Improving Physical Activity Using a Single Personalized Consequence-Based Approach-Avoidance Training: Effects on Self-Reported Behaviors, Attitudes, and Choices

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Abstract

Objective. Despite their role in health behaviors, such as physical activity (PA), the effectiveness of interventions targeting automatic precursors remains inconsistent. We examined the effects of a single session of ABC training – a personalized and consequence-based approach-avoidance training – on PA, relative to an active control condition and a control condition.

Methods. Middle-aged US participants (N = 360, 53% of women) either completed an ABC training (approaching PA in 90% of trials), a typical approach-avoidance training (approaching PA in 90% of trials), or a control training (approaching PA in 50% of trials). Participants selected antecedents (e.g., "When I have little time") in which personalized choices between PA and sedentary alternatives were likely to occur. In the ABC training only, after approaching PA, self-relevant consequences were displayed (e.g., increase in the health status of the participant's avatar). Primary outcome was self-reported PA seven days after the intervention. Secondary outcomes included choices for PA (vs sedentary) alternatives in a hypothetical free-choice task, intention, implicit and explicit attitudes toward PA.

Results. No significant effect of the ABC intervention on PA was observed, so as on intention and explicit attitudes. However, the ABC intervention was associated with higher odds of choosing PA (vs sedentary) alternatives in the free-choice task and with more positive implicit attitudes toward PA.

Conclusions. While the ABC training was not effective at improving PA, its effects on choices and implicit attitudes suggest that this intervention may still have potential. Future studies with intensive trainings and device-based measures of PA remains needed.

Keywords: physical activity, sedentary behaviors, approach-avoidance tendencies, attitudes, cognitive bias modification.

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A fundamental driver of people's health behaviors lies in their ability to set goals and form intentions, such as being physically active (Rhodes et al., 2019). These laudable intentions yet often compete with other behavioral alternatives, including sedentary temptations that are ubiquitous in our modern environment (Cheval et al., 2017). Every day, individuals face situations in which decision-making processes either tip the balance in favor of behavioral alternatives aligning with their goals (e.g., running) or in favor of competing options (e.g., watching TV) (Maltagliati et al., 2022). It turns out that selecting behavioral alternatives aligning with one's intention is far from self-evident: in physical activity (PA), about one in two people fail to translate their intention to be active into action (Rhodes & de Bruijn, 2013). The problem is that this intention-action gap leads to non-negligible consequences: one person dies every six seconds worldwide of causes associated with insufficient physical activity (World Health Organization, 2020). To meet the targeted 15% reduction in the prevalence of insufficient physical activity by 2030 (World Health Organization, 2020), developing interventions that favor the adoption of PA constitutes an urgent need. In the present study, we applied a novel theory-based cognitive-bias modification intervention—the Antecedents Behaviors Consequence (ABC) training (Wiers et al., 2020)— that holds promise in the reduction of insufficient PA.

Automatic approach-avoidance tendencies as a target for interventions

Anchored within dominant socio-cognitive theories (Rhodes et al., 2019), the vast majority of existing interventions assumed that modifying controlled (or deliberative) decision-making features (e.g., intention, self-efficacy) would translate into subsequent changes in behaviors (Ajzen, 1991; Bandura, 1986). However, this assumption has been challenged by the

small effect of these theory-based interventions on behaviors in ecological settings (r = .24; Rhodes et al., 2021). To address this issue, the value of conjointly targeting more automatic processes to change health behaviors has been highlighted (Larsen & Hollands, 2021; Marteau et al., 2012).

Derived from dual process models (Strack & Deutsch, 2004), it has been argued that, in conjunction with controlled precursors, more automatic processes can also explain individuals' engagement in health behaviors (Hofmann et al., 2008), such as PA (Brand & Ekkekakis, 2018; Cheval & Boisgontier, 2021; Conroy & Berry, 2017). Notably, alongside with other automatic precursors (see Chevance et al., 2019; Rebar et al., 2016 for reviews), approach-avoidance tendencies were found to correlate with PA behaviors in both laboratory settings (Cheval et al., 2014) and ecological settings (Cheval et al., 2015). Because these approach-avoidance tendencies are assumed to play a proximal role in behavioral regulation (Friese et al., 2011) and have been shown to consistently associated with PA behaviors (Zenko & Ekkekakis, 2019), they stand as a relevant target for interventional studies.

Effectiveness of interventions targeting automatic approach-avoidance tendencies

Drawing on work applied to other health-related behaviors (Wiers et al., 2011), two studies have examined the effects of a cognitive-bias modification interventions targeting automatic approach-avoidance tendencies toward PA (Cheval et al., 2016; Preis et al., 2021). The first study used the manikin task (Krieglmeyer & Deutsch, 2010)—a computerized approach-avoidance task—to retrain participants' approach-avoidance tendencies toward PA (Cheval et al., 2016). In a first experimental condition, participants were repeatedly asked to move a manikin (that was supposed/expected to represent themselves) toward PA stimuli (i.e., approach) and away from sedentary stimuli (i.e., avoidance) displayed on screen. In two other experimental conditions, participants were either asked to move a manikin toward sedentary stimuli and away from PA stimuli, or to move the manikin equally often toward and away from

PA and sedentary stimuli. Results showed that, when including only inactive participants, individuals in the first condition spent more time practicing squats in a free-choice task, relative to those retrained to approach sedentary stimuli, or those instructed to approach and avoid PA stimuli as often. The second study tested whether the effect of an intervention based on the joystick-task — another computer-based approach-avoidance task (Krieglmeyer & Deutsch, 2010) — was effective to impact PA in ecological settings (i.e., daily pedometer-assessed step counts during two weeks; Preis et al., 2021). Results did not show any significant difference in direct and self-reported PA between the experimental (i.e., six 10-minute sessions during which participants were repeatedly retrained to approach PA and avoid sedentary stimuli) and the control (i.e., not treatment) conditions. However, the small sample size of this study (N = 40) can potentially account for this non-significant result. Altogether, as for other health behaviors (e.g., smoking, drinking; Jayasinghe et al., 2020), the effectiveness of interventions targeting automatic approach-avoidance tendencies toward PA remains to be more strongly established.

From an associative to an inferential perspective on approach-avoidance trainings

At the conceptual level, these two "typical" approach-avoidance trainings were based on an associative account of the effects of cognitive-bias modification intervention. In short, this associative perspective suggests that the mere repetition of stimuli-action pairings (i.e., repeatedly approaching PA stimuli and avoiding sedentary stimuli) leads to a greater accessibility of these stimulus-action associations in memory. In turn, because on this learning process, when encountering specific stimuli (e.g., seeing a bike will generate approach tendencies toward it), these associations would elicit an inclination to engage in PA behaviors and to avoid sedentary behaviors. However, this perspective has been tackled by a review suggesting that data did not support these underlying associative mechanisms (Van Dessel et al., 2019). Specifically, verbal instructions to approach or avoid stimuli, without actually repeating approach and avoidance movements, seem sufficient to alter evaluations toward a

given set of stimuli (Van Dessel et al., 2015). Moreover, the alteration of these evaluations require awareness of relevant contingencies (i.e., knowing that a particular stimulus is associated with an approach or avoidance action and that this action has either positive or negative consequences; Van Dessel et al., 2016). These findings have encouraged the development of renewed conceptual perspectives to better understand the mechanisms through which approach-avoidance trainings may influence behaviors.

In particular, the inferential perspective has emerged (Van Dessel et al., 2019). This perspective argues that altering automatic approach-avoidance tendencies is not only contingent on the repetition of approach-avoidance actions, but also on the consequences that are paired with these actions (e.g., for the person's health; Van Dessel et al., 2019). From the inferential view, the repeated performance of approach-avoidance actions in response to a stimulus (e.g., approaching PA stimuli) coupled with information about concomitant positive or negative consequences (e.g., vitality level) leads to the formation of inferences about evaluative properties of the stimulus (e.g., "approaching PA will increase my vitality"). In turn, these consequence-based associations are assumed to foster the automatization of participants' choice in decision-making situations (i.e., running versus watching TV) and to improve their attitudes (at both the explicit and implicit level) toward targeted behaviors. Ultimately, these changes are expected to affect the inclination to engage in the targeted behaviors in real-life settings ((Van Dessel et al., 2019).

Toward the ABC training procedure

Consistent with this inferential perspective, the ABC training procedure was recently developed (Wiers et al., 2020). In the ABC training, approach-avoidance tendencies toward the targeted behavior are retrained in relation to personalized contextual antecedents that may compromise the completion of long-term goals (e.g., "When I have little energy, I am likely giving up on my planned PA session"). Second, approach-avoidance tendencies toward targeted

behaviors have to be retrained concurrently, rather than distinctly, from competing behavioral alternatives. To do so, participants can select targeted behavioral alternatives that are the most likely favoring goal completion (e.g., "Running would be a good way for me to be more physically active") and temptations that are the most likely hindering goal completion (e.g., "Watching TV can definitely prevent me from running"). This feature ensures that each participant is trained to approach targeted behavioral alternatives in decision-making situations entailing the presence of temptations. Critically, in the ABC training, participants have the opportunity to select self-relevant consequences that are subsequently paired with approach-avoidance actions (e.g., "My main reason for being physically active lies in the pleasure I can feel"). Altogether, these three features characterizing an ABC training procedure (i.e., personalized antecedents, behavioral alternatives and consequences) are expected to increase the effectiveness of interventions and correspond to an inferential account of approach-avoidance trainings.

A handful of studies have provided first hint on the personalization of some aspects of approach-avoidance trainings (i.e., self-relevant antecedents and behavioral alternatives in the context of smoking behaviors; e.g., Kopetz et al., 2017). The most robust evidence for the effectiveness of consequence-based approach-avoidance trainings was provided by a set of experiments conducted by Van Dessel et al. (2018). In a consequence-based training condition, participants first completed a computerized choice task in which, after a learning phase, they had to maximize the health of an avatar (a character that the participants chose beforehand to represent them) by moving the avatar towards or away healthy and unhealthy food items (e.g., carrots and cookies) that appeared in an open refrigerator in front of their avatar. Crucially, when they approached healthy food or avoided unhealthy food items, positive health consequences for this avatar were generated. Specifically, a health bar was gradually filled in, the appearance of the avatar was improving (i.e., looking healthier), and a positive feedback

was displayed (e.g., “I feel healthy”). Conversely, when they approached unhealthy food or avoided healthy food items, negative health consequences were displayed (i.e., the health bar was gradually depleted, the manikin looked unhealthier and a negative feedback was displayed [“I feel sick”]). Relative to a typical approach-avoidance training (i.e., a manikin task in which participants always approached healthy food and avoided unhealthy foods without any consequence) and a control condition (i.e., a manikin task in which participants approached healthy food in 50% of trials without any consequence), participants in the consequence-based training condition consumed less unhealthy snacks in a subsequent consumer-choice task and self-reported lower unhealthy eating behavior in the 24 hours following the intervention. Moreover, right after the intervention, they were more likely to select healthy food (vs unhealthy alternatives) in a hypothetical free-choice task. Finally, relative to the two other conditions, participants in the consequence-based training condition reported more positive implicit and explicit attitudes toward healthy (vs unhealthy) food. These last findings supported that pairing actions with consequences (i.e., approaching healthy food vs unhealthy food triggers positive vs negative health consequences) could modify evaluative properties of the related concept. In sum, consistent with the inferential perspective, this experimental study provided proof-of-concept evidence for the added-value of a consequence-based approach-avoidance training, relative to a typical approach-avoidance training.

Nevertheless, to the best of our knowledge, no study has yet fully taken advantage of the ABC training by simultaneously manipulating all the three components of the procedure. For example, in Van Dessel et al., (2018), participants were exposed to a unique antecedent (i.e., standing in front of a fridge) whereas people differ regarding the situations that they perceive as being “at risk” for their long-term goal (Cerin et al., 2010). Previous work neither allowed participants to personalize the behavioral alternatives on which their subsequent approach-avoidance training was based. Further, while considered as critical in the self-control

dilemmas people experience on a daily basis (Hofmann et al., 2012), existing studies did not retrain these approach-avoidance tendencies toward the long-term concomitantly the presence of tempting alternatives – an important omission if we consider the self-control dilemmas people experience on a daily basis (Hofmann et al., 2012). Finally, participants could not select the consequences that were the most relevant to them when pursuing their long-term goal. In Van Dessel et al. (2018), only the health of the avatar was altered as a result of approach and avoidance actions toward food stimuli. Because the reasons behind pursuing a long-term goal – such as being physically active – greatly varies from an individual to another (Molanorouzi et al., 2015), letting participants selecting self-relevant consequences could increase the effectiveness of the intervention. In sum, the full ABC training (i.e., personalization of antecedents, behavioral alternatives and of consequences, retraining of approach-avoidance tendencies toward the long-term goal in the presence of temptations) remains to be tested in the field of health behaviors.

The current study

To fill this gap, the aim of this preregistered online non-clinical randomized controlled trial was to test the effect of a single session of an ABC training (vs a typical approach-avoidance training and a control condition) on self-reported PA (primary outcome), measured seven days after the intervention. We also aimed to test its effects on secondary outcomes including choices in favor of PA (vs sedentary behaviors) in a hypothetical free-choice task, implicit attitudes toward PA, and more controlled predictors of PA (i.e., intention to be physically active and explicit attitudes toward PA). Exploratory analyses also included reaction times in the free-choice task as an outcome, with faster reaction times to choose PA (vs sedentary behaviors) being indicative of a more automatic mode of behavioral choice.

We first expected that, relative to participants in a control condition (i.e., "sham" approach-avoidance training, with a 50% approach PA ratio, without any consequence),

participants in the ABC training (with a ~90% approach PA ratio, with consequence) would report a higher time spent in moderate-to-vigorous PA in the seven days following the intervention (H1A). We also hypothesized that they would be more likely to choose PA (vs sedentary behaviors) alternatives in the hypothetical free-choice task (H2A) and would report a stronger intention to be physically active across the next seven days (H3A), more positive implicit (H4A) and explicit attitudes (H5A) toward PA. Regarding reaction times in the free-choice task, we expected that, beyond being more likely to choose PA (vs sedentary behaviors), compared to participants in the control training, participants in the ABC training would be also faster to do so (H6A).

We predicted that, participants in the ABC training would also report higher scores on all these outcomes relative to participants in a typical approach-avoidance training (with a 90% approach PA ratio, without any consequence; H1B to H6B). Finally, we hypothesized that participants in the typical approach-avoidance training would report higher scores on all these outcomes than participants in the control condition (H1C to H6C). Altogether, if confirmed, these sets of hypotheses would not only provide first evidence on the effectiveness of the ABC training in PA, but would also lend support to the added-value of an inferential (vs associative) perspective of approach-avoidance trainings.

Prior to addressing these hypotheses, given the novelty of this intervention in the PA domain, we first conducted a preliminary study that aimed to examine the feasibility of the protocol, by evaluating its attrition rate, compliance and acceptance. As preliminary results, descriptive statistics on participants' choices in a free-choice task, implicit and explicit attitudes were computed across two experimental conditions (vs three in the main study): the ABC training versus a typical approach-avoidance training (i.e., approach of PA-related stimuli in 90% of trials).

Methods

Study preregistration can be found at https://osf.io/9x5tu/. The Research Ethics Committee of the university supporting this study approved this study (reference number: IRB00012476-2022-16-02-158).

Preliminary study

The full details of the preliminary study are provided in supplemental material 1. The final sample was composed of 41 participants (Table S1), who were randomly allocated to either the ABC training (n = 23) or the typical approach-avoidance training (n = 18).

Attrition rate, compliance and acceptable were all considered as acceptable and open-ended answers allowed to improve the clarity of instructions. Regarding *preliminary results*, in the free-choice task, participants in the ABC training were descriptively more likely to choose PA over sedentary alternatives than participants in the typical approach-avoidance training (74% in the ABC training vs 67% in the typical approach-avoidance training). Implicit attitudes toward PA were descriptively higher in the ABC training than in the typical approach-avoidance training (DW-score = 1.03 ± 0.29 vs 0.71 ± 0.50) (Figure S2). Explicit affective (5.70 ± 1.07 vs 5.61 ± 1.49) and instrumental attitudes (6.33 ± 1.28 vs 6.67 ± 0.58) were close in the ABC training and in the typical approach-avoidance training.

This preliminary study suggested that the intervention was feasible, with a satisfying attrition rate, compliance and acceptance. Moreover, preliminary results provided proof-of-concept for this consequence-based approach-avoidance training. Relative to participants in the typical approach-avoidance training, participants in ABC training reported higher percentages of choices toward PA in the free-choice task and more positive implicit attitudes. Such effects remained however to be tested through the main fully-powered study whose procedure is described below (Figure S6).

Procedure and sample

Volunteers living in the United States were invited to participate in this study via the Prolific Academic website and received a financial compensation of ~7$ after having completed this two-part study (~ 25 minutes for the first part and 5 minutes for the second part).

Participants were pseudo-randomly allocated (1:1:1 ratio) to either the ABC training, the typical approach-avoidance training or the control condition. Participants in the ABC training, the typical approach-avoidance and in the control conditions completed a three-block training phase (Figure 1 and Figure S3). Afterwards, secondary outcomes (i.e., choices between PA and sedentary behaviors, implicit and explicit attitudes and intention) were measured using a free-choice task, an Implicit Association Test (IAT), and a questionnaire. One week later, participants were invited to complete a second questionnaire, in which they self-reported their PA for the last seven days (primary outcome). The first part of the study was built and run on Inquisit ® (version 6.6.1), while the second questionnaire was developed using Limesurvey ®, a secured online platform hosted by the university supporting this study.

Based on preregistered power analyses (with a conservative medium effect size of $f = 0.25$, an allocation ratio of 1:1:1, $\beta = 90\%$, and $\alpha = .05$), we planned to recruit 400 participants for the first part of the study. Due to a programming error, 459 participants were finally allowed to enter the first part of the study. We excluded participants who either did not fully complete the first part of the study (i.e., training phase and free-choice task; N = 32), who exhibited a high rate of errors or of extreme latencies while completing the training phase or the IAT (N = 27), who reported a health issue preventing them to engage in PA (N = 19), or who reported a combination of at least two of these criteria (N = 21). Finally, 360 participants were included in the analyses for the secondary outcomes that were measured during the first part of the study (53% of women, mean age = 41 ± 13 years) (Table S5). Among them, 335 participants completed the second part of the study seven days later. Three additional participants were excluded from this sample because they reported implausible PA levels (i.e., more than 38 hours

of PA across the last seven days), resulting in a sample of 332 participants for the primary outcome (54% of women, mean age = 41 ± 13 years) (Table S5).

ABC training

In a first phase, participants completed a questionnaire in which they were asked to choose three consequences of PA that they perceived as being the most important to them. Based on previous literature, seven consequences were proposed: competition/ego, enjoyment, mastery, physical appearance, physical health, psychological health, social affiliation (Molanorouzi et al., 2015). Then, participants selected three physical activities, with options. being: climbing, cycling, fitness, running, swimming, playing tennis, walking, yoga. Afterwards, they selected three sedentary behaviors that they considered as temptations preventing them to adopt a more physically active lifestyle. The list included: reading a book, playing cards, using one's computer, lazing, using one's numeric tablet, using one's smartphone, watching television, playing video games. Finally, they were invited to choose three antecedents, described to participants as at-risk situations in which sedentary behaviors were likely to be particularly tempting and to impede the adoption of PA. Antecedents were selected based on previous research (Cerin et al., 2010) and included: lack of time, lack of willpower, lack of social support, lack of perceived competence, lack of energy, poor perceived health. To ensure that the consequences selected were relevant to participants, they rated the importance of each of the selected consequences after the ABC training procedure. Analyses revealed that all participants reported that the three consequences they selected were at least somewhat important to them (i.e., score > 3 on a seven-point Likert scale).

Then, participants in the ABC training completed the three-block training phase (i.e., 81 trials in total). As in Van Dessel et al.,' study (2018), each block was composed of a forced-choice task that aimed to teach participants the consequences of each action for their avatar (i.e., approaching PA and sedentary behaviors triggers positive and negative consequences,

respectively) (9 trials) and a maximization task (18 trials). The latter aimed to supercharge the consequences of participants' approach-avoidance choices on the avatar. In each block, one selected consequence of PA was displayed, with the order of blocks being randomized. Each of the nine pairs of PA vs sedentary alternatives was displayed three times in each block.

In the forced-choice tasks, on each trial, participants were first exposed to a selected antecedent for 1000ms (e.g., “When I have little energy”, each antecedent was displayed 27 times across the 81 trials). Then, an avatar appeared in the middle of the screen. Participants were told that this avatar would represent them across the experiment. After 750ms, two pictures were displayed in the upper left and right corners of the screen. They represented a selected PA alternative and a selected sedentary behavior and were displayed in a first-person perspective. One of the stimuli was surrounded by a blue frame, whereas the other was surrounded by a red frame. Participants were instructed to approach pictures displayed in a blue frame and to avoid pictures displayed in a red frame. To move the avatar on the left and on the right, they respectively used the keys “E” and “I” of their keyboard.

When stimuli depicting PA were surrounded by a blue frame and when participants successfully approached them, positive consequences for the avatar were displayed: the level of the “consequence” bar at the bottom of the screen increased and the appearance of the avatar improved (i.e., the avatar was looking happy, raising its arms to the sky). When stimuli depicting sedentary behaviors were surrounded by a blue frame and when participants successfully approached them, negative consequences for the avatar were displayed: the bar level decreased and the appearance of the avatar deteriorated (i.e., the avatar was looking sad, looking down to the ground). In half of the trials, participants had to approach PA, whereas in the other half of the trials, they had to approach sedentary behaviors.

After forced-choice tasks, participants completed the maximization tasks. Trials were modeled on the same structure that in the forced-choice task but, crucially, stimuli were no

longer surrounded by colored frames. Participants were asked to make choices that maximize positive consequences for their avatar. Consequences of each action on the avatar was displayed after participants' response, as in the forced-choice tasks. Doing that, they learned to make associations between plausible at-risk situations (e.g., "When I have little time"), self-relevant choice situations between PA (e.g., walking) and tempting sedentary alternatives (e.g., watching TV), and personally meaningful consequences to the goal pursued (e.g., being physically active to improve one's psychological health).

Typical approach-avoidance training

As in the ABC training, participants in the typical approach-avoidance training first selected three PA behaviors, three sedentary behaviors and three antecedents. However, they did not choose any consequence of PA. Next, participants completed the three-block training phase (81 trials in total). All these three blocks had the same structure that were almost identical to the ABC training. Yet, crucially, actions (e.g., approaching PA behaviors or sedentary behaviors) did not have any consequence for the avatar (i.e., neither a bar was displayed, nor the appearance of the avatar changed). In 90% of the trials, the images surrounded by a blue frame were PA stimuli, while in the remaining 10%, they were sedentary behaviors. This task aimed to teach the participants to approach PA behaviors and to avoid sedentary behaviors, with any consequences for the avatar being displayed as a result of these actions. In others words, the ABC training and the typical approach-avoidance training conditions were strictly equivalent, with the critical exception that, in the ABC training, approach-avoidance actions were paired with self-relevant consequences.

Control condition

Participants from the control group completed a "sham" approach-avoidance training. The structure of the blocks was the same as in the typical approach-avoidance training, with the only difference being that participants had to approach PA in only 50% of the trials (versus

90% of trials in the typical approach-avoidance training). In the other half of the trials of each block, they had to approach sedentary behaviors (versus 10% in the typical approach-avoidance training). This task aimed to teach participants to approach PA behaviors and sedentary behaviors as often. As such, the typical approach-avoidance trainings and the control condition were strictly equivalent, with the critical exception that, in the typical approach-avoidance training, participants were trained to approached PA stimuli with a 90:10 ratio.

Outcomes

Choices in the free-choice task (secondary outcome). Right after the training procedure, participants completed a hypothetical computerized free-choice task modeled on Van Dessel et al. (2018). Specifically, they were asked to freely indicate which of the two behavioral alternatives they would be the more inclined to engage into if they had the choice. Two alternatives were simultaneously displayed on screen: a physically active alternative and a sedentary alternative, with both alternatives being previously selected by participants. However, to account for potential learning effects, stimuli used in this free-choice task were novel (i.e., another set of first-person perspective pictures was used) (Figure S3). Likewise, in order to minimize common-method variance, participants had to approach stimuli that were now on the upper and lower part of the screen, respectively using the keys “T” and “B” of the keyboard. In this block, choices were still preceded by at-risk situations (e.g., when I have little time), but consequences were no longer displayed on screen after participants’ choice. There were 18 trials in total, with all pairs of choices being displayed twice and participants were instructed to answer within a 10s-time window. Choices (i.e., mean proportion of choices toward PA alternatives) and reaction times when choosing PA and sedentary alternatives were assessed as secondary outcomes.

Implicit attitudes (secondary outcome). Implicit attitudes toward PA (vs sedentary behaviors) were measured using the IAT right after the free-choice task (see supplementary

material 2; Greenwald et al., 1998). Implicit attitudes toward PA (vs sedentary behaviors) were computed using the DW-score which has demonstrated good reliability in the PA domain (Chevance et al., 2017). Higher scores were assumed to reflect more positive implicit attitudes toward PA (vs sedentary behaviors).

Intention to be physically active (secondary outcome). Intention was measured after completing the IAT using a two-item scale (e.g., "Across the next seven days, I have the intention to engage in at least 30 minutes of PA by day, on most of the days of the week during my free time"; Ajzen, 2002). Answers were provided on a seven-point Likert scale (from 1, Strongly disagree to 7, Strongly agree) and were summed to create an average score (Cronbach's alpha = .96).

Explicit affective and instrumental attitudes (secondary outcome). Both explicit affective and instrumental attitudes toward PA were assessed after completing the IAT using three-item bipolar scales (e.g., "unenjoyable" (1) – "enjoyable" (7) for affective attitudes; "useless" (1) – "useful" (7) for instrumental attitudes (Ajzen, 2002). Internal consistency was good (i.e., Cronbach's alphas = .74 and .95 for affective and instrumental attitudes respectively) and average scores were computed for affective and instrumental attitudes separately.

Self-reported physical activity (primary outcome). One week after completing the abovementioned procedure, participants were invited to answer a second questionnaire. They completed a modified version of the International Physical Activity Questionnaire (Craig et al., 2003), in which they reported the time they spent practicing moderate and vigorous PA during their leisure time across the last seven days. Answers were summed to reflect participants' overall PA level over one week. Participants also reported the time spent walking and sitting in leisure time – these outcomes were not further considered as these behaviors were not the target of the training phases.

Covariates and additional outcomes. As a first control variable, participants' intention to be active was measured right after they had provided their written consent, using a dichotomous item (*Do you intend to be physically active during your leisure time*? *Yes/No;* see sensitivity analyses). In contrast to the previously described measure of intention that was used as a secondary outcome, this measure was used as an exclusion criterion in sensitivity analyses. The rationale behind this measure was to ensure that participants reported a minimal intention to be physically active— a requisite to the effectiveness of CBM interventions (Wiers et al., 2013). Participants' gender, age, height, weight and health status were measured during the post-training questionnaire. As another potential control variable, participants' habitual level of PA was also assessed using the Saltin-Grimby questionnaire (Grimby et al., 2015). Expectations toward the intervention were also reported during the post-training questionnaire as an additional outcome (i.e., "Please think about the first part of the first reaction-time task in which you had to approach and to avoid pictures on screen, by moving the avatar toward or away from pictures. To what extent do you consider that this task could help you to be physically active during your leisure time"). Automaticity toward PA, desires toward sedentary behaviors, conflict between desires toward sedentary behaviors and the intention to be active, and resistance toward these desires were also measured during the second part of the study (i.e., one week after the training procedure) but were not examined here.

Statistical analysis

All analyses were computed using the R software ® (version 4.0.4). Descriptive statistics are reported in Table 1 and bivariate correlations between outcomes are provided in Table S6. To examine the effect of experimental conditions on each outcome, linear regression models were fitted. To examine the effect of experimental conditions on each outcome, linear regression models were fitted. We first compared the effects of ABC training relative to the control condition. Then, we compared the effects of the ABC training relative to the typical

approach-avoidance condition, as well as the effects of the typical approach-avoidance condition relative to the control condition. These comparisons allow to determine whether repeatedly pairing action-stimuli together (i.e., associative perspective) is effective and whether adding self-relevant consequences to these action-stimuli pairings has an added-value regarding the effectiveness of the manipulation (i.e., inferential perspective).

In a first set of planned sensitivity analyses, the interaction between experimental conditions and participants' profile of PA level on self-reported PA was examined in order to investigate whether more sedentary individuals benefited to a greater extent of the ABC training. As a second set of sensitivity analyses, participants who did not report the intention to be physically active (i.e., answering "No" on the dichotomous item, right after providing consent) were excluded, resulting in a subsample of N = 317 for secondary outcomes and N = 291 for the primary outcome. Finally, we tested whether expectations regarding the effectiveness of the intervention differed across conditions in order to rule out a potential placebo effect that would explain observed associations (Boot et al., 2013).

Results

Self-reported PA

Contrary to our hypothesis (H1), no significant difference was observed between the ABC training and the control condition on self-reported PA, $b = 25$, 95CI = [-32; 82, $t(329) = -0.863$, $p = .664$. Moreover, participants in the ABC training did not report significantly higher levels of PA relative to participants in the typical approach-avoidance training, $b = 43$, 95CI = [-14; 100], $t(329) = -1.472$, $p = .306$). Finally, participants in the typical approach-avoidance training did not report significantly higher levels of PA relative to participants in the control condition, $b = -18$, 95CI = [-75; 40], $t(329) = -0.607$, $p = .816$. In sum, we did not find significant effect of experimental conditions on subsequent PA behaviors.

After inspecting the distribution of the PA variable (i.e., 19% of participants reported having engaged in zero minute of PA, over dispersed right-skewed distribution; Figure S4) and the residuals of linear models, zero-inflated models with a negative binomial distribution were also computed (see supplementary material for more information). These models predicted the odds of engaging (versus not engaging) in more than 0 minutes of PA using a binomial model (first step), as well as they modeled the level of engaging in this behavior using a log-link function (second step; Green, 2021; Table S7. Although in the expected direction (17% vs 23% of participants reporting 0 minutes of PA in the ABC training and in the control condition, respectively, Table 1), results on the first step of the zero-inflated model did not reveal any significant effects of the ABC training on odds of engaging (versus not engaging) in more than 0 minutes of PA (*ps.* > .269), relative to participants in the control condition. Likewise, results on the second step of the model did not reveal significant effects of the ABC training relative to participants in the control condition. No significant difference was observed between the ABC training vs the typical approach-avoidance training or between the typical approach-avoidance training vs the control condition for either the first step or the second step of the model (*ps.* > .146) (Table S7).

Choices and reaction times in the free-choice task

As expected (H2), in the free-choice task, participants in the ABC training reported a higher proportion of choices toward PA alternatives (58% of choices toward PA) relative to both participants in the control condition – 41% of choices toward PA, $b = 16.81$, 95CI = [8.56; 25.05], $t(357) = 4.01$, $p < .001$; Figure S5 – and in the typical approach-avoidance training – 41% of choices toward PA, $b = 17.22$, 95CI = [8.98; 25.47], $t(357) = 4.11$, $p < .001$ (Figure S5A). No significant difference was observed between the control condition and the typical approach-avoidance training (41% of choices toward PA in both conditions, $b = -0.42$, 95CI = [-8.67; 7.83], $t(357) = -0.10$, $p = .921$.

In planned exploratory analyses about reaction times in the free-choice task, a mixed ANOVA model (i.e., 3-between-factor [experimental conditions: ABC training vs the typical approach-avoidance training vs control condition] × 2-within factor [choice: PA alternatives vs sedentary alternatives]) revealed an interaction between the experimental conditions and participants' choices on reaction times, $F(2, 354) = 6.17$, $p = .002$ (Figure S5B). When decomposing this interaction, we observed that participants in the ABC training, $b = -471$, 95CI = [-672; -271], $t(267) = -4.605$, $p < .001$, and participants in the typical approach-avoidance training, $b = -348$, 95CI = [-531; -165], $t(267) = -3.734$, $p = .003$, were faster when selecting PA alternatives over sedentary ones. In contrast, participants in the control condition were not significantly faster when selecting PA alternatives over sedentary ones, $b = -65$, 95CI = [-244; 114], $t(267) = -0.713$, $p = .980$. Further analyses were computed to identify to which choices (i.e., PA vs sedentary choices) this effect could be attributed. We observed that reaction times were not statistically different across conditions when PA alternatives were chosen (*ps.* > .720). However, relative to participants in the control condition, participants in the ABC training, $b = 499$, 95CI = [264; 734], $t(595) = 4.157$, $p < .001$, and in the typical approach-avoidance training, $b = 348$, 95CI = [119; 576], $t(588) = 2.979$, $p = .008$, were slower when choosing sedentary alternatives. This result suggested that the difference in reaction times between the control condition and the two other conditions could be mainly attributed to trials on which participants selected sedentary alternatives over PA ones.

Intention to be physically active

Contrary to H3, no significant difference was observed across experimental conditions on the intention to be physically active (*ps* > .499).

Implicit and explicit attitudes

As predicted (H4), relative to participants in the control condition, participants in the ABC training exhibited higher scores on the IAT, $b = 0.17$, 95CI = [0.03; 0.32], $t(357) = 2.30$,

p = .022 (Figure S6). Participants in the ABC training also exhibited higher scores on the IAT than participants in the typical approach-avoidance training, b = 0.21, 95CI = [0.06; 0.35], t(357) = 2.77, p = .006. The difference between the control condition and the typical approach-avoidance training was not significant, b = -0.03, 95CI = [-0.18; 0.11], t(357) = -0.46, p = .645. These results suggested that participants in the ABC training had more positive implicit attitudes toward PA (vs sedentary behaviors) than both participants in the typical approach-avoidance training and in the control condition.

Regarding explicit affective and instrumental attitudes toward PA (H5), any significant difference was observed across experimental conditions (ps > .118).

Planned sensitivity analyses

First, participants' PA profiles (i.e., sedentary, some light PA, regular PA, vigorous PA) did not interact with experimental conditions to predict self-reported PA in linear and zero-inflated models. Second, results remain unchanged when analyses only included participants' (N = 317) reporting the intention to be active before completing the training procedure (Yes/No dichotomous item). Finally, participants in the ABC training reported higher expectations toward the effectiveness of the intervention than both participants in the control training, b = -0.53, 95CI = [-1.00; 0.06], t(357) = 3.046, p = .027, and in the typical approach-avoidance training, b = -0.73, 95CI = [-1.19; -0.26], t(357) = 2.223 , p = .002. The difference between the typical approach-avoidance training and the control condition was not significant, b = 0.19, 95CI = [-0.66; 0.27], t(357) = 0.817, p = .415. Additional analyses were conducted to determine whether the effects of the ABC training on choices and implicit attitudes remained significant after adjustment for the expectations toward the effectiveness of the intervention. Results remain unchanged when these expectations were controlled for (Table S8).

Discussion

Main findings

After examining its feasibility in a preliminary study, this non-clinical randomized controlled trial tested the effects of a single personalized ABC training targeting automatic approach-avoidance tendencies toward PA on self-reported PA, as well as on choices during a free-choice task, the intention to be active, as well as on implicit and explicit attitudes. Relative to both a typical approach-avoidance training and a control condition, the ABC training intervention was not significantly associated with a higher level of PA during leisure time a week later. However, supporting an inferential account of approach-avoidance trainings, relative to a typical approach-avoidance training, the ABC training favored participants' choices toward PA alternatives (vs sedentary alternatives) in a hypothetical free-choice task and was associated with more positive implicit attitudes toward PA (vs sedentary behaviors).

Comparison with previous studies

Any significant difference in the leisure time spent in moderate-to-vigorous PA over the week following the intervention was observed between the three conditions. These non-significant effects add to the inconsistency that characterizes the cognitive bias modification literature (Jayasinghe et al., 2020) and contrast with the promising evidence that was first provided by consequence-based approach-avoidance training in the food domain (Van Dessel et al., 2018). Altogether, these non-significant effects of interventions targeting automatic approach-avoidance tendencies—be they anchored within an associative (i.e., approach-avoidance training without consequences) or an inferential (i.e., approach-avoidance training with consequences) perspective—can be accounted by at least three explanations. First, specific to the typical approach-avoidance training, participants were trained to approach PA, but their actions were contingent on the color of the frame, rather than on the content of the stimuli. Yet, cognitive bias modification training based on task-irrelevant instructions have often yielded weaker effects than procedures wherein participants are instructed to evaluate relevant features of stimuli (Phaf et al., 2014). Second, beyond its self-reported nature that provides a crude

estimation of PA levels (Dyrstad et al., 2014), the measure of PA did not meet the correspondence principle as it did not specifically coincide to selected behavioral alternatives. As such, future studies relying upon a personalized approach could benefit from matching the hypothetical training situations with outcomes that are subsequently measured in real-life settings (e.g., measuring the time spent running). Third, as Cheval et al.' study (2016), our study was composed of a single session of cognitive bias modification—a dose that may be insufficient to alter individuals' behaviors (Eberl et al., 2014). All the more since, in contrast with Van Dessel et al. (2018) that observed a reduction in (un-) healthy eating in the 24 hours or immediately following the intervention, our primary outcome was self-reported behaviors over a seven-day time window. It seems possible that a single ABC training only triggers short-lived effects that dissipate over a few hours/days. In light of the long-term effects of more intensive procedures (e.g., reduction of alcohol lapses over a year; e.g., Wiers et al., 2011), future interventions involving multiple training sessions and device-based measures of PA are needed before drawing conclusions on the (in-)effectiveness of personalized approach-avoidance trainings on PA behaviors in ecological settings (see Cheval et al., 2021 for an example).

Regarding secondary outcomes, results were, however, more promising. Relative to the control condition, but also to the typical approach-avoidance training, the ABC intervention improved participants' choices toward PA in a free-choice task and their scores on an IAT between PA and sedentary behaviors. In contrast, we observed non-significant differences between the typical approach-avoidance training and the control training. Because hypothetical choices and implicit attitudes were correlated with self-reported PA in our study (Table S6) and have been shown to predict behaviors in real-life settings (Brand & Schweizer, 2015; Chevance et al., 2019), the ABC training could thus be at least effective at altering some precursors of PA (but see Forscher et al., 2019 for a critical perspective). Replicating descriptive results from our

preliminary study and closely aligning with previous evidence (Van Dessel et al., 2018), these results fit with an inferential approach of automatic approach-avoidance trainings (Wiers et al., 2020). In other words, pairing approach-avoidance actions with positive consequences seems needed to (temporarily) tip the balance in favor of physically active options and to alter implicit attitudes. Still, considering that even in so-called implicit tasks, participants are able to control their answers (Corneille & Hütter, 2020), it remains critical to provide in-depth evidence on to whether the ABC training is effective at altering the associative system stored in memory (e.g., using QUAD models; Conrey et al., 2005) or at modifying the processes behind decisions in choice-tasks (e.g., using mouse-tracking tasks; Stillman et al., 2017).

Interestingly, in the free-choice task, exploratory analyses showed that, relative to those in the control condition, participants in the ABC training and in the typical approach-avoidance condition were faster when choosing PA alternatives than when choosing sedentary ones. A step further, this observation could be mainly accounted by trials on which participants selected sedentary alternatives: participants in the ABC training and in the typical approach-avoidance condition were slower than participants in the control condition when selecting sedentary alternatives, while no significant difference emerged between conditions when PA options were chosen. Although speculative, these findings may suggest that after retraining their automatic approach-avoidance tendencies toward the long-term goal, participants may still opt for competing temptations, but may experience a greater motivational conflict when doing so (Fishbach & Shah, 2006). Because inhibiting one's attraction toward sedentary behaviors is critical to successfully engage in PA (Cheval & Boisgontier, 2021), retraining automatic approach-avoidance tendencies toward PA may "warn" individuals when incompatible choices are being made (e.g., reporting the intention to run, while staying in the sofa, watching TV). To shed further light on this idea, future research relying upon ecological momentary assessment could aim to examine how approach-avoidance trainings extends, in real-life settings, on the

conflicts (and their resolution) triggered between long-term goals and surrounding temptations (e.g., occurrence and strength of these conflicts, effortful vs effortless mode of resolution; Hofmann et al., 2012).

Finally, relative to the two other training conditions, the ABC training procedure neither significantly influenced the intention to be active, nor explicit instrumental and affective attitudes toward PA. Again, these findings contrast with Van Dessel et al.' study (2018) revealing that a consequence-based training enhanced explicit attitudes toward healthy eating. Beyond potential ceiling effects (see Table 1), one critical difference between this study and ours lies in stimuli that were the target of evaluation. In two out of four experiments, they used stimuli that referred to fictitious food brands (i.e., *Vekte* and *Empeya*), whereas our stimuli corresponded to PA and sedentary alternatives that were familiar to participants. Yet, explicit evaluations are likely more malleable when individuals hold weak knowledge/experiences toward related stimuli (e.g., an unknown food brand), but might resist to new information when the concept of interest are well-known by participants (e.g., being physically active; Shoda et al., 2014).

Limitations and strengths

At least three limitations should be acknowledged. First, this study was conducted online which did not allow us to formally standardize the experimental procedure (e.g., checking for participants' vigilance while completing the tasks). Second, as participants in the main study were all adults living in the United Stated that were recruited from a dedicated platform, our results cannot be generalized to other populations. Third, PA was self-reported, which may have led to inaccuracies (Dyrstad et al., 2014), and, as mentioned above, the measure did not specifically capture the amount of time participants spent practicing selected behavioral alternatives. Among the strengths of this study are the inclusion of a preliminary study that allowed to refine the experimental procedure of the main study, the reliance on three

experimental conditions that allowed to disentangle whether the effects of the ABC training could be attributed to associative or inferential mechanisms, and its preregistered protocol that can be considered as a good research practice (Boisgontier, 2022). Finally, examining expectations about the effectiveness of the interventions allowed to control for potential placebo effects (Boot et al., 2013).

Conclusion

The effectiveness of the ABC training on favoring individuals' engagement in PA in ecological settings remains to be established using more intensive trainings and finer-grained measures of PA. However, thanks to its inferential properties, the ABC training was effective at improving hypothetical choices and implicit attitudes toward PA. We hope that this study will encourage researchers in designing personalized consequence-based trainings in PA and other health-related behaviors in order to uncover mechanisms at work and, above all, to determine whether such low cost and easy-to-deliver interventions could contribute to favor the adoption of a healthier lifestyle among the general population.

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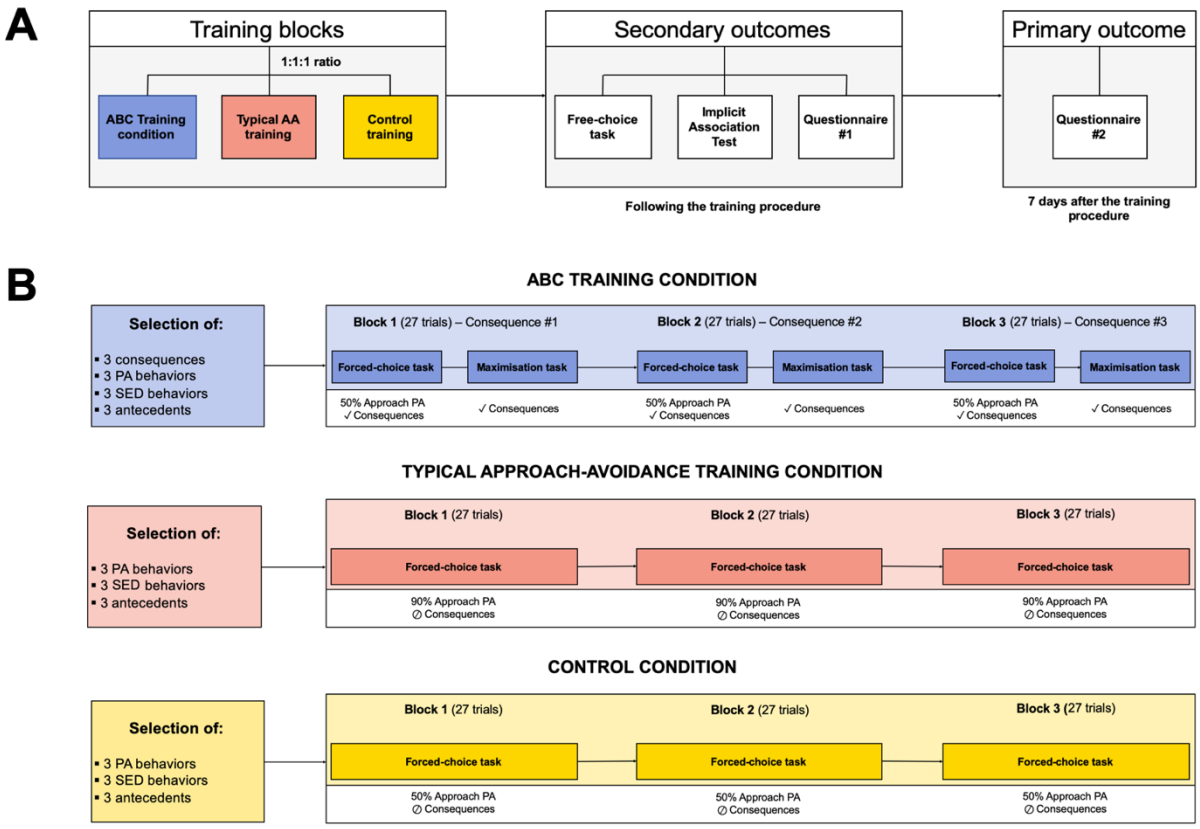
Figure 1. Procedure (A) and training blocks across experimental conditions (B).



Note. Typical AA training: Typical approach-avoidance training. PA: Physical activity; SED: Sedentary behaviors; IAT: Implicit Association Test.

Table 1. Descriptive statistics for the outcomes, across experimental conditions.

Outcomes	ABC training		Typical AA training		Control condition	
	Mean (SD)	**Range**	**Mean (SD)**	**Range**	**Mean (SD)**	**Range**
Overall self-reported MVPA (in minutes)	219 (228)	0; 1020	177 (212)	0; 1140	194 (207)	0; 1260
Engaging in > 0 min of PA (N, %)	94 (83%)		87 (79%)		85 (77%)	
Self-reported MVPA in minutes*	264 (225)	15; 1020	221 (215)	10; 1140	252 (203)	15; 1260
Proportion of choices toward PA (in %)	58 (35)	0; 100	41 (31)	0; 100	41 (31)	0; 100
Proportion of choices toward SED (in %)	42 (35)	0; 100	59 (31)	0; 100	59 (31)	0; 100
Reaction times when choosing PA (in ms)	1400 (578)	467; 2862	1505 (625)	569; 3528	1453 (609)	209; 3918
Reaction times when choosing SED (in ms)	2112 (1430)	551; 7472	1872 (1064)	547; 5850	1499 (628)	369; 3852
Intention to be physically active	5.10 (1.84)	1; 7	5.05 (1.76)	1; 7	5.22 (1.74)	1; 7
Implicit attitudes (DW-Score)	0.89 (0.51)	-0.39; 1.71	0.68 (0.65)	-0.93; 1.75	0.72 (0.56)	-1.21; 1.62
Explicit affective attitudes	4.61 (1.27)	1.67; 7	4.41 1.40)	1; 7	4.35 (1.25)	1.33; 7
Explicit instrumental attitudes	5.70 (1.80)	1; 7	5.58 (1.83)	1; 7	5.69 (1.69)	1; 7

Note. Typical AA training: typical approach-avoidance training; SD: standard-deviation; MVPA: moderate-to-vigorous physical activity. *: This variable represents self-reported PA among participants having practiced more than > 0 minutes of PA (second step of the zero inflated models).