy to leverage the benefits of a within-subjects design. Specifically, each patient per- formed both the control and experimental conditions in a fixed order. Likewise, we wrote that we would follow the patients the week after the intervention. This follow-up was not performed because of time and resources constraints. We also stated that we would measure the approach-avoidance tendencies toward PA as well as the affective responses, perceived effort, and heart rate during each exercise session. These measures were not implemented because of time and resources constraints. All these modifications relative to the ethics protocol were indicated in the pre-registration.

2.2. Participants

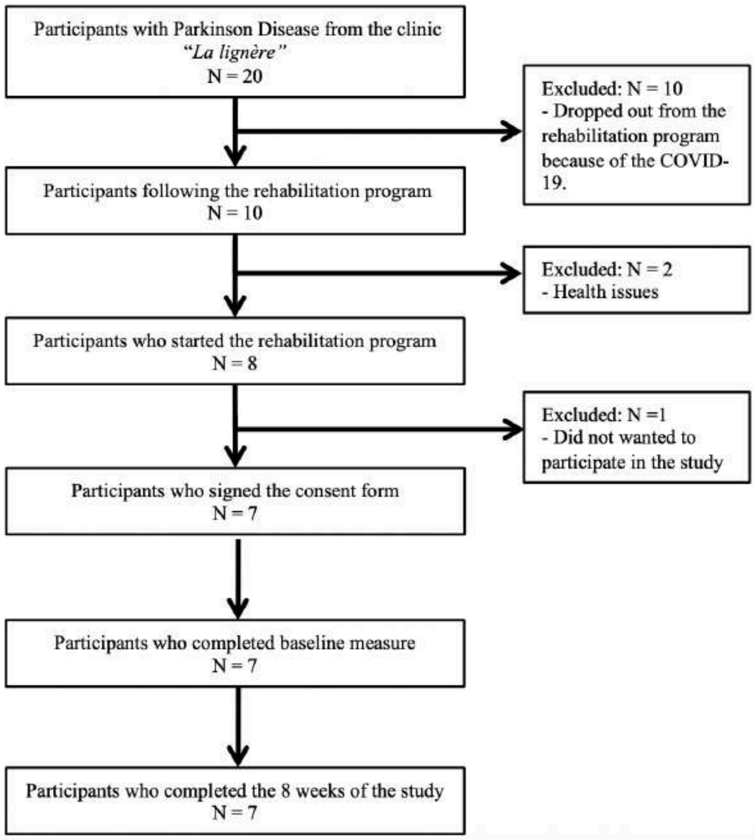
Participants were recruited through the exercise program of a Swiss private clinic in January 2021. To be included in the study, participants should be 18 years of age or older and clinically diagnosed with PD. Participants were excluded if they had contraindications to PA, dementia (Mini-Mental State Examination Score 24; (Folstein, Folstein, & McHugh, 1975) or motor dependence (stage 5 on the Hoehn and Yahr Scale; (Hoehn & Yahr, 1998). All these inclusion and exclusion criteria were checked by the medical staff using patients' clinical records. Given the small number of patients in the department, we initially aimed to recruit as many patients as possible (i.e., n = 20) (Fig. 1). As such, the sample size was limited by resources constraints (Lakens, 2022). The study was approved by the French National Ethics Committee for Research in STAPS (reference number: IRB00012476-2022-08-03-159). All participants signed an informed consent form to participate in the study.

2.3. Procedure

In a within-subjects design, participants were first invited to a clinical visit to provide written informed consent and filled in a self-reported questionnaire about their age, sex, height, and weight, motivation toward PA (i.e., intention, attitudes, and self-efficacy), and usual PA. They also performed a task measuring implicit affective attitudes toward PA (Rebar, Ram, & Conroy, 2015). Participants then completed a four-week exercise program (i.e., control condition) and four additional weeks in which a ten-min exercise bout of light intensity was added (i.e., experimental condition). Exercise sessions were performed once a week for both conditions. The intervention was delivered in the exercise room of the La Lignère Clinic, Switzerland, by the physiotherapists. Implicit and explicit affective attitudes were assessed at baseline, at the end of the control condition, and at the end of the experimental condition. Self-reported and accelerometer-based measures of PA were performed on a daily-basis across the eight weeks.

Figure 1

Flow chart



2.4. Exercise sessions

Each exercise session started with a 15-min warm-up period including light-intensity exercises mobilizing articulations, cardiovascular and muscular systems, gait, and balance. Then, three 9-min bouts of circuit training were performed (see Tab. S1 for more details). Each round was composed of six 1-min bouts of exercise followed by a 30-sec rest period. The circuit included muscle, cardiovascular and balance work at a moderate intensity. In order to ensure the intended exercise intensity for each condition, participants were asked to estimate their perceived effort twice during each 9-min bout using a modified version of the CR10 Scale (Kern & Fautrelle, 2018). Specifically, following the question "What level of effort do you perceive at this very moment?", patients were asked to maintain an effort that matches a rating between a moderate (i.e., 3 on the 10-point scale) and strong (i.e., 5 on the 10-point scale) intensity using the following instruction "Please maintain an effort between 3 (moderate) and 5 (strong). Three refers to an increase in breathing but with the ability to hold a conversation; five refers to a heavier breathing and it becomes difficult to hold a conversation." The last 4weeks of the 8-weeks program, a 9-min exercise bout was added. In this fourth 9-min bout, participants were asked to perform the exercises at an intensity between 1 (very weak; "almost no effort but more difficult than standing still") and 2 (weak; "feels like you can hold it for hours") out of 10. In sum, the total duration of the exercise session was 42 min in the control condition and 51 min (42 min + 9 extra min) in the experimental condition.

2.5. Measures

2.5.1. Usual PA

Usual PA before the onset of the health problem that led to the ambulatory rehabilitation was assessed at baseline using an adapted version of the "Saltin-Grimby PA Level Scale" (Grimby et al., 2015). Respondents could choose between four options used to create four self- reported PA groups: (1) physically inactive; (2) light PA; (3) regular PA and physical training; and (4) regular hard physical training for competition and sports.

2.5.2. Affective attitudes toward PA

These variables were assessed at baseline, at the end of the control condition (i.e., four weeks after the start of the study), and at the end of the experimental condition (i.e., eight weeks after the start of the study).

2.5.2.1. Explicit affective attitudes toward PA

Explicit affective attitudes toward PA were assessed using two items (Rhodes & Courneya, 2003). The stem prior to each item was "Would you say that being physically active is something ...". Participants answered on a seven-point bipolar scale from 1 (unpleasant) to 7 (pleasant) and from 1 (boring) to 7 (fun). Items were averaged to create an overall measure of affective attitudes toward PA (correlation between items = 0.93, 0.73, and 0.88 at baseline, at the end of the control condition, and at the end of the experimental condition, respectively).

2.5.2.2. Implicit affective attitudes toward PA

Implicit affective attitudes toward PA were assessed using an Implicit Association Test (Greenwald, McGhee, & Schwartz, 1998), a response-time categorization task that assesses the relative strength of automatic affective associations between PA and sedentary behavior (see Supplemental Material1 for more details). For each participant, a D-score was calculated on 2 to +2 range to assess negative or positive implicit attitudes toward PA (versus sedentary behavior). D-score ranging from 2 to +2, negative or positive indicating unfavorable and favorable implicit attitudes toward PA (versus sedentary behavior), respectively.

2.5.3. PA behavior

These variables were assessed daily across the eight weeks.

2.5.3.1. Self-reported PA

Self-reported PA during commuting and leisure time was assessed using an adapted version the International PA Questionnaire (IPAQ; Craig et al., 2003). Each week, participants received a notebook and were invited to provide a daily report of the time spent in moderate- to-vigorous PA, walking, and sitting. The time spent walking and moderate-to-vigorous PA was used as an outcome.

2.5.3.2. Accelerometer-based measure of PA

Following recommendations in patients with PD (Mantri, Wood, Duda, & Morley, 2019), a three-axis accelerometer (Actigraph GT3X+; Pensacola, USA) was used to assess PA. Participants were given the accelerometer and related indications on the first exercise session. They were asked to return the accelerometer at the next exercise session, one week later. At the end of each exercise session, participants were given a new accelerometer. One- minute epochs were used for data analyses and non-wear time was defined as ≥59 consecutive minutes of zero counts. Daily data were included if the wear time was ≥10 waking hours per day (Evenson & Terry, 2009). Data were included if ≥4 days met the aforementioned conditions (Matthews, Ainsworth, Thompson, & Bassett Jr, 2002). The time spent in moderate-to-vigorous PA determined through previously validated cut-points (Freedson, Melanson, & Sirard, 1998) in bouts lasting at least 10 min was used as an outcome.

2.5.4. Other measures

Additional measures are described in Supplemental Material 2.

2.6. Statistical analyses

To examine the effect of the intervention (i.e., control versus experimental condition) on the affective evaluation of PA and daily-life PA, linear mixed-effects models (MEMs) were used. MEMs are well-suited to investigate longitudinal data as they allow to handle missing data and to account for the nested structure of the data (i.e., multiple observations from the same individuals over time). Moreover, statistical assumptions associated with MEM can be met even in small data paradigm (Baayen, Davidson, & Bates, 2008; Boisgontier & Cheval, 2016). Regarding statistical power, with a probability of committing a type 1 error <5% (i.e., a-rate of 0.05) and a type 2 error <10% (i.e., power 0.90), a sample size calculation using the G. Power3.1 software (Faul et al., 2007) indicated that a minimum of 32participants were required. Restricted maximum likelihood (REML) was used as it provides less biased estimates of variance components compared with full maximum likelihood (Luke, 2017) particularly in small sample size (McNeish & Stapleton, 2016). Finally, to reduce the inflated type I error rate that results from under-estimated fixed-effects standard errors in small sample size (McNeish & Stapleton, 2016), Kenward-Roger's approximations for degrees of freedom were used to calculate P-values (Kenward & Roger, 1997). An estimate of the effect size was reported using the marginal pseudo R^2 computed using the MuMIn package (Barton, 2018). Statistical assumptions associated with MEM (normality of the residuals, homogeneity of variance, linearity, multi- collinearity, and undue influence) were checked and met for all models. The analyses were conducted in R with the lme4 and lmerTest packages (Bates, Mächler, Bolker, & Walker, 2014; Kuznetsova, Brockhoff, & Christensen, 2017; R Core Team, 2019). To reduce convergence issues, each model was first optimized using the default BOBYQA optimizer (Powell, 2009), followed by the Nelder-Mead's optimizer (Nelder & Mead, 1965), the nlimb optimizer from the optimx package (Nash & Varadhan, 2011), and then the L-BFGS-B optimizer (see Cheval et al., 2021; Cheval et al., 2020; Frossard & Renaud, 2019, for similar procedure).

To examine the evolution of explicit and implicit affective attitudes as a function of the conditions, we used a linear MEM that included condition (baseline versus control versus experimental conditions) as a fixed factor. The MEM specified participants as a random factor and included random effects for the conditions. The models were adjusted for usual PA but not for age, sex, or body mass index because of the low number of participants.

To examine the evolution of self-reported and accelerometer-based measures of PA as a function of the conditions, we used a linear MEM that included the condition (i.e., control condition versus experimental conditions) as a fixed factor and specified the same random structure as the one for the models testing the evolution of affective attitudes. The models were adjusted for usual PA and for the day of the week (i.e., Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday).

2.7. Post-hoc power analysis

Because of the small sample of our study (n = 7), we conducted a post-hoc power analysis using G.Power 3.1 in order to evaluate the achieved power of our study (Faul, Erdfelder, Lang, & Buchner, 2007). We used a within factors ANOVA based on a medium effect size (Cohen's f = 0.25; based on [Hutchinson et al., 2023]), a probability of committing a type 1 error <5%, 2 (PA measures) and 3 (implicit and explicit affective attitudes) groups and measurements, and a correlation among repeated measures of 0.80. The post-hoc power calculation indicated a power of 40% for PA behavior and 46% for explicit and implicit attitudes.

3. Results

After the descriptive statistics, the results are reported in two sections: the first describes results of analyses on explicit and implicit affective attitudes, and the second describes results of analyses on self-reported and accelerometer-based measures of PA. The effect of the experimental condition on the evaluation of the exercise sessions is presented in Supplemental Material 3.

3.1. Descriptive statistics

Table 1 summarizes the characteristics of the participants stratified by condition (i.e., baseline versus control versus experimental). The final sample included 7 patients with PD (72.9 ± 5.6 years, 3 women, 22.8 ± 2.9 body mass index) (Fig. 1). Most patients did regular PA before the onset of their disease (two participants were in stage 3 "regular PA" and five were in stage 2 "some PA" of the Saltin-Grimby Questionnaire). Descriptive statistics stratified by week are provided in Supplemental Table S2.

Table 1

Descriptive statistics across the conditions

	Conditions								
	Baseline			Control			Experimental		
N = 7	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Demographics									
Age (years)	72.9	5.6	63-78						
Gender (number; % women)	3	42.8%							
Body mass index (Kg/M^2)	22.8	2.9	17-26						
Usual level of PA									
(number; %)									
Some physical activity	5	71.4%							
Regular physical activity	2	28.6%							
Stage of motor dependence (number; %)									
Stage 3	7	100%							
Affective attitudes toward PA									
Explicit attitudes	5.9	1.1	4.5-7	5.2	0.6	4.5-6	6.2	0.9	5-7
Implicit attitudes	.58	1.0	-.6-1.56	.89	.99	-.68-1.65	.81	.71	-.56-1.62
PA behavior (min per day)									
Self-reported measure				148.6	80.1	57-262	199.3	111.4	5-359
Accelerometer-based measure				18.5	18.9	3-52	20.9	23.2	5-64
Evaluation of each exercise session									
Perceived effort				3.8	0.7	3-6	3.6	0.5	3-5
Affective evaluation				6.7	1.5	0-10	6.8	2.3	0-10

Note. PA = physical activity; SD = standard deviation. Explicit attitudes ranged from 1 to 7, indicating unfavorable and favorable explicit attitudes toward PA, respectively. For the implicit attitudes, we used a D-score that ranges from 2 to +2, indicating negative or positive implicit attitudes toward PA (versus sedentary behavior), respectively. Perceived effort of the exercise session ranged from 0 to 10, indicating "no effort" and "very very hard" perceived effort, respectively. Affective evaluation of the exercise session ranged from 10 to +10, indicating a very pleasant or a very unpleasant affective evaluation, respectively.

Table 2

Results of the mixed models predicting affective attitudes toward physical activity

	Explicit attitudes (Likert scale from 1 to 7)		Implicit attitudes (D score from -2 to +2)	
	b (CI)	*p*	b (CI)	*p*
Fixed Effects				
Intercept	5.84 (5.03;6.64)	<.001	-.01 (-1.00;0.97)	.979
Condition (ref. control condition)				
Experimental condition	1.00 (.36;1.64)	.022	.19 (-.41;.79)	.564
Baseline condition	.64 (-.15;1.43)	.163	-.16 (-.33;.01)	.163
Covariates				
Usual level of physical activity (ref. regular)				
Some light physical activity	-.87 (-1.74;.01)	.210	0.86 (.25;.1.47)	.109
Random Effects				
Participants				
Intercept	0.312		1.489	
Condition baseline	.832		0.014	
Condition experimental	.439		0.568	
Corr. (Intercept, Condition baseline)	-.58		-.48	
Corr. (Intercept, Condition experimental)	-.42		-.97	
Corr. (Condition baseline; Condition experimental)	.98		.26	
Residual	.155		.115	
R^2	.366		.128	

Note. CI = confidence interval at 95%. D-score ranges from -2 to +2, indicating unfavorable and favorable implicit attitudes toward physical activity (vs. sedentary behaviors), respectively. Explicit attitudes range from 1 to 7, indicating unfavorable and favorable explicit attitudes toward physical activity, respectively.

Table 3

Results of the mixed models predicting daily-life physical activity

	Self-reported (in min per day)		**Direct (in min per day)**	
	b (CI)	*p*	b (CI)	*p*
Fixed Effects				
Intercept	190.8 (79.3;302.2)	.025	40.7 (26.7;54.7)	.003
Condition (ref. control condition)				
Experimental condition	36.5 (-3.22;76.2)	.122	2.3 (-2.6;7.11)	.417
Covariates				
Day (ref. Sunday)				
Monday	16.3 (-11.2;43.9)	.245	3.7 (-3.9;11.2)	.342
Tuesday	27.3 (-.3;54.8)	.053	-2.3 (-9.8;5.1)	.539
Wednesday	26.3 (-1.3;53.8)	.063	1.8 (-5.6;9.2)	.638
Thursday	10.4 (-17.3;38.0)	.459	-5.0 (-12.4;2.4)	.186
Friday	24.7 (-2.8;52.3)	.080	.63 (-6.9;8.1)	.870
Saturday	-2.7 (-30.3;24.8)	.848	-2.9 (-10.4;4.6)	.456
Usual level of physical activity (ref. regular)				
Some light physical activity	-59.6 (-185.9;66.7)	.467	-31.9 (-47.6;-16.3)	.028
Random Effects				
Participants				
Intercept	6806		72.95	
Condition experimental	2466		10.13	
Corr. (Intercept, Condition experimental)	.50		1.00	
Residual	5333		284.89	
R^2	.072		.354	

Note. CI = confidence interval at 95%. Self-reported physical activity was assessed using an adapted version of the International Physical Activity Questionnaire and was expressed in minutes per day. Accelerometer-based measure of physical activity was expressed in minutes per day. The parameter for the correlation between random intercept and random slope is estimated at 1.00 in the model, which is explain by the low number of participants included in the models.

3.2. Effect of the intervention on the affective attitudes toward PA

3.2.1. Explicit affective attitudes

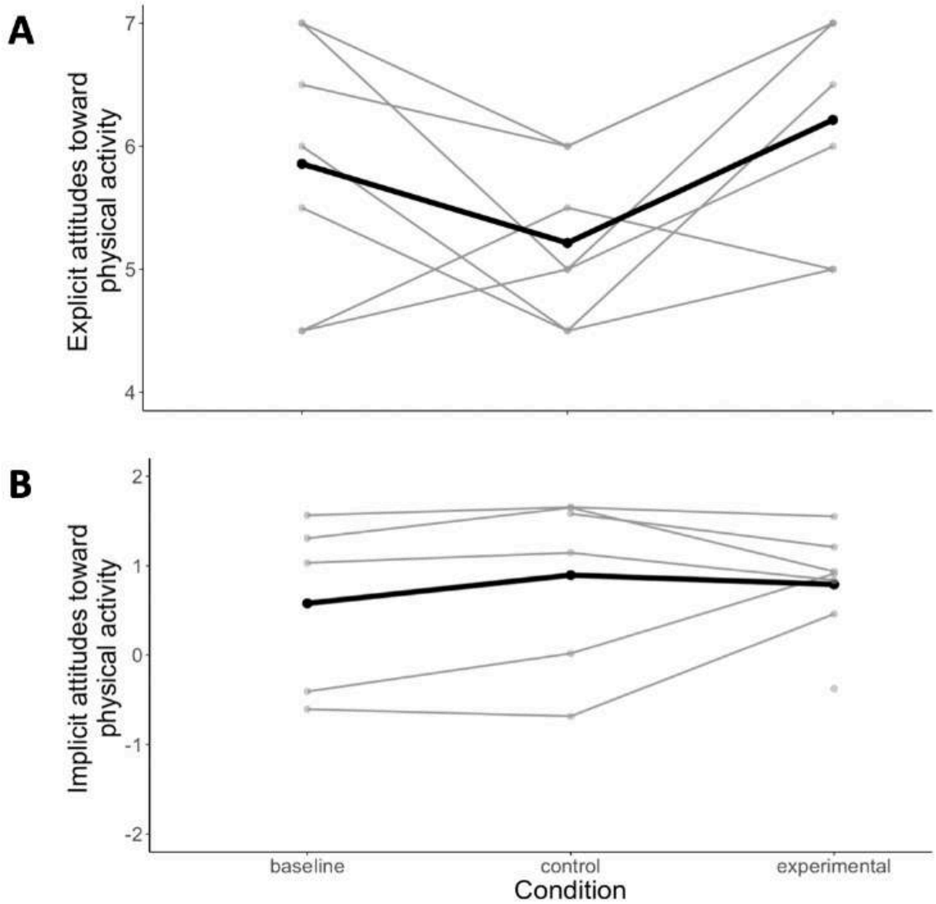
Explicit affective attitudes toward PA were significantly more positive after the four weeks of the experimental condition than after the four weeks of the control conditions (b = 1.00, 95% CI = 0.36 to 1.64, *P* = 0.022). No significant difference was observed between baseline and the control (b = 0.64, 95%CI = 0.15 to 1.43, *P* = 0.163) or experimental condition (b = 0.36, 95%CI = 0.10 to 0.82, *P* = 0.182). The variables under consideration explained 36.6% of the variance in the explicit affective attitudes toward PA (Tab. 2). As illustrated in Figure 2A, the evolution of the explicit attitudes seems to follow a quadratic pattern in which these attitudes first decreased from baseline to the end of the control condition and increased from the end of control condition to the end of the experimental condition. To formally test this evolution, an additional model using polynomial contrasts was conducted. This model included a linear (1 for baseline, 0 for the control condition, and +1 for the experimental condition) and a quadratic (1 for baseline, 2 for the control condition, and +1 for the experimental condition) orthogonal contrast. Results revealed a significant effect of the quadratic contrast only (*P* = 0.014). In other words, this model confirms that explicit affective attitudes followed the aforementioned quadratic pattern.

3.2.2 Implicit affective attitudes

No significant difference in implicit affective attitudes was observed between the control condition and baseline (b = 0.16, 95%CI=0.33 to 0.01, *P* = 0.163), between the control condition and the experimental condition (b = 0.19, 95%CI = 0.41 to 0.79, *P* = 0.564), or between baseline and the experimental condition (b = 0.37, 95% CI = 0.20 to 0.96, P = 0.272) (Tab. 2; Fig. 2B). A model testing the pattern of evolution of the implicit attitudes using the aforementioned polynomial contrasts showed that neither the linear (*P* = 0.366) nor the quadratic (*P* = 0.747) contrasts were significant, thereby confirming that implicit attitudes did not significantly change as a function of condition.

Figure 2

Affective attitudes toward PA



Note. A = explicit attitudes toward PA; B = implicit attitudes toward PA. Dots represent the observations for each participant. Grey lines represent each participant's evolution of the attitudes across conditions. These lines are represented when patients have two consecutive measurement points. The black line represents the averaged evolution of the attitudes across conditions. For the implicit attitudes, we used a D-score that ranges from 2 to +2, indicating negative or positive implicit attitudes toward PA (versus sedentary behavior), respectively. For the explicit attitudes, we used a scale ranging from 1 to 7, indicating negative or positive explicit attitudes toward PA, respectively.

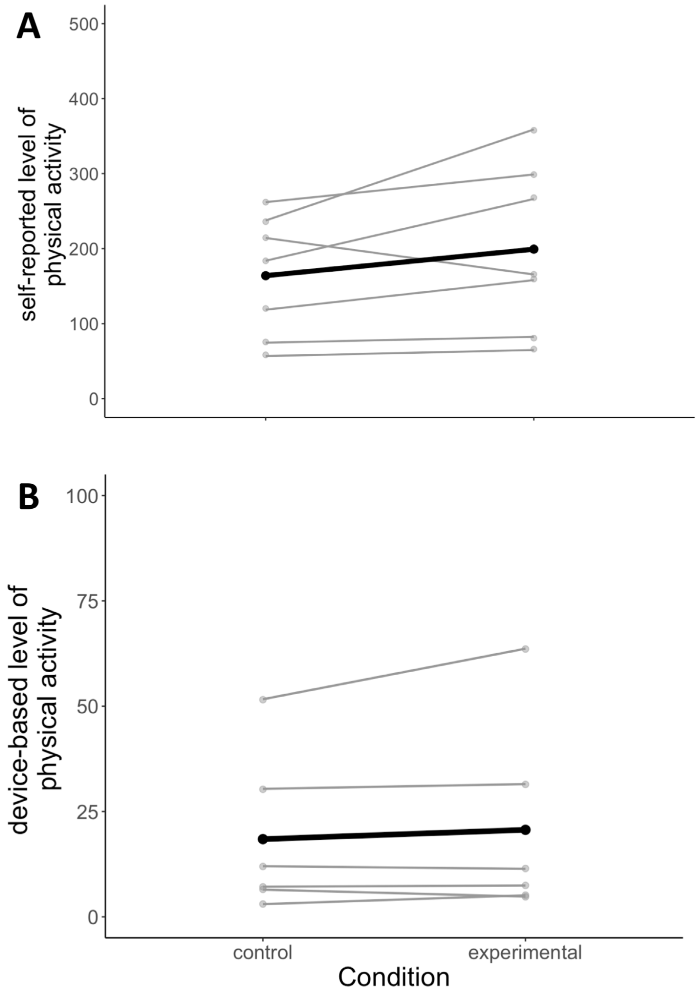
3.3. Effect of the intervention on daily-life PA

3.3.1. Self-reported measure

No significant difference was observed in self-reported moderate-to-vigorous PA between the four weeks of the control condition and the four weeks of the experimental condition (b=36.6min per day, 95%CI=3.2 to 76.2; *P* = 0.122) (Tab. 3; Fig. 3A).

Figure 3

Daily life PA



Note. A = self-reported measure of PA; B = Accelerometer-based measure of PA. Dots represent the observations for each participant. Grey lines represent each participants evolution of the attitudes across conditions. The black line represents the averaged evolution of the PA across conditions.

3.3.2. Accelerometer-based measure

No significant differences were observed in accelerometer-based moderate-to-vigorous PA between the four weeks of the control condition and the four weeks of the experimental condition (b = 2.3min per day, 95% CI= 2.6 to 7.11, P = 0.417). Participants who usually performed some PA before the onset of PD exhibited a lower level of accelerometer-based moderate-to-vigorous PA compared with participants who usually performed regular PA (b = 31.9 min per day, 95%CI = -47.6 to -16.3, P = 0.028) (Tab. 3).

4. Discussion

4.1. Main findings

The present study investigated whether manipulating the intensity of the effort at the end of an exercise session enhances affective attitudes toward PA and promotes daily-life PA behavior in patients with PD. The findings revealed that adding a 9-min period of lower physical effort intensity at the end of a weekly exercise session over four weeks improved explicit affective attitudes toward PA. It is worth noting that, all other things being equal, the experimental condition is more demanding than the control condition both in terms of time duration and total effort to be invested. Consequently, the observation that the experimental condition improves the affective attitudes is consistent with the notion that humans have a bounded rationality (Simon, 1990) and use affective heuristics (or biases) to evaluate a given experience (Finucane, Alhakami, Slovic, & Johnson, 2000). No significant effects of the experimental condition were found on the other outcomes (i.e., implicit attitudes and PA), although results are in the expected direction for self- reported PA (see below).

4.2 Comparison with other studies

Our results are in line with previous studies testing the peak-end rule hypothesis in PA (Hargreaves & Stych, 2013; Hutchinson et al., 2020; Zenko et al., 2016). However, whereas prior studies examined the effect on the affective evaluation of a single exercise session, the present study assessed the effect on the affective evaluation of PA in general. Hence, our study provides preliminary evidence that interventions based on the peak-end rule can enhance the affective determinants of PA (Rhodes et al., 2019; Stevens et al., 2020; Williams & Bohlen, 2019). However, given the sample size, the statistically significant effect on explicit affective attitudes could be due to type 1 error and should be interpreted with caution.

In line with a previous study exploring the peak-end rule in PA (Hargreaves & Stych, 2013), we did not observe that the experimental condition was associated with a significant higher level of self-reported moderate-to- vigorous PA. Nevertheless, although non-significant, participants self-reported an additional 36min per day of daily-life moderate-to-vigorous PA over the four weeks of the experimental condition compared with the control condition. This result is promising but needs to be considered in light of the study design, which cannot determine if the effect observed is explained by the condition or by the effect of time (i.e., the participation in an exercise program). The latter seems to be supported by the evolution of PA across the eight weeks (Fig. S1).

We found no significant evidence that effort manipulation had an impact on implicit affective attitudes or device-measured PA. This non-significant effect on implicit affective attitudes is consistent with the Hutchinson et al.'s study (Hutchinson et al., 2023). In contrast, at the explicit level, we observed a significant and positive effect of the effort manipulation on explicit affective attitudes toward PA. This result stands in contrast with the one observed in the study of Hutchinson et al. (Hutchinson et al., 2023). Yet, it should be noted that, although not significant, results were in the same direction, showing that participants ending with a lower level of effort tend to exhibit higher explicit affective attitudes toward physical activity than participants ending with a higher level of effort. Moreover, this difference can be also explained by the nature of the exercise (resistance versus aerobic) or of the type of effort manipulation (decreasing intensity throughout the session versus adding a lower effort intensity at the end).

Regarding the differences between implicit and explicit measure of affective evaluation of PA could be explained by the fact that the automatic processes could be less malleable than the controlled processes (Joy-Gaba & Nosek, 2010). For example, in line with this suggestion, studies showed that explicit attitudes are more readily to change with relatively few exposures to counter-attitudinal examples, while implicit associations required more exposures to evolve (Rydell & McConnell, 2006; Rydell, McConnell, Strain, Claypool, & Hugenberg, 2007). Consequently, longer interventions would have been necessary to modify implicit affective associations with PA.

The difference in the effect size observed between self- reported and accelerometer-based measure of PA (i.e., ∼36 min versus ∼2 min per day) may be explained by at least two features. First, these measures did not assess the same type of PA. The questionnaire measured the time spent walking and in moderate-to-vigorous PA, irrespective of their duration, while the accelerometer-based measure only included moderate-to-vigorous PA behavior that last a minimum of 10 min. Second, it has been shown that self-reported measures of PA often overestimate PA levels, in comparison with accelerometer-based measures (Prince et al., 2008; Skender et al., 2016), especially in patients with PD (Mantri et al., 2019).

4.3. Strengths and weaknesses

Among the strengths of the present study are the application of the end effect of the peak-end rule principle, a clinical sample of patients with PD, a longitudinal design (i.e., repeated measurements over eight weeks), the measure of both explicit and implicit affective attitudes toward PA, and the use of both self-reported and accelerometer-based measures of daily-life PA. This study also has some limitations. First, our study relied on a small sample size (n = 7) and did not reach a power of 80%. Accordingly, although we used a statistical approach adapted to small samples of participants (Luke, 2017; McNeish & Stapleton, 2016), our underpowered study can bias the effects size estimated (Brysbaert, 2019). Second, this work was an early-phase study aiming to test the potential impact of an intervention anchored in the peak-end rule principle, but it did not meet the criteria of a formal randomized controlled trial. Specifically, our study was drawn on a within-subjects design in which all patients first performed the four weeks of the traditional exercise rehabilitation program and then performed the four weeks of the experimental program. Accordingly, we cannot rule out the possibility that the effects observed were due to an effect of time rather than to the condition. For example, patients' cardiorespiratory fitness improvement over the training sessions or patients' habituation to the exercise may also impact their perceived effort and affective experiences. Future studies using either a random order for the experimental conditions or a between-subject randomization are needed to eliminate such possibility. Finally, four to seven of the participants were taking levodopa medication. Levodopa intake may lead to random fluctuations in their motor performance, called the "on-off" phenomenon (Nutt, Woodward, Hammerstad, Carter, & Anderson, 1984). These fluctuations are likely to affect patients' daily-life PA, irrespective of their affective evaluation of PA, and should therefore be monitored and accounted for in future research.

5. Conclusion

In this study, we tested a manipulation that simply consists of adding a "better (less intensive) end" with all other things being equal. Our findings provide preliminary evidence that an intervention manipulating the effort intensity at the end an exercise session may be effective to enhance explicit evaluation of PA. If these results are confirmed by a randomized controlled trial, this free and easily-deliverable intervention could be rapidly implemented on a large scale to promote PA among patients with PD and other diseases.

Authors' contributions

L.F.: conceptualization, original draft; P.S.: conceptualization, writing–review and editing; S.M.: writing–review and editing; A.S.: conceptualization, writing – review and editing; B.C.: conceptualization, supervision, writing – original draft.

Data availability statement

The data that support the findings of this study are available at https://zenodo.org/record/4742001#.ZAr-FsGZMQM and https://aspredicted.org/see_one.php .

The Supplementary Material is available at https://www.mov-sport-sciences.org/10.1051/sm/2023009/olm.

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Conflicts of interest

The authors declare that they have no conflicts of interest in relation to this article.

Consent to participate

All the participants agreed to participate and signed a written inform consent.

Consent for publication

All the authors listed in the by-line have agreed to the by-line order and to the submission of the manuscript in this form.

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Résumé des résultats principaux de la Contribution empirique n°7

Les résultats de cette étude préliminaire n'ont révélé **aucun effet significatif** de l'intervention sur l'**affect remémoré** des séances, les **évaluations affectives automatiques** liées à l'activité physique ou sur les **niveaux d'activité physique** quotidiens des patient·es. En revanche, les **attitudes affectives réfléchies** envers l'activité physique étaient **significativement plus élevées** après les quatre semaines de la **condition expérimentale** par rapport à la condition contrôle. Ces résultats pourraient suggérer que **l'ajout de neuf minutes d'effort physique** de faible intensité à la fin de chaque séance hebdomadaire d'APA d'intensité modérée pendant quatre semaines pourrait améliorer les attitudes affectives envers l'activité physique chez des patient·es atteint·es de la maladie de Parkinson. Cependant, ces résultats doivent être interprétés avec prudence en raison de la **faible taille de l'échantillon** et d'un **possible effet du temps**. En effet, le protocole utilisé ne permet pas de déterminer si l'amélioration des attitudes affectives est attribuable à l'intervention elle-même ou simplement à **l'effet cumulatif des huit semaines d'APA**. Par exemple, **l'amélioration de la condition cardiorespiratoire** ou **l'accoutumance** des patient·es à l'exercice inhérente au programme pourraient avoir influencé l'évaluation affective de l'activité physique. Ainsi, les résultats actuels ne permettent pas de déterminer précisément les mécanismes sous-jacents à l'amélioration de cette variable affective non-expérientielle.

En résumé, nos données fournissent **des résultats préliminaires** suggérant qu'une intervention diminuant l'intensité de l'effort à la fin d'une séance d'APA pourrait être une stratégie endogène efficace pour **augmenter la quantité d'exercice réalisée durant la séance** (ajout de neuf minutes) et améliorer les **attitudes affectives** envers l'activité physique. Si ces résultats sont confirmés par un **essai contrôlé randomisé**, cette intervention simple et gratuite pourrait facilement être déployée dans les structures proposant des séances d'APA auprès de personnes atteint·es de la maladie de Parkinson ainsi que d'autres pathologies.

Chapitre 9 Discussion générale

Ce travail doctoral avait pour ambition de répondre à trois questions de recherche principales : (1) La prise en compte des mécanismes affectifs, en plus des variables socio-cognitives, améliore-t-elle la prédiction de l’activité physique chez les personnes atteintes de maladies chroniques ? Si oui, quelles sont les variables qui prédisent le plus l’activité physique ? (2) Quelles sont les stratégies d’intervention qui permettent de manipuler des variables affectives ? (3) Est-il possible d’améliorer l’activité physique des personnes atteintes de maladies chroniques en ciblant des variables affectives ? Pour y répondre, nous avons conduit un programme de recherche composé de 7 Contributions qui seront présentées dans trois parties, conformément à l’approche de la médecine expérimentale appliquée au changement de comportement de santé (Sheeran et al., 2017 ; cf. Figure 1, p. 7). La première partie visait à identifier les liens entre les variables affectives liées à l'activité physique (e.g., réponses affectives, attitudes affectives, tendances d’approche-évitement) et les niveaux d’activité physique quotidiens chez les personnes atteintes de maladies chroniques. La deuxième partie s’est concentrée à déterminer et à tester des stratégies d’intervention susceptibles d'améliorer ces variables. Enfin, la troisième partie consistait à identifier, concevoir, mettre en œuvre et évaluer l’efficacité d’interventions ciblant certaines de ces variables, dans le but d’augmenter les niveaux d’activité physique quotidiens des personnes atteintes de maladies chroniques.

Après avoir répondu aux questions de recherche et présenté des perspectives, cette discussion présentera les limites et les forces de ce travail doctoral.

9.1 Quels sont les liens entre les variables affectives et l'activité physique quotidienne des personnes atteintes de maladies chroniques ?

Selon l'AHBF (Williams & Evans, 2014 ; Stevens et al., 2020), les comportements d'activité physique sont influencés par quatre catégories de variables affectives : (1) les réponses affectives, (2) les affects incidents, (3) le traitement de l'affect, et (4) la motivation chargée affectivement (cf. Figure 3, p. 31). Une des originalités de cette thèse réside dans l'examen de la diversité des variables affectives, plutôt que de se limiter à l'étude d'un seul type.

La Contribution empirique n°1 a examiné les liens entre les attitudes affectives, les tendances d'approche-évitement et les niveaux d'activité physique quotidiens de patient·es intégré·es dans un programme de réadaptation cardiovasculaire. La relation entre certaines variables socio-cognitives, telles que l'intention, les capacités perçues et les attitudes instrumentales envers l'activité physique, et les niveaux d'activité physique a également été analysée. La Contribution empirique n°2 a exploré l'association entre les réponses affectives immédiates ressenties à différents moments d'une séance d'APA, l'affect remémoré de cette séance, ainsi que la réponse affective anticipée pour la prochaine séance, et les niveaux d'activité physique quotidiens chez des personnes atteintes de maladies chroniques vivant dans la communauté.

A. Niveaux d'activité physique quotidiens après un programme de réadaptation cardiaque : le rôle des attitudes affectives

La première Contribution empirique montre qu'une semaine après un programme de réadaptation cardiovasculaire, les niveaux d'activité physique quotidiens étaient significativement plus élevés chez les patient·es que chez les participant·es du groupe témoin (i.e., en bonne santé). Parmi les variables étudiées, seules les capacités perçues – une variable motivationnelle – et les attitudes affectives positives – une variable affective – envers l'activité physique étaient positivement associées aux niveaux d'activité physique. En d'autres termes, les participant·es qui estimaient que leurs capacités à réaliser des activités physiques étaient élevées et qui évaluaient ce comportement comme plaisant présentaient des niveaux d'activité physique plus élevés. Ces résultats corroborent les études antérieures sur les liens entre les capacités perçues, les attitudes affectives et les niveaux d'activité physique chez les personnes atteintes de maladies chroniques (Bermudez et al., 2021 ; Du et al., 2012 ; Klompstra et al., 2018 ; Stevens et al., 2020).

Toutefois, l'absence de relation significative entre les tendances d'approche-évitement et l'activité physique contraste avec les études conduites sur des adultes en bonne santé, où une association positive a été trouvée, tant dans des contextes de laboratoire (Cheval et al., 2014) qu'écologiques (Cheval et al., 2015 ; Hannan et al., 2019). Ce résultat pourrait s'expliquer par au moins deux facteurs. Premièrement, la tâche utilisée (VAAST ; Rougier et al., 2018) demandait aux participant·es, d'approcher/éviter un stimulus particulier à partir de la forme de l'image (e.g., approcher une image en format portrait vs. paysage) plutôt que de son contenu (approcher une image d'un avatar actif vs. passif). Ceci a pu limiter la capacité de la tâche à capturer les tendances d'approche-évitement envers l'activité physique des participant·es. En appui de cette limite, une méta-analyse a montré que les effets des interventions utilisant la CBM sont plus marqués lorsque les participant·es réagissent à des caractéristiques explicitement pertinentes (e.g., l'action d'un avatar dans une image) plutôt qu'à des caractéristiques implicites ou non pertinentes pour la tâche (e.g., la forme ou la couleur d'une image) (Phaf et al., 2014). Par conséquent, notre échantillon (N = 59) pourrait avoir été insuffisant pour détecter un effet en raison de la faible taille d'effet attendue.

Deuxièmement, les processus automatiques semblent influencer principalement les activités physiques d'intensité légère et non planifiées, tandis que les processus réfléchis concernent davantage les comportements planifiés, tel que les exercices physiques (Cheval et al., 2014 ; Conroy & Berry, 2017). L'analyse a porté ici sur des activités physiques d'intensité modérée à vigoureuse mesurées par accéléromètres, ce qui ne permet pas de différencier précisément les activités physiques planifiées ou non planifiées. Cela pourrait restreindre la capacité à établir une association entre les tendances automatiques d'approche-évitement et les niveaux d'activité physique. Des études futures, dotées d'une plus grande puissance statistique et capables de distinguer les types d'activité physique, seront nécessaires pour mieux comprendre ces liens chez des personnes atteintes de maladies chroniques.

Nos résultats n'ont révélé aucune association significative entre les variables motivationnelles ou affectives et le temps passé en comportements sédentaires. Comme discuté dans la Contribution empirique n°1, cela pourrait résulter de mesures non spécifiques aux comportements sédentaires, plutôt que d'une absence d'association réelle. Ce résultat est en accord avec les travaux d'O'Leary et al. (2021) qui montrent que l'association entre douleur et comportements sédentaires disparaît après le contrôle des covariables telles que l'âge et le sexe. Nos résultats indiquent que le sexe est le seul facteur associé au niveau de sédentarité, les hommes étant plus sédentaires que les femmes. Ce résultat est concordant avec la littérature actuelle, qui suggère que les hommes passent en général plus de temps assis à regarder la télévision que les femmes (Matthews et al., 2021 ; Yang et al., 2019).

B. Niveaux d'activité physique quotidiens et réponses affectives chez les personnes atteintes de maladies chroniques : effet de débordement ou de confusion ?

La Contribution empirique n°2 révèle que seule la réponse affective mesurée à la dernière minute d'une séance d'APA est positivement et significativement associée à l'activité physique quotidienne subséquente. À notre connaissance, cette étude est la première à examiner la relation entre les réponses affectives mesurées à différents moments d'une séance d'exercice et les niveaux d'activité physique ultérieurs. Ces résultats soutiennent le postulat théorique selon lequel la réponse affective à la fin d'une expérience est déterminante pour la probabilité de la renouveler (Fredrickson, 2000 ; Kahneman et al., 1993 ; Redelmeier & Kahneman, 1996). Cette perspective plus fine sur la relation entre réponses affectives et activité physique dans un contexte écologique (i.e., séances d'APA habituelles), pourrait être utile pour les professionnel·les, en leur permettant de cibler les moments clés d'une séance d'APA, afin d'optimiser les réponses affectives des personnes atteintes de maladies chroniques, maximisant ainsi les effets bénéfiques associés.

La Contribution empirique n°2 a permis de souligner le pouvoir prédictif de la réponse affective de fin sur l'affect remémoré ainsi que la réponse affective anticipée. Ces résultats s'alignent avec une partie de la littérature, qui montre que certaines réponses affectives durant une séance d'exercice (e.g., celles à la fin) influencent positivement l'affect remémoré de la séance et les réponses affectives anticipées pour les futures séances (Hargreaves & Stych, 2013 ; Hutchinson et al., 2023 ; Hutchinson et al., 2020 ; Zenko et al., 2016). En revanche, nos résultats n'ont pas révélé d'associations significatives entre l'affect remémoré, la réponse affective anticipée et les niveaux d'activité physique ultérieurs. La comparaison avec la littérature est cependant difficile, car les résultats semblent inconsistants. En effet, si certaines études indiquent que l'affect remémoré et la réponse affective anticipée ne sont pas associés aux niveaux d'activité physique ultérieurs (Hargreaves & Stych, 2013 ; Rhodes & Kates, 2015 ; Zenko et al., 2024), d'autres suggèrent que ces variables prédisent significativement ce comportement (Feil, Fritsch, Weyland, et al., 2023 ; Kwan et al., 2017).

L'absence d'effet statistiquement significatif observé dans notre étude pourrait s'expliquer par une entorse au « principe de correspondance » (Ajzen & Fishbein, 1977 ; Ajzen & Timko, 1986). Selon ce principe, pour évaluer correctement la force d'une association entre une variable psychologique (e.g., les attitudes affectives) et un comportement cible (e.g., l'activité physique), il est nécessaire de respecter une correspondance étroite, en termes de spécificité ou de généralité, dans la mesure de ces variables (Ajzen & Fishbein, 1977 ; Ajzen & Timko, 1986 ; Irving & Smith, 2020). Autrement dit, une absence apparente de relation entre les attitudes affectives et l'activité physique pourrait résulter d'une inadéquation dans la spécificité des mesures ; par exemple, si les attitudes étaient mesurées de manière générale (e.g., « Faire de l'activité physique est quelque chose d'agréable vs d'ennuyeux »), et que le comportement était mesuré de manière spécifique (e.g., « pratiquer 30 minutes d'activité physique modérée par jour la plupart des jours de la semaine »). Dans notre étude, ce principe de correspondance n'a pas été respecté puisque l'affect remémoré et la réponse affective anticipée ont été mesurés en référence à une séance d'APA spécifique, tandis que l'activité physique, mesurée par accélérométrie, incluait tous types d'activités de la vie quotidienne. Cette absence de correspondance entre les mesures affectives et comportementales pourrait ainsi avoir affaibli l'association présumée. Pour mieux comprendre le lien entre ces variables affectives et les niveaux d'activité physique, de futures études devraient utiliser des indicateurs comportementaux plus spécifiques, tels que le temps consacré aux séances ultérieures d'APA ou la fréquence de participation à celles-ci.

Les résultats ont également révélé que l'association entre la réponse affective de fin et l'activité physique quotidienne n'était plus significative après avoir contrôlé les effets de l'IMC, du sentiment d'efficacité personnelle et de l'effort perçu. En définitive, la Contribution empirique n°2 montre que l'effet de débordement qui est présumé plus ou moins explicitement dans les recherches antérieures (Kwan & Bryan, 2010 ; Liao et al., 2017 ; Rhodes & Kates, 2015 ; Schneider et al., 2009 ; Williams et al., 2008 ; Williams et al., 2016 ; Williams et al., 2012) n'est peut-être qu'un effet de confusion. Il est en effet peu probable que les réactions affectives éprouvées lors d'une séance d'APA soient la cause de l'activité physique quotidienne observée la semaine suivante (e.g., Liao et al., 2017), voire plusieurs mois après (e.g., Williams et al., 2008 ; Williams et al., 2012). Il est en revanche plus probable que les participant·es qui ont ressenti des réactions affectives plus positives possèdent d'autres caractéristiques susceptibles d'expliquer pourquoi elles et ils sont également plus actif·ves dans les semaines ou mois qui suivent. Un moindre IMC et un sentiment d'efficacité personnelle plus élevé à l'égard de l'activité physique sont des candidats sérieux pour expliquer cette relation (e.g., Biddle et al., 2021 ; Ekkekakis et al., 2016). Il existe probablement d'autres variables affectives ou motivationnelles, comme une attitude affective ou une motivation autodéterminée plus élevée, qui pourraient aussi expliquer la covariation non causale que nous avons observée. D'un point de vue méthodologique, mais aussi théorique, nos résultats mettent en évidence la nécessité de contrôler soigneusement certains facteurs démographiques (âge, genre, IMC, état de santé) ainsi que les variables socio-cognitives « traditionnelles », afin de mieux cerner le rôle des mécanismes affectifs dans la régulation de l'activité physique.

9.2 Quelles sont les stratégies d'intervention permettant l'amélioration de certaines variables affectives ?

Dans les Contributions empiriques n°1 et n°2, nous avons identifié des associations entre certaines variables affectives (i.e., attitudes affectives et réponses affectives) et les comportements d'activité physique quotidiens. Cependant, les limites de ces Contributions suggèrent que ces liens, ou leur absence, restent ambigus et nécessitent davantage de recherches. L'étape suivante du modèle de la médecine expérimentale de Sheeran et al. (2017) consiste à tester si certaines de ces variables affectives peuvent être manipulées expérimentalement (étape C, Figure 1). Afin de répondre à cet objectif, nous avons identifié trois type de stratégie d'intervention : (1) les stratégies d'intervention « endogènes » basées sur l'expérience directe de l'activité physique, ciblant les réponses affectives, l'affect remémoré et la réponse affective anticipée ; (2) les stratégies d'intervention « exogènes » basées également sur l'expérience directe de l'activité physique, visant les mêmes variables affectives ; et (3) les stratégies d'interventions digitales, qui ciblent les réponses automatiques, telles que les tendances d'approche-évitement, sans nécessiter d'expérience directe avec l'activité physique.

A. Stratégies endogènes et exogènes : intervenir sur l'expérience directe de l'activité physique

Dans la Contribution n°3 nous avons identifié trois stratégies endogènes qui ont fait l'objet de recherches importantes chez la population générale : (1) le maintien d'une intensité modérée, sous le premier seuil ventilatoire ; (2) la personnalisation de l'intensité de l'effort, en fonction de la tolérance et des préférences individuelles ; et (3) la diminution de l'intensité à la fin d'une séance d'activité physique. De plus, trois stratégies exogènes ont également été recensées : (1) l'utilisation de musique pendant l'exercice ; (2) la pratique d'activités en extérieur, dans des environnements naturels ; et (3) le soutien aux besoins psychologiques fondamentaux ?

Bien que ces stratégies semblent prometteuses pour améliorer les variables affectives liées à l'activité physique, la plupart des études antérieures qui ont testé l'efficacité de certaines stratégies ont été conduites chez des participants en bonne santé. Les études faites avec des malades chroniques sont rares et inconsistantes (Jones & Zenko, 2023). En somme, l'efficacité des stratégies d'intervention endogènes et exogènes pour cibler les réponses affectives chez les personnes atteintes de maladies chroniques reste à clarifier. De recherches supplémentaires sont nécessaires pour identifier les stratégies les plus efficaces pour cette population. La Contribution empirique n°7 ainsi que le protocole présenté dans la Contribution empirique n°4 visaient précisément à combler cette lacune.

La Contribution empirique n°7 a testé la troisième stratégie endogène identifiée : la diminution de l'intensité à la fin d'une séance d'activité physique. Dans cette section, nous abordons les résultats concernant les variables affectives, tandis que ceux relatifs aux niveaux d'activité physique sont discutés dans la section 9.3. Conformément à nos hypothèses, la Contribution empirique n°7 a montré une amélioration des attitudes affectives après une période d'intervention dans laquelle les séances d'activité physique se terminaient par une intensité plus faible. En revanche, nous n'avons pas observé d'amélioration significative de l'affect remémoré ni des évaluations affectives automatiques. Ces résultats contrastent avec ceux obtenus auprès de populations en bonne santé, montrant que la stratégie endogène basée sur la diminution de l'effort au cours d'une séance d'activité physique influençait positivement l'affect remémoré de la séance (Hutchinson et al., 2023 ; Hutchinson et al., 2020 ; Zenko et al., 2016), mais pas les attitudes affectives envers l'activité physique (Hutchinson et al., 2023). Toutefois, ces différences sont à interpréter à la lumière des limites de notre étude préliminaire, telles que notre faible taille d'échantillon et l'absence de contrebalancement des conditions.

La Contribution empirique n°4 a présenté un protocole visant à évaluer l'efficacité d'une intervention combinant l'utilisation de la musique – une stratégie exogène – et le principe du pic et de la fin – une stratégie endogène – sur les réponses affectives, l'affect remémoré et les réponses affectives anticipées lors de séances d'APA chez des patient·es en réadaptation cardiovasculaire stationnaire. Les résultats ont pour ambitions d'identifier les conditions les plus efficaces pour manipuler ces variables, telles que l'écoute de la musique tout au long de la séance, ou uniquement à la fin. Cela ouvrira la voie à de futures études interventionnelles visant à tester l'impact de ces stratégies sur l'adhésion aux séances d'APA dans les services de réadaptation cardiovasculaire.

B. Stratégies d'interventions digitales pour modifier les réponses automatiques : cibler les tendances d'approche-évitement sans expérimenter véritablement l'activité physique

De façon assez intrigante, la littérature actuelle suggère que les interventions digitales de CBM pourraient modifier directement les tendances d'approche-évitement, sans nécessiter une expérience physique directe avec l'activité physique (Cheval et al., 2021 ; Farajzadeh et al., 2023 ; Larsen & Hollands, 2022 ; Maltagliati, Sarrazin, et al., 2024 ; Preis et al., 2021). Autrement dit, ces stratégies d'intervention pourraient « tromper le cerveau » en créant des associations affectives favorables à l'approche de l'activité physique, sans que celle-ci ne soit réellement pratiquée. Bien que la Contribution empirique n°1 n'ait pas trouvé d'association entre les tendances d'approche-évitement et les niveaux d'activité physique quotidiens, les cadres théoriques récent semblent indiquer que cette variable affective pourrait constituer une cible prometteuse pour améliorer les niveaux d'activité physique (Cheval et al., 2024 ; Conroy & Berry, 2017 ; Larsen & Hollands, 2022). Ainsi, la Contribution n°6 visait à tester l'efficacité d'une stratégie d'intervention digitale de CBM sur les tendances d'approche-évitement envers l'activité physique et les niveaux d'activité physique des patient·es participant à un programme de réadaptation cardiovasculaire ambulatoire. Cependant, après un an et demi de recrutement, nous avons rencontré un taux d'attrition de 37 % pour la complétion des tâches de CBM et de 75 % pour les mesures d'activité physique. Moins de 5 % de l'échantillon initial a finalement complété le protocole. Il convient de noter que ces taux ne sont pas fondamentalement différents comparés à ceux d'autres études évaluant les effets des interventions de CBM sur des comportements tels que le jeu (Snippe et al., 2024), le tabagisme (Wen et al., 2020 ; Wittekind et al., 2019), ou la consommation d'alcool (Wiers et al., 2015). Les taux d'attrition pour la complétion des tâche de CBM observés dans ces études varient de 43 % (Wiers et al., 2015) à 90,1 % (Snippe et al., 2024). Par exemple, Snippe et al. (2024) ont dû interrompre leur étude en raison d'un taux d'attrition de 90,1 % après trois ans de collecte de données. Il convient également de noter que ces études étaient réalisées en ligne sans supervision, tandis que dans notre étude, les tâches de CBM étaient supervisées par des assistant·es de recherche. Ce manque de contact et de soutien humain dans les protocoles précédents pourrait avoir diminué la motivation des participant·es à compléter le programme (Snippe et al., 2024). Par conséquent, notre taux d'attrition relativement faible pourrait suggérer que la supervision des assistant·es de recherche pendant l'intervention a contribué à limiter la perte de participant·es. Cependant, en raison de la taille de l'échantillon, nous n'avons pas pu tester les hypothèses initiales.

La Contribution n°6 a permis d'identifier quatre raisons principales expliquant le manque d'engagement et d'adhésion au protocole de recherche : (1) la charge additionnelle du protocole interventionnel sur la prise en charge hospitalière classique ; (2) la perception de la tâche de CBM comme étant ennuyeuse ; (3) un scepticisme quant à l'efficacité de la tâche ; (4) un manque de lien perçu entre la tâche de CBM et l'activité physique. Les raisons en lien avec le faible taux de complétion identifiées dans cette Contribution concordent avec celles décrites dans la littérature antérieure. Plusieurs études ont rapporté que la nature fastidieuse et répétitive des tâches de CBM pouvait réduire la motivation des participant·es à compléter le protocole (Snippe et al., 2024 ; Wen et al., 2020 ; Wiers et al., 2015).

Pour pallier ces obstacles, nous avons formulé quatre recommandations : (1) impliquer de manière plus active le personnel hospitalier dans le protocole d'étude afin d'intégrer les tâches de CBM directement dans l'emploi du temps des patient·es ; (2) intégrer des tâches plus engageantes et intrinsèquement motivantes, via notamment la gamification ou l'utilisation de la réalité virtuelle ; (3) mettre en évidence les conséquences de chaque action effectuée dans la tâche, par exemple, l'amélioration de la vitalité après avoir adopté un comportement d'activité physique ; (4) établir un lien clair entre la tâche de CBM et les comportements d'activité physique. Ces recommandations concordent également avec celles proposées dans la littérature actuelle. Par exemple, Snippe et al. (2024) ont également suggéré de recourir à la gamification, définie comme l'utilisation d'éléments de conception de jeux dans des contextes non ludiques (Deterding et al., 2011). À notre connaissance, seules quatre études interventionnelles ont exploré l'implémentation de la gamification dans des interventions de CBM

(Boendermaker et al., 2016 ; Dennis & O'Toole, 2014 ; Dennis-Tiwary et al., 2016 ; Pieters et al., 2017), observant des résultats mitigés (Zhang et al., 2018). Par exemple, Dennis et O'Toole (2014) ont montré qu'une application mobile de CBM intégrant des éléments de gamification – tels que des personnages animés et des effets sonores – pouvait réduire la tendance automatique à diriger son attention vers des menaces (comme un visage en colère) chez des participant·es présentant un fort trait d'anxiété. Cependant, des résultats contrastés ont été observés dans une étude similaire menée auprès de participant·es souffrant de troubles liés à l'alcool (Boendermaker et al., 2016). Dans cette dernière, l'utilisation de la gamification, incluant animations et effets sonores, n'a montré aucun effet significatif sur la tendance automatique à diriger son attention vers des stimuli liés à l'alcool. Ces résultats contrastés soulignent la nécessité d'études supplémentaires pour déterminer si la gamification intégrée à des tâches de CBM peut non seulement influencer positivement les tendances d'approche-évitement envers l'activité physique, mais aussi réduire le taux d'attrition dans ce type d'intervention. L'efficacité de ce type d'intervention pour modifier les comportements d'activité physique sera discuté dans la section suivante.

9.3 Quelles est l'efficacité des interventions ciblant certaines variables affectives pour augmenter l'activité physique quotidienne des personnes atteintes de maladies chroniques ?

La dernière étape du modèle de la médecine expérimentale (Sheeran et al., 2017) consiste à tester l'efficacité des stratégies d'intervention sur le comportement d'activité physique en modifiant le médiateur présumé, à savoir la variable affective identifiée (Figure 1, étape D). Conformément à cette étape, cette section vise à répondre au troisième objectif de ce travail doctoral : identifier, concevoir, mettre en œuvre et évaluer l'efficacité d'interventions ciblant certaines variables affectives afin d'augmenter les niveaux d'activité physique quotidiens chez des personnes atteintes de maladies chroniques. Nous commencerons par rappeler les résultats principaux de notre revue systématique (Contribution n°5), puis nous analyserons les particularités des stratégies d'intervention digitales ciblant les réponses automatiques, dans le contexte spécifique et complexe des comportements d'activité physique (Contribution n°6). Enfin, nous aborderons les apports de notre étude préliminaire (Contribution empirique n°7) à la littérature actuelle.

A. La planification du comportement : un ingrédient actif essentiel ?

Dans la Contribution n°5, nous avons constaté que les études montrant des améliorations significatives des variables affectives (Fessler et al., 2024 ; Hagberg et al., 2009 ; Höchsmann et al., 2019), ainsi que celles suggérant un effet médiateur du plaisir *(enjoyment)* et de la motivation intrinsèque dans l'impact des interventions sur les comportements d'activité physique (Hagberg et al., 2009 ; Höchsmann et al., 2019 ; Pinto et al., 2023), s'appuient principalement sur la planification comportementale (e.g., préciser quand, où, comment et avec qui faire une séance d'activité physique) comme TCC de. Ce résultat corrobore en partie ceux de la littérature actuelle, qui suggèrent que la planification comportementale est une TCC efficace pour améliorer l'engagement à court terme (< 6 mois[8]) dans des activités physiques chez des personnes atteintes de cancer (Salisbury et al., 2023).

Deux facteurs pourraient expliquer l'effet de la planification comportementale sur le plaisir et la motivation intrinsèque pour l'activité physique chez les personnes atteintes de maladies chroniques. Premièrement, cette TCC pourrait aider les participant·es à choisir des conditions optimales pour réaliser leurs activités physiques, telles que des moments, des lieux ou des partenaires d'exercice plus agréables, améliorant ainsi l'expérience (Fishbach & Woolley, 2022). Deuxièmement, la planification comportementale s'est révélée être l'une des stratégies les plus efficaces pour renforcer le sentiment d'efficacité personnelle vis-à-vis de l'activité physique (Williams & French, 2011). Comme indiqué dans la <u>Contribution empirique n°2</u>, un sentiment élevé d'efficacité personnelle peut influencer positivement certaines variables affectives, telles que les réponses affectives immédiates ou anticipées vis-à-vis de l'activité physique. Ainsi, la planification comportementale pourrait influencer le plaisir lié à l'activité physique à travers une amélioration du sentiment d'efficacité personnelle.

Les résultats de notre revue de littérature indiquent également que le plaisir *(enjoyment)* et la motivation intrinsèque sont des médiateurs potentiels de l'effet des interventions sur les niveaux d'activité physique chez les personnes atteintes de maladies chroniques (Hagberg et al., 2009 ; Höchsmann et al.,

[8] Temporalité utilisée par les auteur·es pour définir à un changement à court terme

2019 ; Pinto et al., 2023). Ces conclusions rejoignent celles de méta-analyses réalisées auprès d'adultes en bonne santé, montrant que l'amélioration des réponses affectives, des humeurs, des attitudes affectives, du plaisir *(enjoyment)*, de l'affect remémoré et de la motivation intrinsèque peut améliorer les niveaux d'activité physique (Chen et al., 2020 ; Rhodes, Gray, et al., 2019). Cependant, il convient de noter qu'une seule étude de notre revue systématique a réalisé une analyse de médiation (Pinto et al., 2023). Cette même étude présentait un risque de biais élevé et une qualité modérée, en raison de la connaissance par les participant·es du protocole et de leur condition expérimentale, du manque de représentativité de l'échantillon et du manque d'informations sur le taux d'adhésion des participant·es au protocole. Par conséquent, le niveau de confiance dans les résultats de l'analyse de médiation relativement limité.

En somme, bien que la Contribution n°5 ait identifié la planification du comportement comme TCC prometteuse pour améliorer les variables affectives liées à l'activité physique et les niveaux d'activité physique chez les personnes atteintes de maladies chroniques, l'hétérogénéité des études incluses a limité notre capacité tirer des conclusions fermes. De plus, la qualité des études et les risques de biais observés réduisent la confiance dans l'effet médiateur des variables affectives pour expliquer l'effet des interventions sur l'activité physique dans cette population. Des recherches supplémentaires sont donc nécessaires pour évaluer l'efficacité des TCC sur l'amélioration des variables affectives et pour déterminer si ces améliorations influencent les niveaux d'activité physique chez des personnes atteintes de maladies chroniques.

B. Stratégies d'interventions digitales ciblant la réponse automatique : faut-il jeter le bébé et l'eau du bain ?

Comme évoqué dans le Chapitre 6, plusieurs travaux ont suggéré de cibler les processus automatiques comme stratégie pour modifier les comportements de santé et prévenir les maladies chroniques (Marteau et al., 2012). Dans cette perspective, les tendances d'approche-évitement, une variable affective automatique la plus proximale du comportement, semble constituer une cible prometteuse pour les interventions visant à améliorer les niveaux d'activité physique (Cheval &

Boisgontier, 2021 ; Conroy & Berry, 2017). Cependant, notre Contribution n°6 a mis en évidence les limites de ce type d'intervention (e.g., utilisation de la VAAST) pour modifier ces tendances et améliorer les niveaux d'activité physique quotidienne des personnes atteintes de maladies chroniques. Comme nous l'avons signalé plus haut, le taux important d'attrition pourrait s'expliquer notamment par le caractère répétitif de la tâche et la difficulté des patient·es à comprendre le sens de l'intervention ou à croire en son efficacité potentielle.

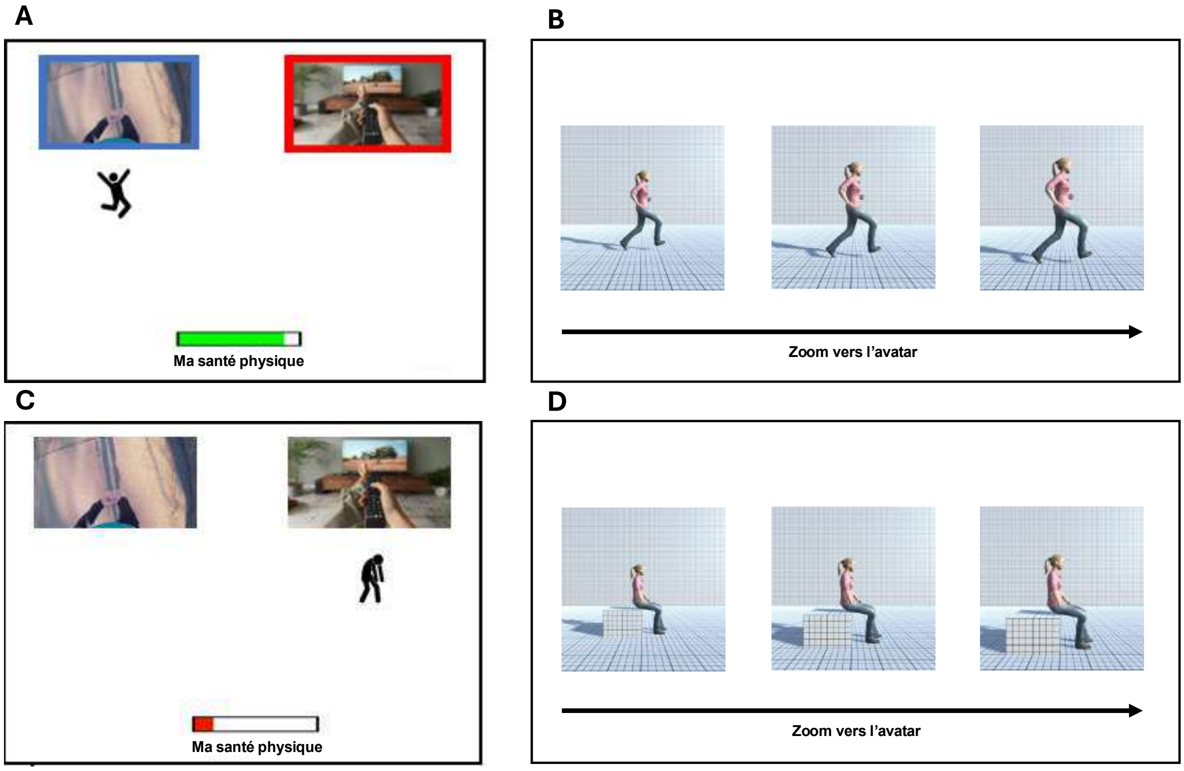
Ces retours posent la question de la pertinence de la VAAST comme stratégie d'intervention dans un programme de réadaptation cardiaque. Cependant, avant de remettre complètement en question l'intérêt de ce type d'intervention, il serait pertinent de tester d'autres formes de CBM, qui pourraient non seulement être plus motivantes pour les patient·es, mais aussi s'avérer plus efficaces. En effet, ces tâches pourraient, au-delà de la simple répétition d'associations stimulus-action (e.g., approcher l'activité physique ; Van Dessel et al., 2018), mais en intégrant également des informations sur les antécédents et les conséquences du comportement recherché (Van Dessel et al., 2018). C'est dans cette optique que la procédure d'entraînement A-B-C (*Antecedent-Behaviour-Consequence*) a été développée (Wiers et al., 2020). Elle se concentre sur trois éléments clés, chacun adapté aux expériences personnelles : (a) les antécédents contextuels spécifiquement liés à des obstacles potentiels pour atteindre des objectifs à long terme (e.g., « Lorsque j'ai peu d'énergie, je suis plus enclin·e à renoncer à ma séance d'activité physique ») ; (b) les alternatives comportementales adaptées à la situation individuelle (e.g., « Courir est un bon moyen pour moi de rester actif·ve » vs. « Regarder la télévision pourrait m'empêcher de courir ») ; et (c) les conséquences personnelles associées aux actions (e.g., « Le plaisir que je ressens pendant l'activité physique est ma principale motivation »).

Dans une étude récente (Maltagliati, Sarrazin et al., 2024), nous avons évalué l'efficacité d'un entraînement A-B-C chez des adultes d'âge moyen en bonne santé. La tâche proposée dans cette étude offrait plusieurs avantages par rapport à la VAAST, notamment une personnalisation accrue, un réalisme plus marqué et une approche plus ludique. Tout d'abord, les participant·es pouvaient choisir les stimuli d’activité physique et de comportements sédentaires qui leur étaient pertinents. Ensuite, elles et ils avaient la possibilité de sélectionner trois situations à risque (i.e., les antécédents) dans lesquelles les comportements sédentaires étaient particulièrement susceptibles de faire obstacle à l'adoption de l’activité physique (e.g., manque de temps, manque d’énergie). Enfin, elles et ils devaient choisir trois conséquences de l’activité physique qui leur paraissaient particulièrement importantes (e.g., plaisir, santé mentale, affiliation). Dans les blocs d’entrainement, les participant·es étaient d’abord exposé·es à l’un des antécédents sélectionnés (e.g., « Quand j’ai peu d’énergie »). Ensuite, un avatar les représentant apparaissait au centre de l’écran, suivi par deux images dans les coins supérieurs : l’une représentant une activité physique, l’autre un comportement sédentaire parmi les options sélectionnées. Quand les participant·es parvenaient à s’approcher de l’activité physique, des conséquences positives s’affichaient sous la forme d’une « barre des conséquences » dont le niveau augmentait, et un avatar qui devenait plus heureux. À l’inverse, lorsqu’elles et ils se rapprochaient du comportement sédentaire, la barre des conséquences diminuait et l'avatar avait l’air plus triste (Figure 6).

Bien que cette étude n’ait pas montré d’amélioration significative des niveaux d’activité physique ultérieurs, les participant·es à l’entrainement A-B-C ont rapporté des évaluations affectives automatiques plus positives envers l’activité physique et une probabilité plus élevée de choisir une activité physique (vs. un comportement sédentaire) dans une tâche de libre choix. Ce protocole pourrait inspirer des adaptations pour surmonter les limites de la VAAST identifiées dans la Contribution n°6 (e.g., la perception de la tâche comme étant ennuyeuse, un manque de lien perçu entre la tâche et l’activité physique). Des études futures pourraient ainsi explorer l’intégration de l’entraînement A-B-C dans un programme de réadaptation hospitalier, pour augmenter les niveaux d’activité physique des patient·es à la sortie du programme, en renforçant leurs tendances automatiques à s'approcher de l'activité physique.

Figure 6

Tâches d'entraînement A-B-C (figure A et C) et VAAST (figure B et D)



Note. Les figures A-C et B-D correspondent aux réponses d'une action d'approche d'un stimulus d'activité physique versus de comportement sédentaire, dans une tâche d'entraînement A-B-C et de VAAST, respectivement. Les figures A et C sont adaptées de Maltagliati, Sarrazin, et al. (2024). Les figures B et D sont adaptées de Cheval et al. (2021).

Bien que ce type de stratégie d'intervention ait démontré une certaine efficacité pour réduire les comportements addictifs tels que l'arrêt du tabac, la diminution de la consommation d'alcool ou la restriction alimentaire (Aulbach et al., 2019 ; Boffo et al., 2019 ; Jones & Sharpe, 2017 ; Van Dessel et al., 2018 ; Wiers et al., 2011), les résultats sont plus mitigés concernant l'amélioration de l'activité physique (Cheval et al., 2015 ; Maltagliati, Sarrazin, et al., 2024 ; Preis et al., 2021). Cette différence pourrait s'expliquer par la nature même des comportements ciblés. En effet, dans le cas des comportements addictifs, il s'agit d'entrainer les tendances automatiques à *éviter* un comportement nocif. Ces tendances n'ont en théorie aucune raison d'être altérées, tant que les participant·es ne font pas l'expérience du comportement indésirable, dont les bénéfices affectifs pourraient les amener à les réviser. Autrement dit, l'intervention est efficace tant que les participant·es ne font pas de rechute. Dans le cas des comportements positifs comme l'activité physique, l'objectif est d'entrainer les tendances automatiques à *approcher* un comportement positif. Si l'entrainement pourrait maximiser la décision de faire de l'activité physique (Maltagliati, Sarrazin, et al., 2024), il se heurte à une difficulté majeure : les participant·es doivent passer à l'action et réaliser le comportement d'activité physique, ce qui les expose directement à une expérience qui peut être positive ou négative.

Si l'expérience de l'activité physique est positive, elle renforcera les effets de l'entraînement d'approche et, *in fine*, l'adoption du comportement. En revanche, une expérience négative pourrait entrer en conflit avec l'entraînement, compromettant son efficacité. Dans ce cas, il est probable que l'expérience vécue prédomine sur la modification des tendances d'approche, dont les effets pourraient n'être que temporaires (e.g., Cheval, Sarrazin, Pelletier, et al., 2016). Les résultats de Maltagliati, Sarrazin, et al. (2024) appuient cette hypothèse. Bien que l'entraînement A-B-C ait amélioré les évaluations affectives automatiques envers l'activité physique et la préférence pour cette activité par rapport à un comportement sédentaire, il n'a pas influencé le comportement réel. Cela suggère que les participant·es ont peut-être ressenti une envie initiale de pratiquer une activité physique après l'intervention (e.g., Cheval et al., 2016), mais que seul·es ceux·celles qui ont ressenti des expériences positives ont continué de pratiquer alors que ceux·celles qui ont éprouvé des expériences négatives n'ont pas persévéré ; d'où l'absence d'efficacité de l'intervention sur le comportement réel.

C. Stratégies d'interventions endogènes : tout est bien qui finit bien ?

Dans la section 9.1, nous avons vu que la somme des réponses affectives ressenties lors d'expériences d'activité physique pouvait favoriser le développement d'associations affectives positives envers ce comportement, augmentant ainsi la probabilité d'engagement dans des activités physiques (Ekkekakis et al., 2021 ; Williams et al., 2019). Par conséquent, les stratégies d'intervention basées sur des expériences directes d'activité physique sont susceptibles d'améliorer les réponses affectives immédiates ou anticipées, l'affect remémoré, les attitudes affectives, les évaluations affectives automatiques ou encore les tendances d'approches évitement, et en retour, les niveaux d'activités physiques.

Bien qu'une amélioration significative des attitudes affectives envers l'activité physique ait été observée, la Contribution empirique n°7 n'a pas révélé d'effet significatif de la diminution de l'intensité en fin de séances d'APA sur les niveaux d'activité physique quotidiens durant la période de prise en charge hospitalière, chez des patient·es atteint·es de la maladie de Parkinson. À notre connaissance, cette étude est la première à évaluer l'effet de ce type de stratégie endogène sur les niveaux d'activité physique quotidiens, alors que les recherches précédentes se sont principalement concentrées sur son impact sur les variables affectives (Hutchinson et al., 2023 ; Hutchinson et al., 2020 ; Zenko et al., 2016), sans examiner les comportements d'activité physique. Outre les limites déjà mentionnées de notre étude, à savoir la faible taille de l'échantillon et l'absence de contrebalancement des conditions, il est possible que les spécificités de la population incluse dans cette étude préliminaire aient limité notre capacité à observer un effet de l'intervention. En effet, les traitements médicamenteux prescrits pour les personnes atteintes de maladies chroniques peuvent induire des fluctuations motrices appelées « phénomène on-off » (Bhidayasiri & Tarsy, 2012). Ces fluctuations se caractérisent par des périodes d'amélioration de la mobilité (« on ») et des périodes d'altération de la fonction motrice (« off »), avec des transitions parfois brutales entre mobilité et immobilité (Bhidayasiri & Tarsy, 2012). Il est donc possible que l'efficacité de cette stratégie d'intervention endogène soit limitée chez cette population en raison de ces fluctuations motrices.

En conclusion, la Contribution empirique n°7 ne permet pas de conclure quant à l'efficacité de cette stratégie d'intervention endogène pour améliorer les variables affectives et les niveaux d'activité physique chez les personnes atteintes de la maladie de Parkinson. Des essais randomisés contrôlés de plus grande envergure seront nécessaires pour valider cette approche, avec un contrôle plus rigoureux de l'intensité de l'effort. Ces études devront inclure à la fois des maladies chroniques qui limitent directement la mobilité (e.g., maladie de Parkinson) et d'autres pathologies qui présentent moins de difficultés motrices, comme les maladies cardiovasculaires ou le diabète de type 2.

9.4 Limites et forces de ce travail doctoral

En plus des limites propres à chacune des contributions empiriques, il est également important de considérer des limites générales qui peuvent affecter l'interprétation globale de ce travail doctoral.

Premièrement, la validité prédictive des variables affectives sur les niveaux d'activité physique constitue une limite importante. Bien que les Contributions n°6 et 7 aient cherché à tester expérimentalement cette relation, l'essentiel des conclusions repose sur des données corrélationnelles. Même si nous avons soigneusement contrôlé des variables de confusion et appliqués des analyses statistiques rigoureuses, ces données ne permettent pas d'établir de relations causales. Des recherches supplémentaires utilisant une méthode expérimentale pour manipuler les variables affectives seraient donc nécessaires pour mieux cerner l'impact des variables affectives sur les niveaux d'activité physique des personnes atteintes de maladies chroniques.

Deuxièmement, l'hétérogénéité des études incluses dans notre revue systématique (Contribution n°5), ainsi que le faible nombre participants de nos études interventionnelles (Contributions n°6 et 7), ont limité la capacité à identifier les stratégies d'intervention les plus efficaces pour améliorer les variables affectives liées à l'activité physique. Cela a également restreint la possibilité d'évaluer si ces améliorations contribuaient en retour à des niveaux d'activité physique plus élevés.

Troisièmement, la diversité des maladies chroniques, dont étaient atteints les patient·es inclus·es dans les protocoles, bien qu'elle permette d'explorer les mécanismes affectifs communs, complique la généralisation des résultats. Chaque maladie chronique possède des caractéristiques uniques, telles que la sévérité des symptômes et les limitations fonctionnelles (Barlow et al., 2000 ; Bhidayasiri & Tarsy, 2012 ; Kroenke et al., 2013 ; Slysz et al., 2021 ; World Health, 2003), qui pourraient influencer de manière distincte les variables affectives et les niveaux d'activité physique.

Cependant, ce travail doctoral possède aussi des forces théoriques et méthodologiques significatives qui contrebalancent ses limites. Tout d'abord, il s'inscrit dans le courant de l'affectivisme et s'appuie sur les modèles théoriques affectifs les plus récents (Brand & Ekkekakis, 2018 ; Cheval &

Boisgontier, 2021 ; Conroy & Berry, 2017 ; Stevens et al., 2020), en explorant les variables et mécanismes affectifs qu'ils proposent (e.g., réponses affectives), tout en intégrant des variables issues de modèles socio-cognitifs traditionnels (e.g., sentiment d'efficacité personnelle). Cette approche intégrative permet ainsi de mieux comprendre les mécanismes affectifs et cognitifs qui sous-tendent les comportements d'activité physique chez les personnes atteintes de maladies chroniques. Par ailleurs, ce travail doctoral est, à notre connaissance, le premier à distinguer clairement trois stratégies d'intervention sur les variables affectives liées à l'activité physique : (1) des stratégies endogènes basées sur l'expérience directe de l'activité physique, (2) des stratégies exogènes également basées sur cette expérience directe, et (3) des interventions digitales ciblant les réponses automatiques sans expérience réelle de l'activité physique. Les deux premières stratégies, endogène et exogène, visent à influencer les réponses affectives immédiates à travers l'expérience vécue. Les stratégies endogènes manipulent des caractéristiques intrinsèques à l'activité physique, telles que la fréquence, l'intensité ou la durée, tandis que les stratégies exogènes agissent sur des facteurs environnementaux et situationnels externes (e.g., la musique) pour améliorer l'expérience physique. La troisième stratégie repose vise à créer artificiellement de nouvelles associations affectives via des tâches telles que la manipulation des tendances d'approche-évitement, souvent réalisées sans véritable pratique d'activité physique (Cheval, Sarrazin, Pelletier, et al., 2016 ; Maltagliati, Sarrazin, et al., 2024 ; Preis et al., 2021).

Sur le plan méthodologique, l'une des forces de ce travail réside dans la diversité des mesures employées pour capturer les construits étudiés. Nous avons utilisé des tâches de temps de réaction pour évaluer les variables affectives automatiques (i.e., évaluations affectives automatiques et tendances d'approche-évitement), conformément à une approche à doubles processus (Zenko & Ekkekakis, 2019). De plus, les niveaux d'activité physique ont été mesurés à l'aide d'accéléromètres pour mesurer, ce qui a permis de réduire les biais généralement associés aux mesures auto-rapportées (Dyrstad et al., 2014). Enfin, des questionnaires auto-rapportés ont également été utilisés, complétant ces mesures directes et offrant une évaluation globale des comportements et expériences liés à l'activité physique.

La diversité des analyses statistiques employées représente également une force de ce travail doctoral, avec des modèles de régressions linéaires et logistiques, des modèles linéaires mixtes, ainsi que des analyses de modulation et de médiation, des comparaisons de tailles d'effet, et des évaluations de risques de biais et de qualité de preuves scientifiques. Enfin, ce projet doctoral s'inscrit dans une démarche de science ouverte. Le matériel utilisés, les données, et les analyses sont publiquement accessibles sur des plateformes dédiées (Contributions n°1, 2, 4, 5, 6 et 7). De plus, les protocoles de recherche de certaines contributions empiriques ont été préenregistrés (Contributions n°5 et 7), assurant ainsi une transparence accrue. Il convient également de noter qu'à l'exception des participant·es du groupe contrôle de la Contribution empirique n°1, ce travail doctoral a exclusivement recruté des personnes atteintes de maladies chroniques (Contributions n°1, 2 et 7), ce qui renforce la pertinence des résultats pour cette population cible.

9.5 Conclusion

Ce travail doctoral défendait la thèse suivante : « La manipulation de variables affectives telles que les réponses affectives, l'affect remémoré et les tendances d'approche-évitement pourrait améliorer l'engagement dans les activités physiques chez les personnes atteintes de maladies chroniques ». Bien que nos résultats suggèrent (a) une association significative entre les attitudes affectives, les réponses affectives et les niveaux d'activité physique quotidiens dans cette population (Contributions empiriques n°1, et 2), ainsi que (b) la possibilité de manipuler ces variables affectives à travers plusieurs stratégies d'interventions endogènes et exogènes (Contributions n°3, 4 et 7), ils ne permettent pas de valider pleinement cette thèse. En effet, ce travail doctoral n'a pas permis d'identifier des stratégies d'intervention efficaces pour favoriser la pratique d'activité physique en manipulant des variables affectives chez les personnes atteintes de maladies chroniques (Contributions n°5, 6 et 7). Toutefois, certaines pistes prometteuses ont été esquissées, qui méritent d'être approfondies. Des études futures seront nécessaires pour confirmer et affiner ces résultats, en explorant plus largement leur impact sur l'engagement à long terme dans l'activité physique.

Bien qu'il soit encore prématuré de tirer des conclusions appliquées de ce travail, dans la mesure où il n'apporte pas de données probantes solides, quelques pistes peuvent néanmoins être envisagées pour promouvoir l'activité physique chez les personnes atteintes de maladies chroniques. De manière générale, ce travail réaffirme l'idée que la pratique d'activités physiques peut évoluer au-delà d'une simple recommandation médicale, pour devenir une véritable source de plaisir et d'épanouissement. Il invite alors les professionnel·les de santé et de l'activité physique, ainsi que les instances gouvernementales, à accorder une plus grande importance au plaisir associé aux expériences d'activité physique dans leur stratégie de promotion de ces activités. De plus, les interventions endogènes et exogènes proposées dans cette thèse se démarquent par leur simplicité d'application, leur faible coût et leur flexibilité, permettant une adaptation aux besoins des personnes et aux ressources disponibles. Cette approche ouvre de nouvelles perspectives pour améliorer la qualité de vie les personnes atteintes de maladies chroniques, en transformant la pratique d'activités physiques en une opportunité d'épanouissement personnel, ancrée dans une expérience affective positive.

Glossaire

Activité physique adaptée : La pratique d'activité physique dans un contexte d'activité du quotidien, de loisir, de sport ou d'exercices programmés, des mouvements corporels produits par les muscles squelettiques, basée sur les aptitudes et les motivations des personnes ayant des besoins spécifiques qui les empêchent de pratiquer dans des conditions ordinaires (Article D. 1172-1 du Code de la santé publique – décret n° 2016-1990 du 30 décembre 2016 – art. 1).

Affect : Terme générique décrivant les états affectifs tels que les émotions et les humeurs (Niven, 2020).

Affect fondamental *(core affect)* : État neuro-physiologique accessible à la conscience en tant que simple sentiment primitif non réfléchi, qui se manifeste le plus souvent à travers l'humeur et l'émotion (Russell & Feldman Barrett, 2009b). Il est caractérisé par deux dimensions élémentaires indépendantes et transculturel : la valence (sensation de plaisir-déplaisir) et l'activation (ou *arousal*, sensation d'énergie-épuisement).

Affect remémoré : « Le souvenir de la réponse affective lors d'une activité physique précédente. » (Stevens et al., 2020, p. 10 ; traduction libre).

Attentes de résultat (ou utilité) **:** La valeur subjective d'un résultat donné pour un individu (American Psychological Association, 2018).

Attitudes instrumentales : La mesure dans laquelle la réalisation d'un comportement est perçue comme ayant une valeur positive ou négative de manière instrumentale, c'est-à-dire son importance (Ajzen, 1991). Autrement dit, il s'agit de savoir si le comportement est anticipé comme étant délétère ou bénéfique, ainsi que s'il est considéré comme utile ou inutile (La Barbera & Ajzen, 2024).

Associations affectives : Liens mémorisés entre un comportement cible et les réponses affectives éprouvées lors d'expériences antérieures de ce comportement (Kiviniemi et al., 2007).

Effet de débordement (*spillover effect*) **:** L'adoption d'un comportement (e.g., courir tous les jours 30 min) influence la probabilité d'adopter un second comportement (e.g., prendre les escaliers plutôt que l'ascenseur) (Nilsson et al., 2017). Selon Nilsson et al. (2017), trois types d'effet de débordement sont à distinguer : (a) l'effet comportemental (réaliser le comportement A influence la probabilité de réaliser le comportement B), (b) l'effet temporel (réaliser le comportement A au temps 1 affecte la probabilité de réaliser le comportement A au temps 2), et (c) l'effet contextuel (réaliser le comportement A dans un contexte 1 affecte la probabilité de réaliser le comportement A dans le contexte 2).

Émotion : « Processus rapide, focalisé sur un événement et constitué de deux étapes. La première est un mécanisme de déclenchement fondé sur la pertinence de l'événement qui façonne la seconde étape. Cette seconde étape est une réponse constituée de plusieurs composantes (les tendances à l'action, les réactions du système nerveux autonome, l'expression et le sentiment). » (Sander, 2016, p. 4).

Évaluations affectives automatiques (ou attitudes implicites) : Actions ou jugements qui sont sous le contrôle d'une évaluation activée automatiquement, sans que l'exécutant·e soit conscient·e de cette causalité (Greenwald et al., 1998, p. 1464).

Évaluations affectives réfléchies (ou attitudes affectives) : Évaluations d'un comportement basées sur l'agrégation de différentes réponses affectives potentielles anticipées (e.g., l'activité physique est amusante vs. ennuyeuse, énergisante vs. fatigante, déplaisante vs. plaisante) (Williams & Evans, 2014).

Jugements affectifs : Un terme générique développé par Rhodes et al. (2009) pour inclure collectivement tout construit qui mesure les réflexions ou les attitudes passées concernant le plaisir *(enjoyment*) ou l'amusement associé à un comportement cible (Williams & Rhodes, 2023).

Humeur : « Un état affectif de longue durée, de faible intensité et qui présente un caractère diffus. » (Frijda, 2009b, p. 383 ; traduction libre).

Inactivité physique : Un niveau d'activité physique insuffisant pour atteindre les recommandations actuelles en matière d'activité physique (Bull et al., 2020 ; Tremblay et al., 2017). Par exemple, chez les adultes, il s'agit d'atteindre 150 minutes d'activité physique d'intensité modérée à vigoureuse par semaine ou 75 minutes d'activité physique d'intensité vigoureuse par semaine, ou une combinaison équivalente d'activité physique d'intensité modérée et vigoureuse (Bull et al., 2020).

Intention : Degré de volonté, d'effort ou de motivation qu'une personne est prête à consentir pour réaliser un comportement donné (Rhodes & Rebar, 2017).

Maladie chronique : État chronique qui se caractérise par : 1) la présence d'un état pathologique de nature physique, psychologique ou cognitive, appelé à durer, 2) une ancienneté minimale de trois mois, ou supposée telle ; 3) un retentissement sur la vie quotidienne comportant au moins l'un des éléments suivants : a) une limitation fonctionnelle des activités ou de la participation sociale, b) une dépendance vis-à-vis d'un médicament, d'un régime, d'une technologie médicale, d'un appareillage ou d'une assistance personnelle, c) la nécessité de soins médicaux ou paramédicaux, d'une aide psychologique, d'une adaptation, d'une surveillance ou d'une prévention particulière pouvant s'inscrire dans un parcours de soins médico-social » (Haut Conseil de la Santé Publique, 2009).

Mécanisme affectif : Processus par lesquels les différentes variables affectives interagissent entre elles et se manifestent (Schiller et al., 2024).

Modèles socio-cognitifs : Le cadre socio-cognitif est né du désir croissant des chercheur·euses en psychologie d'aller au-delà du béhaviorisme et d'adopter un paradigme cognitif impliquant l'apprentissage social et les représentations mentales de la motivation (Kerlinger, 1966 ; Locke, 1968 ; Rhodes, McEwan, et al., 2019). Dans le domaine des comportements de santé, les modèles socio-cognitifs dominants considèrent que les choix individuels sont influencés par une évaluation consciente et rationnelle des avantages et des inconvénients potentiels des actions envisagées (Rhodes, McEwan, et al., 2019).

Motivation autonome : Engagement dans un comportement régulé pour des raisons intrinsèques ou intégrées et associées au fait d'être à l'origine de son choix, à de l'intérêt et de la satisfaction (Ryan & Deci, 2017).

Motivation contrôlée : Engagement dans un comportement régulé pour des raisons introjectées ou externes et associées à des pressions, à un sentiment d'obligation (Ryan & Deci, 2017).

Motivation extrinsèque : Tout engagement dans une activité dans le but d'atteindre un résultat quelconque qui lui est associé, tels que l'obtention d'une récompense ou l'évitement d'une punition (Sarrazin et al., 2011). On parle parfois de motivation « instrumentale », pour signifier que l'activité ou l'objet qui motive n'est qu'un moyen, ou un instrument, pour atteindre autre chose (Sarrazin et al., 2011).

Motivation hédonique : Mécanisme par lequel les expériences affectives passées influencent le comportement futur, conformément au principe hédonique (Williams, 2018, 2019).

Motivation intrinsèque : Réalisation d'une activité pour la satisfaction qu'elle lui procure en elle-même, et non pour une conséquence quelconque qui en découlerait, tels que les passe-temps ou les activités de loisir (Deci & Ryan, 2000 ; Sarrazin et al., 2011).

Plaisir (*enjoyment*) : La définition du terme *enjoyment* est complexe et fait difficilement consensus. Dès la fin des années 1990, Kimiecik et Harris (1996) critiquaient la manière dont cette variable était abordée dans les études de psychologie du sport et de l'exercice. Ces auteurs distinguaient l'*enjoyment* du plaisir, des attitudes affectives et de la motivation intrinsèque, le définissant comme « *un état psychologique facultatif qui conduit à réaliser une activité principalement pour elle-même et qui est associé à des états affectifs positifs*. » (Czikszentmihalyi, 1990 ; Kimiecik & Harris, 1996). Selon eux, « *la recherche en psychologie du sport et de l'exercice qui a étudié l'enjoyment comme un affect positif devrait être considérée comme un travail qui a examiné l'affect positif et non l'enjoyment* » (Kimiecik & Harris, 1996, p. 259). Les auteurs critiquent également la conception du Physical Activity Enjoyment Scale (Kendzierski & DeCarlo, 1991), un outil de référence pour mesurer l'*enjoyment*, qu'ils jugent fondé sur une définition insuffisante du construit. Vingt-quatre ans plus tard, Stevens et al. (2020) intègrent l'*enjoyment* dans la même catégorie que les attitudes affectives, le considérant comme une évaluation affective d'un objet, tel que l'activité physique.

Prévention primaire : Mesures d'intervention visant à prévenir l'apparition (incidence) d'une nouvelle maladie, d'un nouveau handicap ou d'une nouvelle blessure (Clark & Leavell, 1965). Cette intervention doit être mise en œuvre avant la pathogenèse et s'adresser aux individus ou aux groupes à risque (Baumann & Ylinen, 2020).

Prévention secondaire : Ensemble de mesures utilisées pour la détection précoce et l'intervention rapide afin de contrôler un problème ou une maladie (prévalence) et d'en minimiser les conséquences. La prévention secondaire englobe les interventions qui augmentent la probabilité qu'une personne atteinte d'une affection soit diagnostiquée à un stade où le traitement est susceptible d'entraîner une guérison ou une réduction de la gravité de l'affection (Baumann & Ylinen, 2020).

Principe de correspondance : Pour évaluer correctement la force d'une association entre une variable psychologique (e.g., les attitudes affectives) et un comportement cible (e.g., l'activité physique), il est nécessaire de respecter une correspondance étroite, en termes de spécificité ou de généralité, dans la mesure de ces variables (Ajzen & Fishbein, 1977 ; Ajzen & Timko, 1986 ; Irving & Smith, 2020).

Prévention tertiaire : Réduction des complications ultérieures d'une maladie, d'un handicap ou d'une blessure existants, par le biais d'un traitement et d'une rééducation (Baumann & Ylinen, 2020).

Rebond affectif : Niveaux de plaisir plus élevés dans les minutes qui suivent la fin d'une séance d'exercice, comparativement à ceux mesurés au début de celle-ci (Ekkekakis et al., 2020).

Réponse affective : Les réponses affectives font référence aux affects fondamentaux *(core affect)* ressentis à un instant donné, incluant les dimensions de valence et d'activation (Brand & Ekkekakis, 2018 ; Stevens et al., 2020). Cependant, ces réponses affectives sont également mentionnées par certain·es auteur·es comme l'expérience affective de plaisir ou de déplaisir, faisant référence à la valence uniquement (Ekkekakis et al., 2020 ; Williams & Evans, 2014). Dans ce manuscrit, nous utilisons le terme *réponses affectives* pour faire référence à la dimension de valence (plaisir-déplaisir) et le terme *affect fondamental* pour faire référence aux dimensions de valence et d'activation *(core affect)*.

Réponse affective anticipée : « L'attente de ce qu'une personne ressentira en s'engageant ou en ne s'engageant pas dans une activité physique. » (Stevens et al., 2020, p. 10 ; traduction libre).

Sédentarité (ou comportement sédentaire) : Tout comportement éveillé associé à une dépense énergétique inférieure à 1,5 Metabolic Equivalent Task (MET) et réalisé en position assise ou inclinée (Tremblay et al., 2017).

Sentiment d'efficacité personnelle : La croyance d'une personne en ses capacités à organiser et à réaliser les actions nécessaires pour obtenir des résultats spécifiques (Bandura, 1997).

Sophisme du jingle-jangle *(jingle-jangle fallacy)* **:** Ce concept consiste à utiliser le même mot pour décrire des choses différentes (jingle ; Thorndike, 1904) et/ou utiliser des mots différents pour décrire la même chose (jangle ; Kelley, 1927).

Tendances à l'action : Une envie/urgence de réaliser certains comportements expressifs ou instrumentaux liés à une émotion spécifique. Par exemple, la tendance à l'action de la peur implique une envie/urgence de fuir, et celle de la colère une envie/urgence d'attaquer (American Psychological Association, 2018).

Tendances d’approche-évitement : Préparation automatique de l'organisme pour exécuter un schéma moteur en direction ou en évitement d'un comportement (Friese et al., 2011). Les tendances d’approche-évitement font partie des composantes constitutives de la réponse émotionnelle (Sander et al., 2018).

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Annexes

Annexe 1
Matériel supplémentaire — Contribution empirique n°2

Supplementary Material 1. Hypothesised Relationships

Supplementary Material 2. Inclusion Criteria and Additional Measures

Supplementary material 3. Sample Size Calculation and Sensitivity Analyses

Supplementary Material 4. Exercise Sessions Information

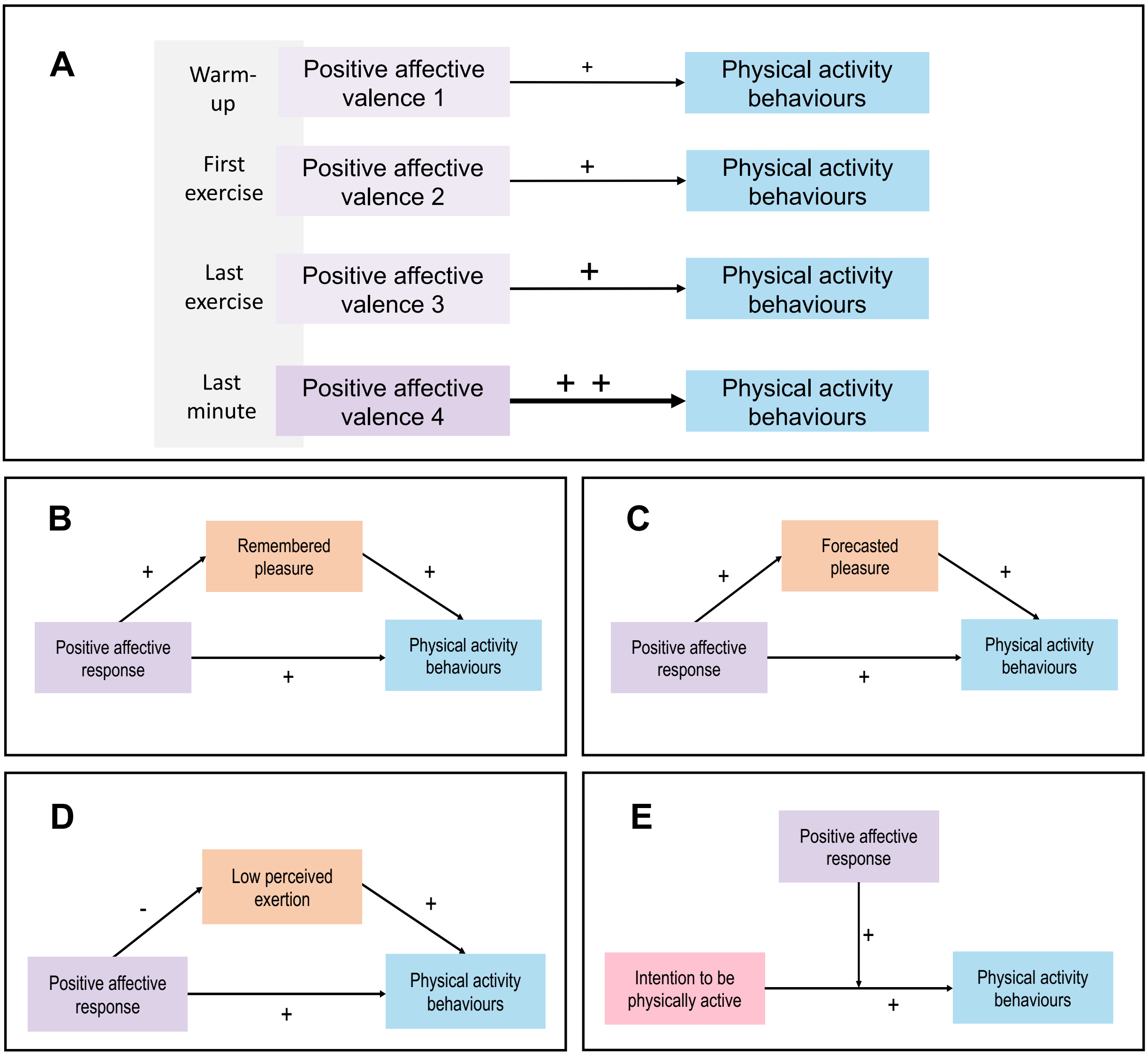
Supplementary Material 5. Additional Descriptive Analyses

Supplementary Material 6. Additional Univariate and Multivariate Regression Analyses

Supplementary Materials 1. Hypothesised Relationships

Figure S1

Hypothesised Relationships Across Psychological Variables and Physical Activity Behaviours



Note. Affective responses and perceived exertion were measured four times during an exercise session: (1) at the start of the warm-up, (2) at the start of the first exercises, (3) at the start of the last exercises, (4) and at the last minute of the session. Panel A show the association between each affective response and physical activity behaviours (H_1). Panels B, C, D and E shows the potential mechanisms underlying this association (H_2, H_3, H_4, E_1).

Supplementary Materials 2. Inclusion Criteria and Additional Measures

Inclusion Criteria

Participants were included in the study if they met the following criteria: (a) age over 18 years; (b) be exempt from any medical condition that would prohibit unsupervised physical activity; (c) be part of a rehabilitation programme or be enrolled in a sports club or association that includes at least one session of physical activity per week; (d) have declared at least one chronic disease or being enrolled in sport and health programmes for specific groups requiring special precautions (i.e., vulnerable individuals); (e) without a history of serious psychiatric, neurological or mental disorders, or taking psychotropic or illicit drugs at the time of the study; and (g) be able to fully understand spoken and written French. Compliance with the inclusion criteria was determined with the help of each association's team.

Post-Exercise Measure

Global perceived exertion was measured using the following item: « Overall, what level of effort did you put in during the exercise session? » (Foster et al., 2001). Participants answered on a scale from 0 (no effort at all) to 10 (maximal effort).

Participants Characteristics

Usual PA level was assessed using the Global Physical Activity Questionnaire (GPAQ; Armstrong & Bull, 2006). The GPAQ is a standardized survey developed by the World Health Organization to assess physical activity levels across various domains of daily life, including work, transportation, and leisure time. It consists of a series of questions aimed at capturing the frequency, duration, and intensity of physical activity performed in a typical week.

The socioeconomic status of the participants was evaluated by inquiring about their primary, secondary, and tertiary education qualifications, as well as their financial comfort (Fessler et al., 2023).

Self-efficacy towards the exercise session was measured using the following item: « How capable did you feel of doing the exercises during the session? » (Cheval et al., 2017). Participants answered on a scale from 1 (totally uncapable) to 7 (totally capable).

Self-efficacy towards PA was measured using the following questions: « How much do you feel able to do at least 30 minutes of MVPA a day on most days of the week in your free time or when travelling? » (Cheval et al., 2017). Participants were asked to answer using a 7-point scale ranging from 1 (totally uncapable) to 7 (totally capable).

Instrumental attitudes towards PA were assessed using the following item « For me, doing at least 30 minutes of MVPA a day on most days of the week in my free time or when travelling is something… » (Phipps et al., 2021). Participants answered on two scales from « 1 (useless, harmful) » to « 7 (useful, beneficial) ». Items were averaged (Pearson correlation =.73).

Affective attitudes towards PA were assessed using the following item « For me, doing at least 30 minutes of MVPA a day on most days of the week in my free time or when travelling is something… » (Phipps et al., 2021). Participants answered on two scales from « 1 (unpleasant, boring) » to « 7 (pleasant, fun) ». Items were averaged (Pearson correlation =.55).

A control variable assessing non-specific treatment effects of the coach across exercise sessions (Hutchinson et al., 2023) was measured using the four following items: ''I trust the coach to suggest appropriate exercises,'' ''The coach was very friendly,'' ''The coach listened carefully to the needs and difficulties I expressed during the session,'' and ''I feel that what the coach did and said in this session helped me to make progress.'' Participants answered on a scale from « 1 (strongly disagree) » to « 7 (strongly agree) ». Ratings indicated high levels of agreement for each statement (M_{trust} = 6.9±0.4; $M_{friendly}$ = 6.9±0.5; M_{needs} = 6.8±0.6; $M_{progress}$ = 6.5±0.9).

Additional measures were taken 24-48 hours after the exercise session. These measures belong to another associated project and are not relevant to the present study. The additional measures included motivations towards physical activity (Motivation Scale Towards Health-Oriented Physical

Activity; Boiché et al., 2019), automatic affective evaluation towards physical activity (Single-Category Implicit Association Test; Karpinski & Steinman, 2006) and approach-avoidance tendencies towards physical activity (Conflictual Manikin Task; Maltagliati, 2023).

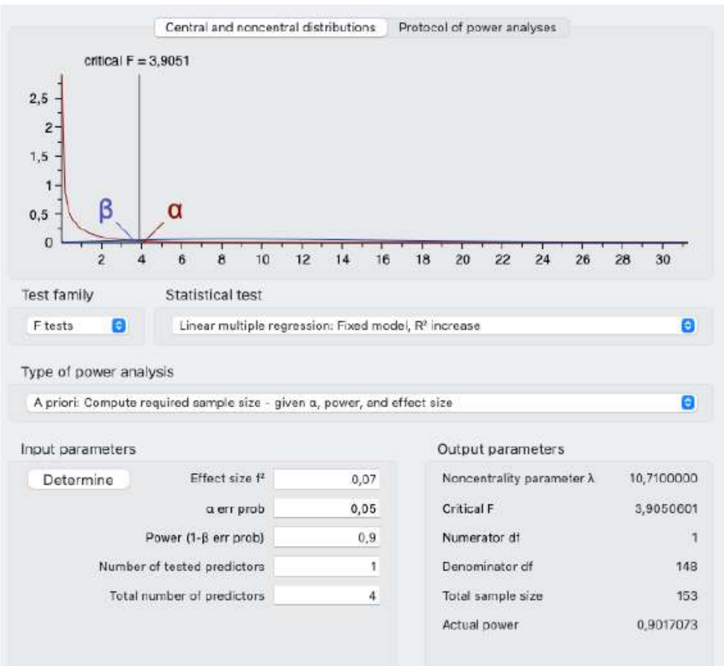
Physical Activity Measure

In addition to accelerometer, daily physical activity was self-reported using the short form of the International Physical Activity Questionnaire (Craig et al., 2003). Because self-reported physical activity is more likely to have estimation bias compared to device-based measures such as accelerometery (Atkin et al., 2012; Colley et al., 2018; Dyrstad et al., 2014), we used the accelerometer-based daily time spent engaging in physical activity of light, moderate, vigorous, and moderate-to-vigorous intensity as indicators of PA levels.

Supplementary materials 3. Sample Size Calculation and Sensitivity Analyses

Figure S2

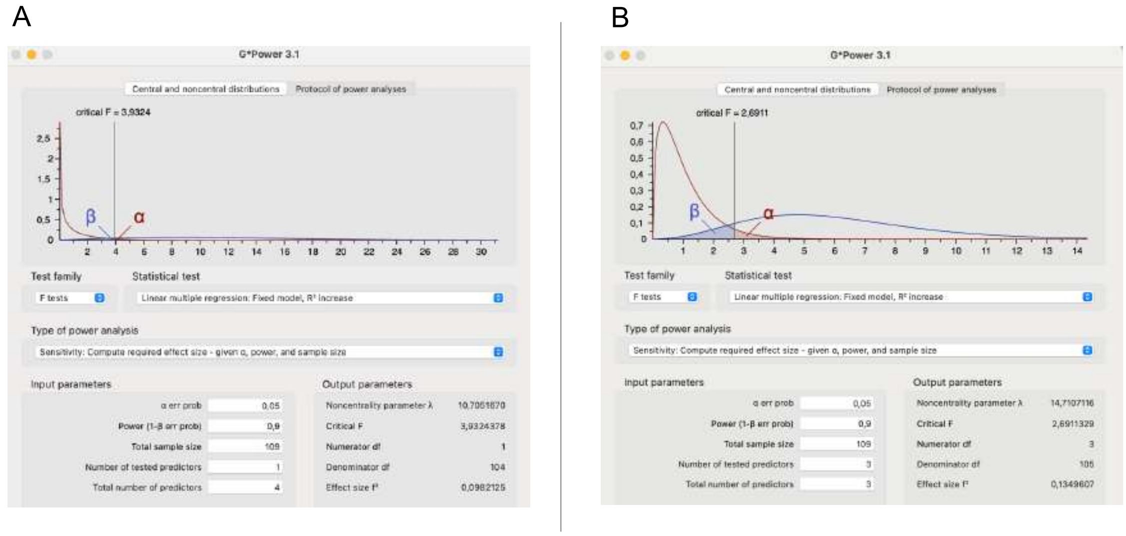
A priori power analysis



Note. Using G*Power (v. 3.1; Faul et al., 2009), an a priori power analysis for a linear multiple regression, an f^2 = .07/*r* =.25*,* an alpha level of .05 and a power of .90, for one predictor tested and four predictors in total (four timing of measurement) indicated that a sample 153 participants would be required to detect the SESOI (*rSESOI* =.25).

Figure S3

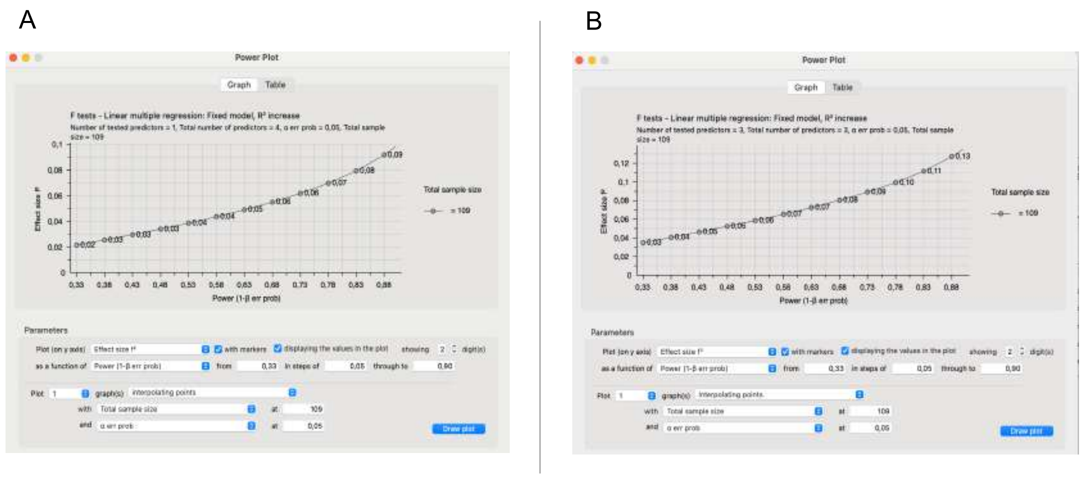
Sensitivity Analysis



Note. Panel A shows that with an alpha level of .05, with a sample size of 109 participants, for an univariate regression analysis (e.g., the affective response score at the end of an exercise session), the minimum effect size the present study can detect with 90% power is f^2 = .10/r =.31. B shows that with an alpha level of .05, with a sample size of 109 participants, for a multivariate regression analysis (i.e., one affective response score, body mass index and self-efficacy), the minimum effect size the present study can detect with 90% power is f^2 = .13/r = .35.

Figure S4

Sensitivity Plots



Note. Panel A shows that the present study had 78% power to detect the smallest effect size of interest (f^2_{SESOI} = .07/r_{SESOI} =.25), for an univariate linear regression analysis. Panel B shows that the present study had 63% power to detect the smallest effect size of interest (f^2_{SESOI} = .07/r_{SESOI} =.25), for a multivariate linear regression analysis with three predictors.

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Supplementary Material 4. Exercise Sessions Information

Table S1

Exercise Sessions Information

N = 109	Number of participants (%)	Missing (%)
Type of exercise		7 (6.42)
Aqua-aerobic	4 (3.92%)	
Cardiovascular training	5 (4.90%)	
Circuit training	30 (29.41%)	
Core training	1 (0.98%)	
Hiking	3 (2.94%)	
Resistance training	7 (6.86%)	
Soft gym	35 (34.31%)	
Step workout	1 (0.98%)	
Walk	9 (8.82%)	
Walk and resistance training	3 (2.94%)	
Yoga	4 (3.92%)	
Session's characteristics		7 (6.42)
Intervals	87 (85.29%)	
Continue	15 (14.71%)	
Group	102 (100%)	
Individual	0 (0%)	
Indoor	82 (80.39%)	
Outdoor	20 (19.61%)	
With music	86 (84.31%)	
Without music	16 (15.69%)	
With cool-down	4 (3.92%)	
Without cool-down	98 (96.08%)	

Continued

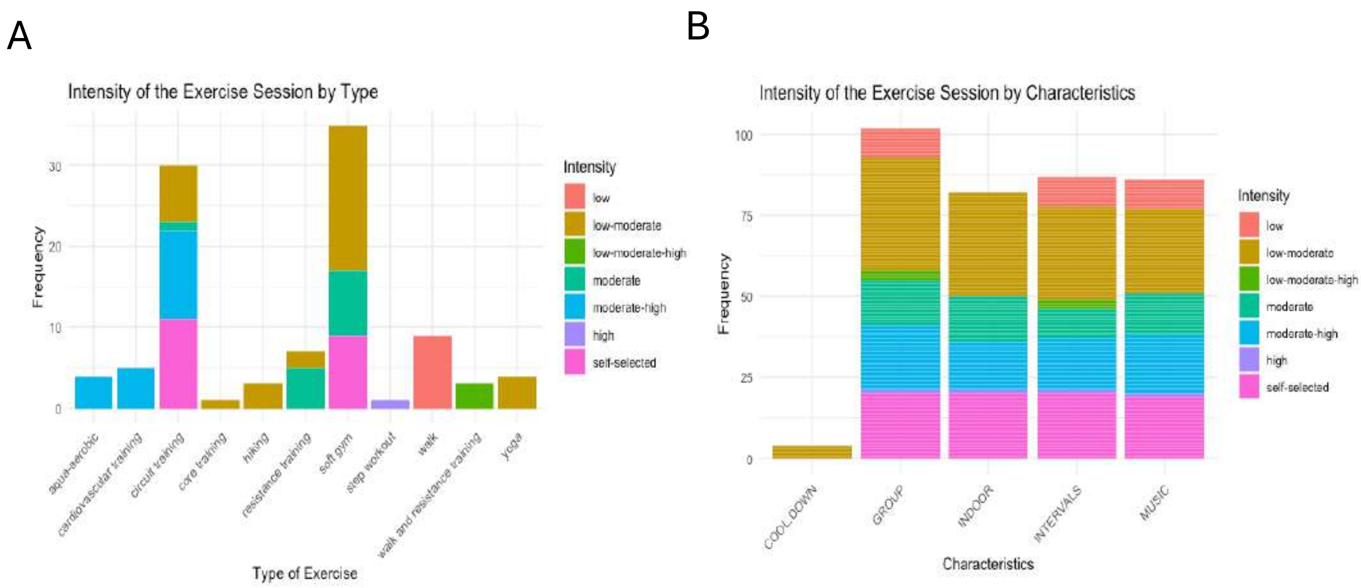
Table S1 (*continued*)

N = 109	Number of participants (%)	Missing (%)
Intensity		7 (6.42)
Low	9 (8.82%)	
Low to moderate	35 (34.31%)	
Low to moderate to high	3 (2.94%)	
Moderate	14 (13.73%)	
Moderate to high	20 (19.61%)	
High	1 (0.98%)	
Self-selected	20 (19.61%)	

Note. Soft gym, which involves low-impact, gentle movements aimed at improving flexibility, strength, and overall physical well-being, was the most common activity (34.31%). Low-to-moderate intensity was the most common exercise intensity (34.31%). Only four participants included a cool-down in their exercise sessions. Non-imputed data were carried out for the descriptive analyses.

Figure S5

Exercise Sessions Characteristics



Supplementary Materials 5. Additional Descriptive Analyses

Table S2

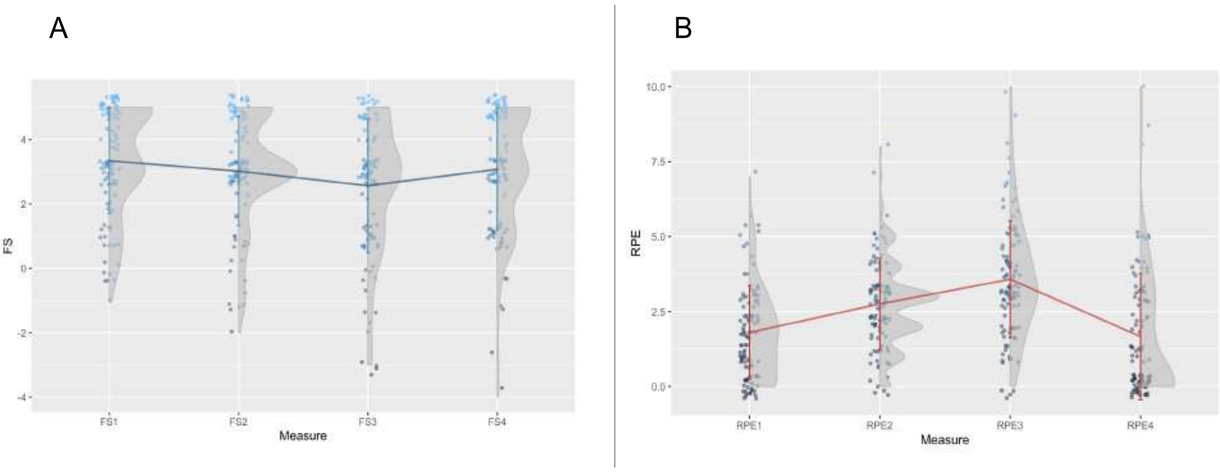
Mean Exercise-Related Variable During and After the Exercise Session

Variables	Mean (*SD*)	Missing (%)
Affective responses [-5–5]		
FS_1	3.34 (1.63)	7 (6.42)
FS_2	3.02 (1.69)	7 (6.42)
FS_3	2.57 (2.08)	7 (6.42)
FS_4	3.08 (1.90)	7 (6.42)
FS_{mean}	3.00 (1.38)	7 (6.42)
Perceived exertion [0–10]		
RPE_1	1.80 (1.56)	7 (6.42)
RPE_2	2.75 (1.52)	7 (6.42)
RPE_3	3.58 (1.95)	7 (6.42)
RPE_4	1.66 (2.10)	8 (7.34)
RPE_{mean}	2.45 (1.33)	7 (6.42)
Global perceived exertion [0–10]	3.38 (1.50)	17 (15.60)
Remembered pleasure [-5–5]	3.47 (1.50)	17 (15.60)
Forecasted pleasure [-5–5]	3.41 (1.52)	17 (15.60)
Self-efficacy towards exercise [1–7]	5.76 (1.30)	17 (15.60)
Intention towards PA [1–7]	5.53 (1.63)	17 (15.60)

Note. FS = Feeling Scale; RPE = rating of perceived exertion; PA = physical activity; MVPA = moderate-to-vigorous physical activity; RP = remembered pleasure; FP = forecasted pleasure. FS and RPE were measured four times during an exercise session: at the start of the warm-up (FS_1, RPE_1), at the start of the first exercises (FS_2, RPE_2), at the start of the last exercises (FS_3, RPE_3), and at the last minute of the session (FS_4, RPE_4).

Figure S6

Affective Responses and Perceived Exertion During the Exercise Session



Note. FS = feeling scale; RPE = rating of perceived exertion. FS and RPE were measured four times during an exercise session: at the start of the warm-up (FS_1, RPE_1), at the start of the first exercises (FS_2, RPE_2), at the start of the last exercises (FS_3, RPE_3), and at the last minute of the session (FS_4, RPE_4).

Supplementary Material 6: Additional Univariate and Multivariate Regression Analyses

Table S3

Association Between Affective Responses and Remembered Pleasure

Predictors	Univariate models				Multivariate model			
	b (95% CI)	*ß* (95% CI)	R^2 adj.	*p*	b (95% CI)	*ß* (95% CI)	Partial R^2	*p*
Intercept	3.51 (3.23; 3.79)	.01 (-0.18; .20)		<.001				
FS_1	0.43 (0.15; 0.71)	.29 (.10; .48)	.09	.003				
Intercept	3.51 (3.23; 3.78)	.01 (-0.18; .20)		<.001				
FS_2	0.56 (0.28; 0.84)	.36 (.17; .55)	.14	<.001				
Intercept	3.51 (3.26; 3.75)	.01 (-0.17; .18)		<.001				
FS_3	0.81 (0.56; 1.06)	.53 (.35; .70)	.30	<.001				
Intercept	3.50 (3.23; 3.77)	.01 (-0.17; .18)		<.001				
FS_4	0.63 (0.36; 0.90)	.41 (.22; .59)	.18	<.001				
R^2 adj.								
Intercept					3.50 (3.26; 3.74)	.01 (-0.16; .17)		<.001
FS_1					0.23 (-0.03; 0.51)	.17 (-.02; .36)	.09	.089
FS_2					-0.07 (-0.41; 0.28)	-.04 (-.28; .20)	.07	.701
FS_3					0.64 (0.32; 0.96)	.40 (.19; .63)	.17	<.001
FS_4					0.29 (-0.00; 0.59)	.19 (-.00; .39)	0.02	.052
Total R^2								.35

Note. FS = Feeling Scale. FS was measured four times during an exercise session: at the start of the warm-up (FS_1), at the start of the first exercises (FS_2), at the start of the last exercises (FS_3), and at the last minute of the session (FS_4).

Table S4

Association Between Affective Responses and Forecasted Pleasure

Predictors	Univariate models				Multivariate model			
	b (95% CI)	*ß* (95% CI)	R^2 adj.	*p*	b (95% CI)	*ß* (95% CI)	Partial R^2	*p*
Intercept	3.41 (3.11; 3.71)	.00 (-0.19; .19)		<.001				
FS_1	0.35 (0.04; 0.66)	.24 (.05; .48)	.05	.030				
Intercept	3.41 (3.11; 3.71)	.01 (-0.18; .20)		<.001				
FS_2	0.49 (0.19; 0.79)	.32 (.11; .52)	.11	.002				
Intercept	3.41 (3.12; 3.69)	-.00 (-0.18; .17)		<.001				
FS_3	0.70 (0.42; 0.98)	.44 (.27; .62)	.21	<.001				
Intercept	3.40 (3.10; 3.70)	-.01 (-0.17; .18)		<.001				
FS_4	0.46 (0.17; 0.75)	.31 (.11; .50)	.09	.002				
R^2 adj.								
Intercept					3.41 (3.13; 3.69)	-.00 (-0.18; .17)		<.001
FS_1					0.17 (-0.14; 0.49)	.13 (-.07; .34)	.05	.907
FS_2					0.01 (-0.38; 0.40)	.01 (-.28; .30)	.07	.760
FS_3					0.59 (0.21; 0.96)	.35 (.11; .58)	.11	.454
FS_4					0.13 (-0.21; 0.47)	.11 (-.12; .33)	.01	.679
Remembered pleasure					1.04 (0.77; 1.32)	.70 (.53; .87)	.29	<.001
Total R^2								.53

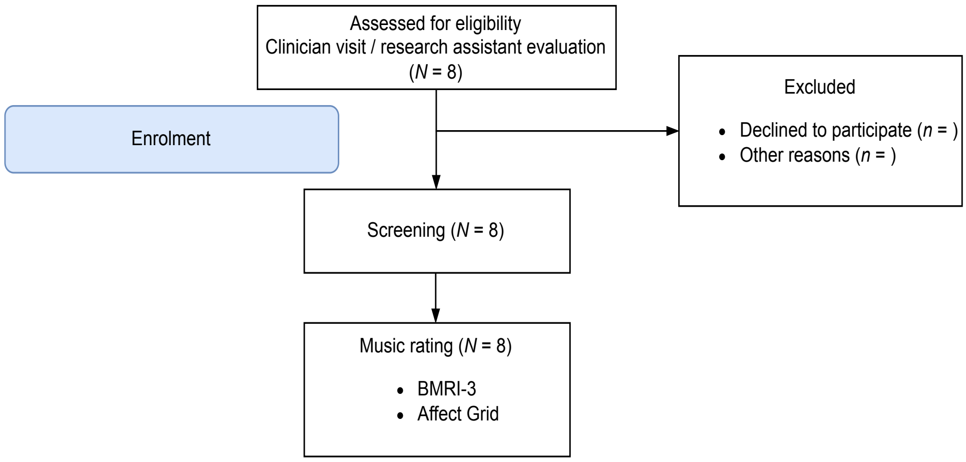
Note. FS = Feeling Scale. FS was measured four times during an exercise session: at the start of the warm-up (FS_1), at the start of the first exercises (FS_2), at the start of the last exercises (FS_3), and at the last minute of the session (FS_4).

Annexe 2
Matériel supplémentaire — Contribution empirique n°4

Supplementary Materials 1. Music Rating Panel

Figure 1

Music Rating Panel Flowchart



Note. BMRI-3 = Brunel Music Rating Inventory-3. Music selection will be determined using the BMRI-3 (Karageorghis, 2008) and the Affect Grid (Russell et al., 1989) to account for the motivational and affective aspects of a piece of music, respectively.

Table S1

Music Rating Panel Characteristics

N = 10	Mean (*SD*)
Age (years)	66.1 (5.95)
Sex (female, %)	5 (50%)
Country of secondary school (*n*, %)	
Bosnia	1 (10)
Spain	2 (20)
Portugal	1 (10)
Switzerland	6 (60)

References

Karageorghis, C. I. (2008). The scientific application of music in sport and exercise. *Sport and exercise psychology*, *109*, 138.

Russell, J. A., Weiss, A., & Mendelsohn, G. A. (1989). Affect grid: a single-item scale of pleasure and arousal. *Journal of personality and social psychology*, *57*(3), 493. https://doi.org/https://doi.org/10.1037/0022-3514.57.3.493

Brunel Music Rating Inventory-3 Track n°1 : GIMME! GIMME! GIMME!

This questionnaire is designed to assess how motivating you find the piece of music you are about to hear for exercising at a moderate intensity (where you are out of breath but can still hold a conversation). In this context, the word "motivate" means that the music would help you want to continue the session with more intensity, stay longer, or both. While listening to the piece of music, please indicate how much you agree with the six statements by circling one of the numbers to the right of each statement. Answer each statement honestly. Choose the response that best represents your opinion and try not to spend too much time on any single statement.

		Not agree at all						Totally agree
1	The **rhythm** of this music would motivate me during exercise sessions.	1	2	3	4	5	6	7
2	The **style** of this music would motivate me during exercise sessions.	1	2	3	4	5	6	7
3	The **melody** of this music would motivate me during exercise sessions.	1	2	3	4	5	6	7
4	The **tempo** (speed) of this music would motivate me during exercise sessions.	1	2	3	4	5	6	7
5	The **sound** of the instruments used (guitar, synthesiser, saxophone, etc.) would motivate me during exercise sessions.	1	2	3	4	5	6	7
6	The **beat** of this music would motivate me during exercise sessions.	1	2	3	4	5	6	7

Affect Grid   Track n°1 : GIMME! GIMME! GIMME!

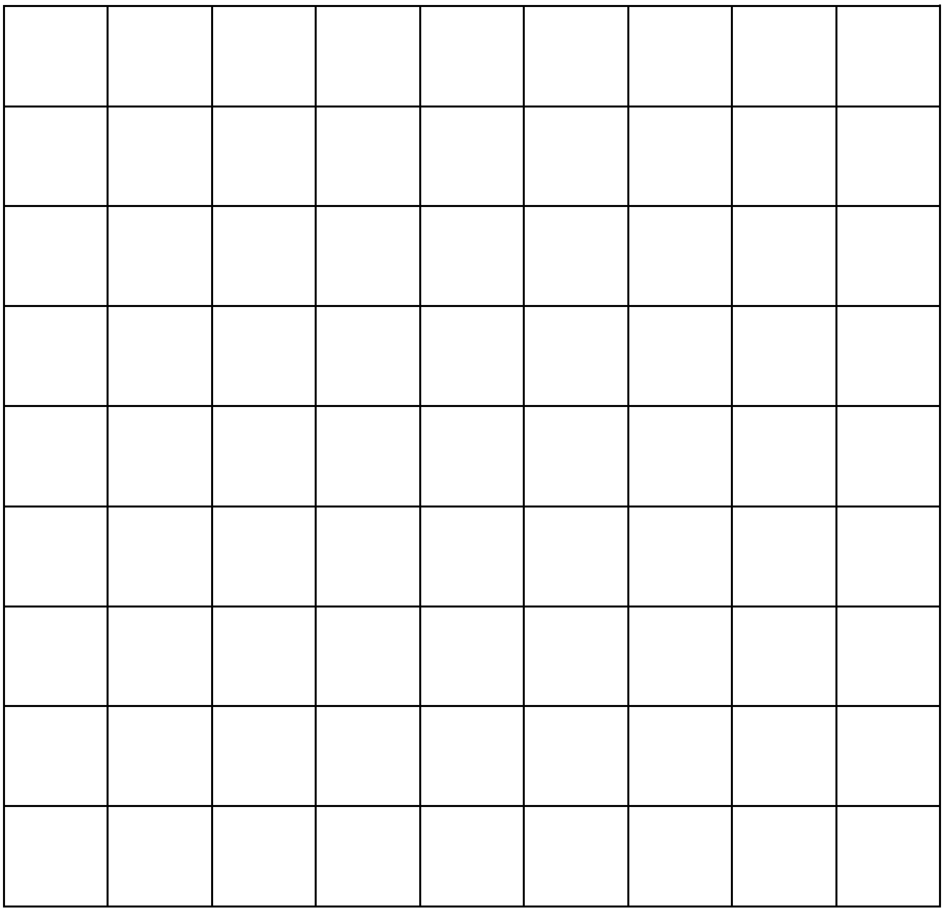
This grid is designed to evaluate the affective reaction that the piece of music you will hear elicits in you, particularly if it were played during exercise sessions of moderate intensity (you are a bit out of breath but can still hold a conversation with someone).

The grid assesses two dimensions: (1) the level of pleasure (pleasure vs. displeasure) and (2) the level of arousal (high arousal vs. sleepiness). By “arousal,” we mean the level of alertness or excitement you are experiencing. You can feel high arousal in various ways, such as through a sense of excitement, anxiety, or anger. Low arousal can also be felt in different ways, such as through a feeling of relaxation, calmness, or boredom.

The centre of the grid represents a "neutral" state. The vertical line corresponds to your level of arousal (the upper part if you feel high excitement, the lower part if it elicits a state of drowsiness). Please place a single cross on the grid at the intersection of these two axes.

Stress   **High Arousal**   Excitement

Unpleasant Feelings



Pleasant Feelings

Depression   **Sleepiness**   Relaxation

Table S2

Initial Playlist No. 1: 50–62 Years Group (1978–1993)

No. Presented	Track name	Artist(s)	Year of release	Tempo (bpm)	Sex of Vocalist(s)	Lenght (min)	Youtube Weblink
5	Love Is In The Air	John Paul Young	1978	123	Male	3:22	https://www.youtube.com/watch?v=NNC0kIzM1Fo
3	Shake Your Body	The Jacksons	1978	118	Male	8:01	https://www.youtube.com/watch?v=-qBqHnevIn4
1	I Love The Nightlife	Alicia Bridges	1978	125	Female	3:07	https://www.youtube.com/watch?v=TZzLKIhmse8
16	Boogie Oogie Oogie	A Taste Of Honey	1978	124	Female	5:38	https://www.youtube.com/watch?v=PhD58dP9kq8
20	Last Dance	Donna Summer	1978	125	Female	4:57	https://www.youtube.com/watch?v=561fy1vqlo8
19	Love Will Find A Way	Pablo Cruise	1978	124	Male	4:11	https://youtu.be/Kj4-_-iq1A8?feature=shared
15	One Way Ticket	Eruption	1979	124	Male	3:33	https://youtu.be/O1k9ZVU4S8A?feature=shared
18	Le Freak	CHIC	1979	120	Male and Female	3:38	https://www.youtube.com/watch?v=aXgSHL7efKg

Continued

Table S2 (*Continued*)

No. Presented	Track name	Artist(s)	Year of release	Tempo (bpm)	Sex of Vocalist(s)	Lenght (min)	Youtube Weblink
23	Gimme! Gimme! Gimme!	ABBA	1979	119	Female	4:49	https://www.youtube.com/watch?v=JWay7CDEyAI
14	Don't Stop 'Til You Get Enough	Michael Jackson	1979	119	Male	4:14	https://www.youtube.com/watch?v=yURRmWtbTbo
6	Celebration	Kool & The Gang	1981	121	Male	4:17	https://www.youtube.com/watch?v=3GwjfUFyY6M
22	Let's Groove	Earth, Wind & Fire	1981	125	Male	3:35	https://www.youtube.com/watch?v=Lrle0x_DHBM
9	Ai No Corrida	Quincy Jones	1981	123	Male	6:26	https://www.youtube.com/watch?v=NVTVheyDY4s
17	Thriller	Michael Jackson	1983	118	Male	5:57	https://www.youtube.com/watch?v=in5IYOatFb8
7	Let's Hear It For The Boy	Deniece William	1984	123	Female	4:09	https://www.youtube.com/watch?v=gI7YHZVc7mM
24	Girls Just Want To Have Fun	Cyndi Lauper	1984	120	Female	4:26	https://www.youtube.com/watch?v=PIb6AZdTr-A
25	Like A Virgin	Madonna	1984	120	Female	3:09	https://www.youtube.com/watch?v=DtZ6gMzx0bk&pp=ygUNbGlrZSBhIHZpcmdpbg==

Continued

Table S2 (*Continued*)

No. Presented	Track name	Artist(s)	Year of release	Tempo (bpm)	Sex of Vocalist(s)	Lenght (min)	Youtube Weblink
21	I Feel For You	Chaka Khan	1984	125	Male/Female	4:08	https://www.youtube.com/watch?v=YW0sxgYAmLM&pp=ygUZaSBmZWVsIGZvciB5b3UgY2hha2Ega2hhbg==
11	Lovergirl	Teena Marie	1984	123	Female	4:52	https://youtu.be/1fyWgjhe_Zg?feature=shared
12	Manic Monday	The Bangles	1986	122	Female	3:11	https://youtu.be/SsmVgoXDq2w?feature=shared
8	When The Going Gets Tough, The Tough Get Going	Billy Ocean	1986	122	Male	4:05	https://youtu.be/-n3sUWR4FV4?feature=shared
13	I Wanna Dance With Somebody (Who Loves Me)	Whitney Houston	1987	119	Female	5:14	https://www.youtube.com/watch?v=eH3giaIzONA
2	Opposites Attract	Paula Abdul	1990	117	Male/Female	3:43	https://www.youtube.com/watch?v=xweiQukBM_k
4	Finally	CeCe Peniston	1992	120	Female	4:03	https://www.youtube.com/watch?v=xk8mm1Qmt-Y
10	An Everlasting Love	Andy Gibb	1978	125	Male	4:10	https://youtu.be/dK5VKo7FUe0?feature=shared

Note. No. Presented = the sequence in which the music has been presented to the participants of the music rating panel.

Table S3

Initial Playlist No. 2: 63–75 Years Group (1968–1986)

No. Presented	Track name	Artist(s)	Year of release	Tempo (bpm)	Sex of Vocalist(s)	Lenght (min)	Youtube Weblink
19	My Little Lady	The Tremeloes	1968	125	Male	2:37	https://www.youtube.com/watch?v=WAVI58eknms
12	Sugar Sugar	The Archies	1969	122	Make/Female	2:47	https://www.youtube.com/watch?v=C7T4aQMxTTM
9	Knock Three Times	Dawn	1970	123	Male/Female	2:58	https://www.youtube.com/watch?v=iUUv9S3LKII
4	I've Got To Use My Imagination	Gladys Knight & the Pips	1973	121	Female	3:33	https://www.youtube.com/watch?v=9VQ-YomaphA
13	Daddy Cool	Boney M.	1976	124	Male/Female	3:30	https://www.youtube.com/watch?v=50ObRkB7xHI
18	Boogie Nights	Heatwave	1976	119	Male	3:18	https://www.youtube.com/watch?v=GTR27qWXGqU
17	Don't Let Me Be Misunderstood	Santa Esmeralda	1977	118	Male	10:28	https://youtu.be/yCGFfz7LfDQ?feature=shared
14	Yes Sir, I Can Boogie	Baccara	1977	123	Female	3:53	https://www.youtube.com/watch?v=32wDFCM7iSI
8	Love Is In The Air	John Paul Young	1978	123	Male	3:22	https://www.youtube.com/watch?v=NNC0kIzM1Fo

Continued

Table S3 (*Continued*)

No. Presented	Track name	Artist(s)	Year of release	Tempo (bpm)	Sex of Vocalist(s)	Lenght (min)	Youtube Weblink
16	Shake Your Body	The Jacksons	1978	118	Male	8:01	https://www.youtube.com/watch?v=-qBqHnevIn4
18	Boogie Oogie Oogie	A Taste Of Honey	1978	124	Female	5:38	https://www.youtube.com/watch?v=PhD58dP9kq8
21	Last Dance	Donna Summer	1978	125	Female	4:57	https://www.youtube.com/watch?v=561fy1vqIo8
11	I Love The Nightlife	Alicia Bridges	1978	125	Female	3:07	https://www.youtube.com/watch?v=TZzLKIhmse8
15	One Way Ticket	Eruption	1979	124	Male	3:33	https://youtu.be/O1k9ZVU4S8A?feature=shared
6	Le Freak	CHIC	1979	120	Male and Female	3:38	https://www.youtube.com/watch?v=aXgSHL7efKg
1	Gimme! Gimme! Gimme!	ABBA	1979	119	Female	4:49	https://www.youtube.com/watch?v=JWay7CDEyAI
17	Don't Stop 'Til You Get Enough	Michael Jackson	1979	119	Male	4:14	https://www.youtube.com/watch?v=yURRmWtbTbo
10	Celebration	Kool & The Gang	1981	121	Male	4:17	https://www.youtube.com/watch?v=3GwjfUFyY6M
25	Let's Groove	Earth, Wind & Fire	1981	125	Male	335	https://www.youtube.com/watch?v=Lrle0x_DHBM

Continued

Table S3 (*Continued*)

No. Presented	Track name	Artist(s)	Year of release	Tempo (bpm)	Sex of Vocalist(s)	Lenght (min)	Youtube Weblink
24	Ai No Corrida	Quincy Jones	1981	123	Male	6:26	https://www.youtube.com/watch?v=NVTVheyDY4s
23	Thriller	Michael Jackson	1983	118	Male	5:57	https://www.youtube.com/watch?v=in5IYOatFb8
7	Let's Hear It For The Boy	Deniece William	1984	123	Female	4:09	https://www.youtube.com/watch?v=gI7YHZVc7mM
3	Girls Just Want To Have Fun	Cyndi Lauper	1984	120	Female	4:26	https://www.youtube.com/watch?v=PIb6AZdTr-A
22	Like A Virgin	Madonna	1984	120	Female	3:09	https://www.youtube.com/watch?v=DtZ6gMzx0bk&pp=ygUNbGlrZSBhIHZpcmdpbg==
2	Manic Monday	The Bangles	1986	122	Female	3:11	https://youtu.be/SsmVgoXDq2w?feature=shared

Note. No. Presented = the sequence in which the music has been presented to the participants of the music rating panel.

Table S4

Final Playlist No. 1: 50—62 Years Group (1978—1993)

MFH	MSH	MT	Track name	Artist(s)	Year of release	Tempo (bpm)	Sex of Vocalist(s)	Lenght (min)	Youtube Weblink
5		4	Love Is In The Air	John Paul Young	1978	123	Male	3:22	https://www.youtube.com/watch?v=NNC0kIzM1Fo
	1	2	Shake Your Body	The Jacksons	1978	118	Male	8:01	https://www.youtube.com/watch?v=-qBqHnevIn4
10		1	I Love The Nightlife	Alicia Bridges	1978	125	Female	3:07	https://www.youtube.com/watch?v=TZzLKIhmse8
	5	15	Boogie Oogie Oogie	A Taste Of Honey	1978	124	Female	5:38	https://www.youtube.com/watch?v=PhD58dP9kq8
	3	17	Love Will Find A Way	Pablo Cruise	1978	124	Male	4:11	https://youtu.be/Kj4-_-iq1A8?feature=shared
	10	10	An Everlasting Love	Andy Gibb	1978	125	Male	4:10	https://youtu.be/dK5VKo7FUe0?feature=shared
3		14	One Way Ticket	Eruption	1979	124	Male	3:33	https://youtu.be/O1k9ZVU4S8A?feature=shared
	8	19	Gimme! Gimme! Gimme!	ABBA	1979	119	Female	4:49	https://www.youtube.com/watch?v=JWay7CDEyAI
2		13	Don't Stop 'Til You Get Enough	Michael Jackson	1979	119	Male	4:14	https://www.youtube.com/watch?v=yURRmWtbTbo
9		5	Celebration	Kool & The Gang	1981	121	Male	4:17	https://www.youtube.com/watch?v=3GwjfUFyY6M

Continued

Table S4 (*continued*)

MFH	MSH	MT	Track name	Artist(s)	Year of release	Tempo (bpm)	Sex of Vocalist(s)	Lenght (min)	Youtube Weblink
	9	18	Let's Groove	Earth, Wind & Fire	1981	125	Male	335	https://www.youtube.com/watch?v=Lrle0x_DHBM
	7	8	Ai No Corrida	Quincy Jones	1981	123	Male	6:26	https://www.youtube.com/watch?v=NVTVheyDY4s
4		16	Thriller	Michael Jackson	1983	118	Male	5:57	https://www.youtube.com/watch?v=in5IYOatFb8
8		6	Let's Hear It For The Boy	Deniece William	1984	123	Female	4:09	https://www.youtube.com/watch?v=gI7YHZVc7mM
	2	19	Girls Just Want To Have Fun	Cyndi Lauper	1984	120	Female	4:26	https://www.youtube.com/watch?v=PIb6AZdTr-A
6		20	Like A Virgin	Madonna	1984	120	Female	3:09	https://www.youtube.com/watch?v=DtZ6gMzx0bk&pp=ygUNbGlrZSBhIHZpcmdpbg==
7		11	Lovergirl	Teena Marie	1984	123	Female	4:52	https://youtu.be/1fyWgjhe_Zg?feature=shared
	6	12	Manic Monday	The Bangles	1986	122	Female	3:11	https://youtu.be/SsmVgoXDq2w?feature=shared
	4	7	When The Going Gets Tough, The Tough Get Going	Billy Ocean	1986	122	Male	4:05	https://youtu.be/-n3sUWR4FV4?feature=shared
1		3	Finally	CeCe Peniston	1992	120	Female	4:03	https://www.youtube.com/watch?v=xk8mm1Qmt-Y

Note. MFH = the sequence in which the music will be presented to the participants during the "music in the first half" condition; MSH = the sequence in which the music will be presented to the participants during the "music in the second half" condition; MT = the sequence in which the music will be presented to the participants during the "music throughout" condition.

Table S5

Final Playlist No. 2: 63–75 Years Group (1968–1986)

MFH	MSH	MT	Track name	Artist(s)	Year of release	Tempo (bpm)	Sex of Vocalist(s)	Lenght (min)	Youtube Weblink
	9	16	My Little Lady	The Tremeloes	1968	125	Male	2:37	https://www.youtube.com/watch?v=WAVI58eknms
5		10	Sugar Sugar	The Archies	1969	122	Make/Female	2:47	https://www.youtube.com/watch?v=C7T4aQMxTTM
	4	8	Knock Three Times	Dawn	1970	123	Male/Female	2:58	https://www.youtube.com/watch?v=iUUv9S3LKII
1		4	I've Got To Use My Imagination	Gladys Knight & the Pips	1973	121	Female	3:33	https://www.youtube.com/watch?v=9VQ-YomaphA
9		11	Daddy Cool	Boney M.	1976	124	Male/Female	3:30	https://www.youtube.com/watch?v=50ObRkB7xHI
4		17	Don't Let Me Be Misunderstood	Santa Esmeralda	1977	118	Male	10:28	https://youtu.be/yCGFfz7LfDQ?feature=shared
	5	12	Yes Sir, I Can Boogie	Baccara	1977	123	Female	3:53	https://www.youtube.com/watch?v=32wDFCM7iSI
	8	7	Love Is In The Air	John Paul Young	1978	123	Male	3:22	https://www.youtube.com/watch?v=NNC0kIzM1Fo
7		13	Shake Your Body	The Jacksons	1978	118	Male	8:01	https://www.youtube.com/watch?v=-qBqHnevIn4
	1	5	Boogie Oogie Oogie	A Taste Of Honey	1978	124	Female	5:38	https://www.youtube.com/watch?v=PhD58dP9kq8

Continued

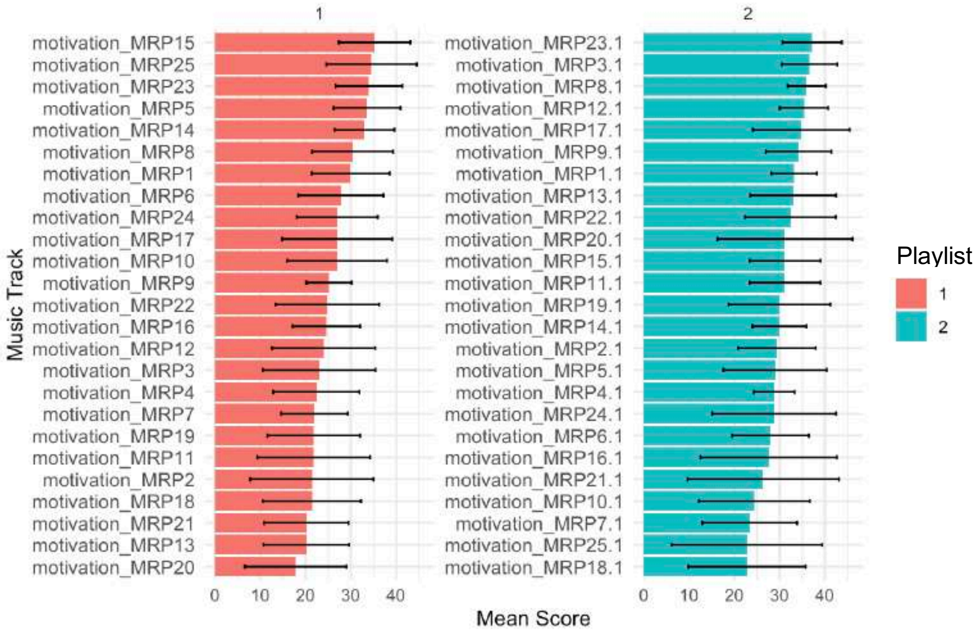
Table S5 (*Continued*)

MFH	MSH	MT	Track name	Artist(s)	Year of release	Tempo (bpm)	Sex of Vocalist(s)	Lenght (min)	Youtube Weblink
	7	9	I Love The Nightlife	Alicia Bridges	1978	125	Female	3:07	https://www.youtube.com/watch?v=TZzLKIhmse8
	10	14	One Way Ticket	Eruption	1979	124	Male	3:33	https://youtu.be/O1k9ZVU4S8A?feature=shared
	3	6	Le Freak	CHIC	1979	120	Male and Female	3:38	https://www.youtube.com/watch?v=aXgSHL7efKg
10		1	Gimme! Gimme! Gimme!	ABBA	1979	119	Female	4:49	https://www.youtube.com/watch?v=JWay7CDEyAI
2		15	Don’t Stop ’Til You Get Enough	Michael Jackson	1979	119	Male	4:14	https://www.youtube.com/watch?v=yURRmWtbTbo
8		20	Ai No Corrida	Quincy Jones	1981	123	Male	6:26	https://www.youtube.com/watch?v=NVTVheyDY4s
3		19	Thriller	Michael Jackson	1983	118	Male	5:57	https://www.youtube.com/watch?v=in5IYOatFb8
6		3	Girls Just Want To Have Fun	Cyndi Lauper	1984	120	Female	4:26	https://www.youtube.com/watch?v=PIb6AZdTr-A
	2	18	Like A Virgin	Madonna	1984	120	Female	3:09	https://www.youtube.com/watch?v=DtZ6gMzx0bk&pp=ygUNbGlrZSBhIHZpcmdpbg==
	6	2	Manic Monday	The Bangles	1986	122	Female	3:11	https://youtu.be/SsmVgoXDq2w?feature=shared

Note. MFH = the sequence in which the music will be presented to the participants during the “music in the first half” condition; MSH = the sequence in which the music will be presented to the participants during the “music in the second half” condition; MT = the sequence in which the music will be presented to the participants during the “music throughout” condition.

Figure S2

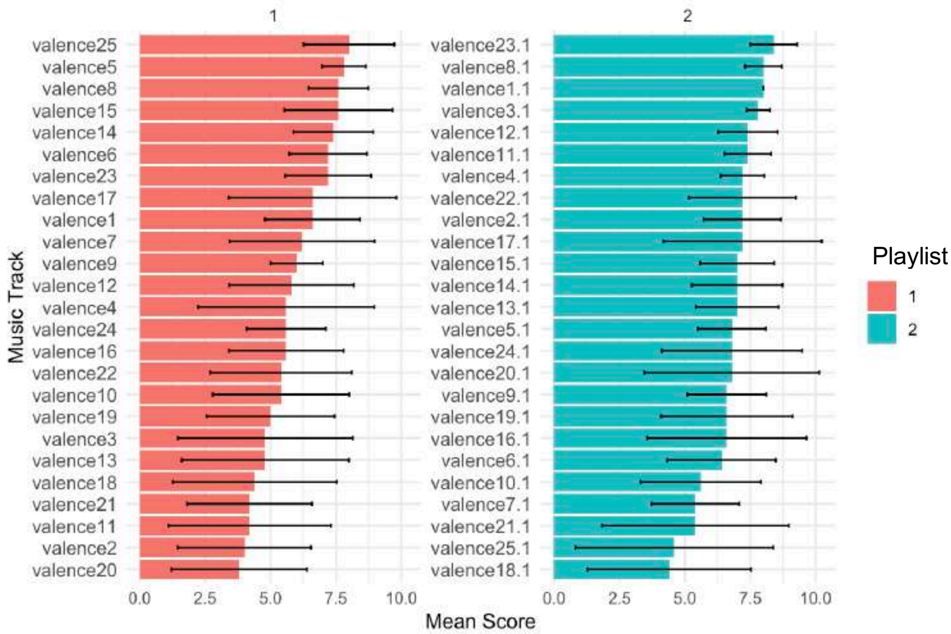
Motivation Scores by Music Track and Playlist



Note. "Motivation_MRP" represents the motivation score (Brunel Music Rating Inventory-3; Karageorghis, 2008). Each number represents the number of a music track.

Figure S3

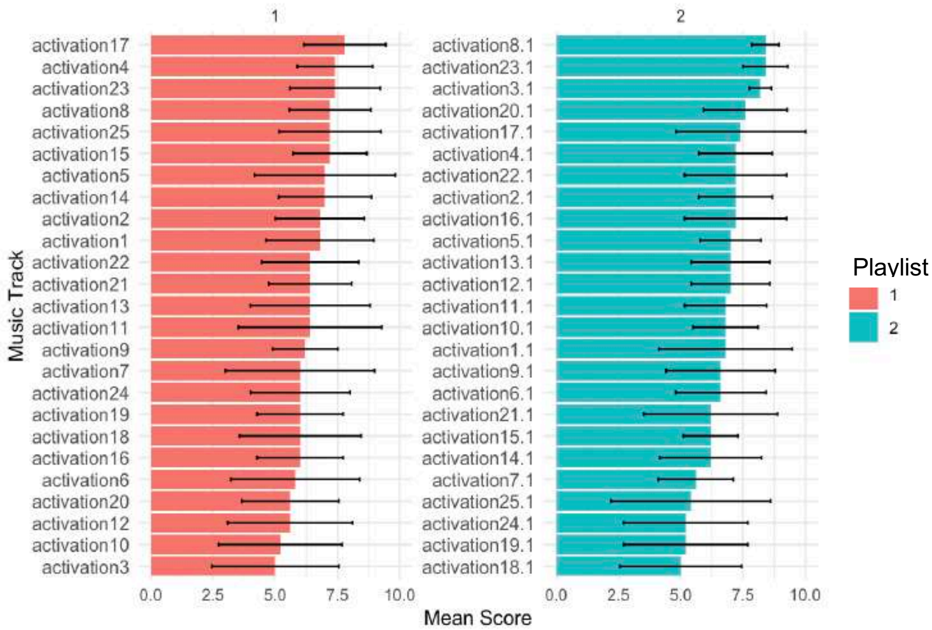
Valence Scores by Music Track and Playlist



Note. "valence" represents the valence score (Affect Grid; Russell et al., 1989). Each number represents the number of a music track.

Figure S4

Top 20 Arousal Scores by Music Track and Playlist



Note. "activation" represents the arousal score (Affect Grid; Russell et al., 1989). Each number represents the number of a music track.

Annexe 3

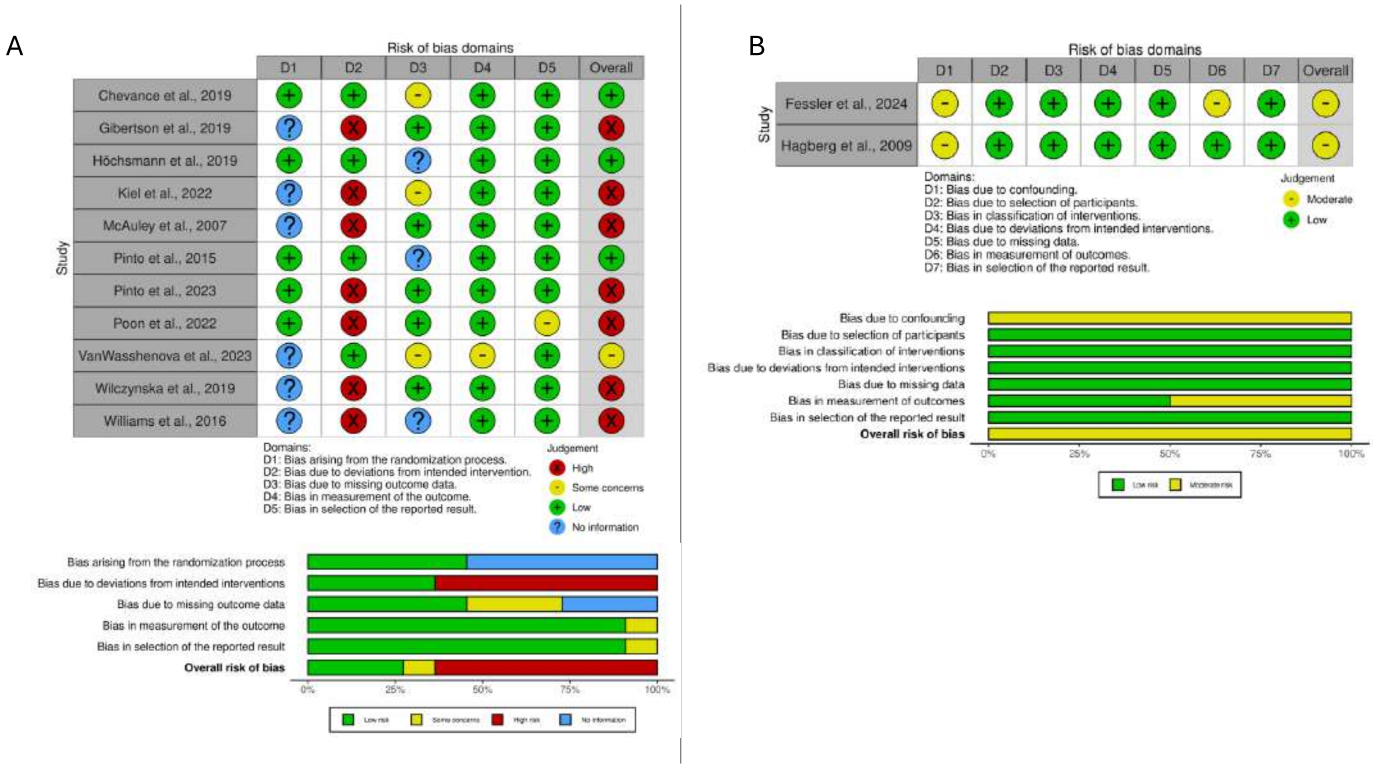
Matériel supplémentaire — Contribution n°5

Supplementary Material 1. Risk-of-Bias Assessment

Supplementary Material 2. Quality Checklist

Supplementary Material 1. Risk-of-Bias Assessment

Figure S1 Risk-of-Bias Assessment



Panel A shows randomized controlled trials. Panel B shows non-randomized controlled trials. Plots created using risk-of-bias visualization (robvis) tool (McGuinness & Higgins, 2020).

Reference

McGuinness, L. A., & Higgins, J. P. T. (2020). Risk-of-bias VISualization (robvis): An R package and Shiny web app for visualizing risk-of-bias assessments. *Research Synthesis Methods*. https://doi.org/10.1002/jrsm.1411

Supplementary Material 2. Quality Checklist

Supplementary Table S2 Modified Rhodes and Kates (2015) Quality Checklist

Item No.	Item
1	Is the hypothesis/aim/objective of the study clearly described?
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? (e.g., physical activity behavior, enjoyment)
3	Were the subjects asked to participate in the study representative of the entire population from which they were recruited?
4	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? The proportion of those asked who agreed should be stated.
5	Are the characteristics of the patients included in the study clearly described? This includes gender, age, sedentary/active. All must be reported for a « Yes ».
6	Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive?
7	Is the exercise dose clearly defined?
8	Are all correlations and/or effect sizes (i.e. insignificant ones) included?
9	Have the characteristics of patients lost to follow-up been described?
10	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance <5% for physical activity or affective outcomes?
11	Were the statistical tests used to assess the main outcomes appropriate?
12	Was compliance with the intervention reliable? (i.e. was the adherence reported)
13	Were the analyses controlled for confounding?
14	Were the measure(s) of affect used accurate (valid and reliable)?
15	Were the main outcome measures used accurate (valid and reliable)?
16	Were losses of patients to follow-up taken into account?

All items are scored on a bivariate scale (0 = no, 1 = yes) with the exception of item seven which is scored as follows: 0 = the exercise dose was poorly standardized (i.e. an intervention where exercise was not directly monitored), 1 = the exercise dose was somewhat defined (i.e. self-selected intensity); 2 = the exercise dose was clearly defined (i.e. 65% $\dot{V}O_2max$).

Reference

Rhodes, R. E., & Kates, A. (2015). Can the Affective Response to Exercise Predict Future Motives and Physical Activity Behavior? A Systematic Review of Published Evidence. *Annals of Behavioral Medicine, 49*(5), 715–731. https://doi.org/10.1007/s12160-015-9704-5

Annexe 4

Matériel supplémentaire — Contribution n°6

Supplementary Materials 1. Post-hoc power analysis

Figure 1 Post-Hoc Analysis