Bachelor Thesis:

I Hate Sport: Uncovering and Modifying Hidden barriers to become more physically active

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Abstract

Introduction: Physical activity is essential for maintaining both physical and mental health, yet a large part of the global population remains insufficiently active. One possible explanation lies in cognitive biases. These automatic, unconscious distortions that can negatively influence decision-making and attitudes can be altered by Cognitive Bias Modification (CBM). This study aimed to investigate whether CBM can reduce negative cognitive bias toward physical activity, and whether depressive symptoms, which are often associated with lower motivation, play a role in bias levels or the intervention's effectiveness.

Methods: A single-group pre–post experimental design consisting of nineteen participants completed baseline and post-intervention measurements using the Single Category Implicit Association Test (SC-IAT) and the depression subscale of the Profile of Mood States (POMS). The CBM intervention was carried out via the TIIM mobile application and completed twice daily over three days. Data were analysed using paired t-tests, Spearman correlations, and linear mixed-effects models to evaluate changes in implicit attitudes and potential moderation by depressive symptoms.

Results: The findings indicated that participants' implicit attitudes toward physical activity significantly improved ($p < .001$) after completing the CBM training, with a large effect size (Cohen's $d = -1.19$). Although there seemed to be a trend suggesting that individuals with higher depressive symptoms held less positive implicit attitudes toward physical activity, this relationship was only marginally significant ($p = .068$). Furthermore, depressive symptoms did not significantly influence the effectiveness of the CBM training on bias over time (interaction $p = .65$).

Discussion: This study demonstrated that the CBM training was effective in reducing negative cognitive bias toward physical activity. Although depressive symptoms showed a trend toward being associated with more negative implicit attitudes, they did not significantly influence the effectiveness of the CBM intervention. These findings contribute to the emerging field of CBM applications for health-related behaviours and suggest that such interventions hold promise. Future research should aim to replicate these results with larger, more diverse samples, incorporate behavioural outcome measures, and further explore the role of depressive symptoms in shaping intervention outcomes.

Key words: Cognitive Bias Modification, Physical Activity, Depressive Symptoms, SC-IAT

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Introduction

Physical activity is widely recognised as a fundamental element of good health, with numerous studies highlighting its role in preventing chronic diseases and promoting longevity. According to Rhodes et al. (2017) and Warburton and Bredin (2016), regular physical activity can lead to risk reductions of 20%-30%, helping to prevent a wide range of chronic diseases and premature death. Despite the widely accepted benefits of physical activity, a significant proportion of the population engages in insufficient physical activity. Approximately one-third of the global population above the age of 15 does not meet the recommended activity levels (Park et al., 2020). Given this broad lack of physical activity, it is important to clarify what defines physical activity and how it can be measured. Physical Activity (PA) refers to all physical actions that lead to increased energy use (Rhodes et al., 2017). The international physical activity guidelines strongly suggest performing 150 minutes of moderate-to-vigorous intensity per week (Warburton & Bredin, 2016). These activities can include vigorous, intense behaviour such as running, but also walking or mowing the lawn can be seen as moderately intense physical activity. Although physical activity exists on a spectrum, from highly sedentary states to exceptionally active levels, research studies often categorise participants based on whether they meet established guidelines (Rhodes et al., 2017). Stenner et al. (2019) argue that people are motivated to participate in sports and perform physical behaviour for multiple reasons. There is a social aspect that drives people to sport, this can be increased by joining a sports team or a supportive community. Other reasons Stenner et al. (2019) found were accomplishing feelings of achievement and competence. The motivation to be physically active may be caused by the physical health benefits.

Despite the benefits that physical activity can cause, some people stay physically inactive or perform sedentary behaviour. Sedentary behaviour refers to any awake state with an energy expenditure of 1.5 metabolic equivalents or less while sitting, reclining, or lying down (Tremblay et al., 2017). The term ‘physical inactivity’ refers to engaging in an insufficient amount of physical activity, in other words, not reaching the recommended physical activity guidelines (Sedentary Behaviour Research Network, 2012). This type of behaviour, in particular sitting down, poses independent health risks (Warburton & Bredin, 2016). A meta-analytic review found a significant relationship between sedentary behaviours and health in adolescents. They argue that video game use and TV watching are risk factors for being overweight or even obese (Tremblay & Willms, 2003).

But what are the reasons for people to behave sedentary? One of the reasons people engage in sedentary behaviour can be the practical barriers people experience that make physical activity less accessible. There are numerous obstacles to engaging in regular physical exercise, which can be grouped into practical, psychological, social and contextual barriers (Martins et al., 2020). According to Webb et al. (2012), reasons for an increase in sedentary time can also be associated with a negative self-perception. Furthermore, Zou et al. (2022) found that in their cohort, higher physical inactivity levels can be linked to feelings of negative emotions. This can indicate that individuals may avoid physical activity not only because of practical barriers but also because of deeper psychological factors. Their self-perception may influence whether they see themselves as the "type" to engage in exercise, while their cognitive evaluations weigh the effort against potential benefits. Additionally, negative emotions associated with exercise, such as frustration or embarrassment, can further discourage participation. Another study of Nielsen and Reiss (2012) revealed that most adults are aware of the advantages of being active, which can indicate that there is a lack of motivation, issues with self-control or difficulties with self-regulation. This can suggest that providing information about the benefits of physical activity may not be enough to change behaviour, as deeper psychological factors likely play a crucial role in determining activity levels. For example, Jung et al. (2017) found that participants with depressive symptoms had significantly lower durations of light-intensity physical activity (LPA) than those without depressive symptoms. Individuals experiencing depressive symptoms not only interpret information in systematically distorted ways, but their thoughts also tend to be negative and focus on recurring themes, such as perceptions of the self, their experiences, and the future (Caballo, 1998). This negative cognitive pattern can contribute to the negative perception of exercise as exhausting, pointless, or unachievable. Consequently, individuals with depressive symptoms are more likely to avoid physical activity and engage in sedentary behaviour, reinforcing a cycle of inactivity and worsening mental health.

There are cognitive biases that can be linked to this negative cognitive pattern. Cognitive biases influence decisions and judgments by introducing consistent, unconscious distortions into the way people interpret information around them (Tversky & Kahneman, 1974). Such biases are often shaped by underlying attitudes that individuals hold, which can be either implicit or explicit. Explicit attitudes refer to conscious evaluations that individuals can deliberately reflect on and report. These attitudes consist of instrumental and affective components. Implicit attitudes, on the other hand, are automatic mental associations between a concept and a positive or negative evaluation. As opposed to explicit attitudes, individuals may not be consciously aware of these associations (Rydell & McConnell, 2006).

Implicit and explicit attitudes are part of the decision-making process. As dual-process models suggest, human behaviour and decision-making are influenced by two distinct types of cognitive systems: one that is fast, automatic, and unconscious, and another that is slower, more deliberate, and conscious. The Reflective-Impulsive Model (RIM) is a dual-process model that proposes both explicit and implicit attitudes can influence behaviour (Muschalik et al., 2019). This model explains behaviour as the result of two different information-processing systems: the reflective system and the impulsive system. The reflective system formulates behavioural choices by drawing on factual knowledge and personal values, while the impulsive system drives actions through associative connections and inherent motivational tendencies (Strack & Deutsch, 2004). The RIM model uses cognitive, emotional and motivational factors to emphasise their influence on behaviour (Strack & Deutsch, 2014). The RIM framework makes it easier to understand the implicit and explicit attitudes toward physical activity (PA). While explicit attitudes can lead individuals to acknowledge the benefits of exercise, implicit attitudes can create negative biases against physical activity. The RIM helps explain why some individuals, despite positive explicit intentions, struggle to create an active lifestyle due to deep-seated implicit aversions. By understanding these dual influences, interventions such as Cognitive Bias Modification (CBM) can be explored to shift automatic associations and encourage more positive attitudes toward PA.

To assess implicit attitudes, often reaction-time-based tasks are used, one of which is the Implicit Association Test (IAT). Participants must categorise stimuli, such as words or images, into four distinct categories using only two response keys. Each key is linked to two categories at a time (e.g., physical activity + positive versus sedentary behaviour + negative). Suppose an individual has a strong mental association between two categories. In that case, they will complete the sorting task more quickly and accurately when those categories are paired under the same response key, compared to when assigned to different keys (Chevance et al., 2017). The principle behind the IAT is that the stronger an individual's automatic positive or negative association with a concept, the faster they will categorise related stimuli accordingly. This allows researchers to infer implicit attitudes toward specific behaviours or objects (Muschalik et al., 2019). An IAT normally includes two targets. In the context of physical activity, a Single Category Implicit Association Test (SC-IAT) can be used. This is a test in which the focus is on one target only (e.g. physical activity) instead of two targets (e.g. physical activity and sedentary behaviour) (Karpinski & Steinman, 2006). A reason for using this single target is that there is no clear opposite of physical behaviour (Conroy et al., 2010).

Therefore, it will be clearer to only use one unambiguous target. Research using the SC-IAT has found that individuals who have more positive automatic associations with physical activity tend to engage in physical activity more than those who have less favourable automatic associations (Conroy et al., 2010). Furthermore, Hyde et al. (2010) found that automatic evaluations of physical activity, measured by the SC-IAT, are separate from an individual's conscious emotional attitudes toward exercise. One important implicit bias to focus on is the negative memory bias. This refers to the tendency to recall negative information better than positive information (Gotlib & Joormann, 2010). These associations are often formed through repeated experiences and can shape how individuals respond to specific stimuli without conscious awareness.

Cognitive Bias Modification can be used to try to minimise the cognitive biases individuals can have against physical activity. Cognitive Bias Modification (CBM) is a procedure designed to directly change automatic cognitive processes that play a role in the onset and persistence of psychopathological conditions (Jones & Sharpe, 2017). CBM procedures modify the unconscious aspects of thought to influence behaviour or emotional responses (MacLeod & Mathews, 2012). CBM aims to encourage more positive associations with physical activity, potentially increasing physical activity and reducing sedentary behaviour, by reshaping automatic responses. CBM has already been proven effective on other fronts, such as anxiety and substance abuse (Jones & Sharpe, 2017; Van Der Baan et al., 2023). Although evidence on the effectiveness of Cognitive Bias Modification (CBM) in individuals with depressive symptoms is still limited, it can be reasoned that CBM may have a greater impact in this group. People experiencing depressive symptoms are known to exhibit stronger negative cognitive biases (Caballo, 1998), which suggests they may have more room for change at baseline. From this perspective, one could expect that the difference in cognitive bias before and after the intervention would be larger for individuals with more depressive symptoms, simply because they start with a higher level of bias. This assumption is theoretical and highlights a potential mechanism by which CBM could be especially effective for those with elevated depressive symptoms.

This study will focus on how Cognitive Bias Modification (CBM) can be used to reduce cognitive biases against physical activity. In particular, it will examine how depressive symptoms may influence this process. Since individuals with higher levels of depressive symptoms are expected to have stronger negative biases toward physical activity, it is anticipated that CBM will have a greater impact in reducing these biases among those scoring higher on the POMS-D scale. To explore these relationships, the present study aims to answer the following research questions:

RQ1: Can Cognitive Bias Modification enhance implicit perceptions of physical activity?

Hypothesis 1: Participants will have more positive implicit perceptions towards physical activity after participating in the Cognitive Bias Modification Intervention.

RQ2: How does cognitive bias against physical activity differ between individuals with varying levels of depressive symptoms at baseline?

Hypothesis 2: Participants with depressive symptoms will have greater cognitive bias against physical activity compared to participants with less depressive symptoms.

RQ3: What effect do depressive symptoms have on the effectiveness of Cognitive Bias Modification in altering bias toward physical activity?

Hypothesis 3: Participants with higher levels of depressive symptoms will show a greater reduction in physical activity bias from pre- to post-intervention, compared to participants with lower levels of depressive symptoms.

By addressing these questions, this research seeks to provide insight into the possible psychological mechanisms underlying physical activity avoidance and how CBM may serve as an intervention, particularly for individuals experiencing depressive symptoms.

Methods

Design

The University of Twente's Ethics Committee BMS/Domain Humanities and Social Sciences approved the study (registration number 250481, merged with registration number 250452). Data was collected in April and May 2025. This study made use of a single-group pre- and post-test experimental design to investigate the effects of cognitive bias modification (CBM) on cognitive biases against physical activity. This study contained two time points of data collection within a longitudinal study. Participants' outcomes were analysed using both between-subject and within-subject comparisons. The aim of this research was to assess the impact of the CBM training, using the TIIM App, on implicit bias toward physical activity and depressive symptoms.

Participants

The dataset consisted of 29 participants. Seven participants did not finish the second part of the SC-IAT; therefore, they were excluded from the data analysis. Furthermore, in the second SC-IAT, three participants had four missing values due to extreme response times (values that were either too high or too low). These outlier values were not recorded by SoSci Survey, as they fell outside the acceptable range. Because such extremes can significantly influence the results, these cases were excluded from further analysis. Thus, the dataset used for the data analysis consisted of 19 participants in total. The age range goes from 18 to 56 ($M = 25.3$, $SD = 10.73$). 13 participants were female (68.4%) and 6 participants were male (31.6%). Furthermore, 7 participants were Dutch (36.8%), 3 were German (15.8%), and 9 came from another country, namely Greece (47.4%). Looking at their current or highest achieved educational level, 4 participants indicated Secondary school (21.1%), 10 indicated University (Bachelor degree) (52.6%), 2 indicated University (Master degree) (10.5%), 2 indicated University of Applied Sciences (10.5%) and 1 indicated Vocational Education (5.3%).

Participants were recruited via the SONA system, the participant pool of the University of Twente and convenience sampling within the researchers' network. To be accepted, participants had to be at least 18 years old, have adequate English reading and writing skills, and have access to a computer or laptop with a working keyboard to complete the tasks. Before the pre-test began, participants had to give informed consent, and it was ensured that they were aware of the voluntary nature of their participation.

Materials

POMS

Depressive symptoms were measured using the abbreviated version of the Profile of Mood States (POMS), a self-report tool aimed at capturing temporary shifts in emotional mood. Originally developed by McNair, Lorr, and Droppleman (1971), the POMS assesses six distinct mood subscales. In this research, only the depression mood subscale has been used, which consisted of 7 items. This is because the research is only focused on depressive symptoms. The POMS questionnaire and the scoring form can be found in Appendix C. This questionnaire was validated by Grove and Prapavessis (1992) and has shown robust psychometric properties. In their study, the internal consistency of the subscales, measured by Cronbach's alpha, ranged from .76 for Confusion to .91 for Depression. The Total Mood Disturbance score showed an alpha of .84, indicating good to excellent reliability across the different mood dimensions. The test–retest reliability over a two-week interval showed a Pearson correlation coefficient range from .65 to .74, suggesting reasonable temporal stability of mood measurements in the short form. The construct validity of the abbreviated version was supported by strong correlations with the original full-length POMS, ranging from .89 to .97 for individual subscales and .96 for the total mood score. As a result, the abbreviated POMS is particularly useful in research settings where time is limited or repeated assessments are needed, while still offering a reliable way to capture mood changes.

Measuring Implicit Bias with SC-IAT

The Single Category Implicit Association Test (SC-IAT) is a computer-based reaction time task used to measure implicit attitudes toward a single target concept (Karpinski & Steinman, 2006). The traditional IAT compares a target category with a contrast category. The SC-IAT, however, measures the strength of associations between one single focal category and evaluative attributes (positive vs. negative). The SC-IAT is designed to assess the strength of automatic associations between a single target category (physical activity) and two opposing evaluative attributes (positivity and negativity). The stimuli used in the SC-IAT consisted of physical activity words (target category) and positive and negative evaluative words, which can be found in Appendix A. These words were selected to represent typical forms of physical activity and common emotional or physical experiences associated with it, both positive and negative. The SC-IAT consisted of two blocks, each reflecting a different evaluative pairing:

1. Block 1: Physical Activity and Positivity (Practice)
   In this block, participants had to categorise physical activity words and positive words using the ‘E’ and ‘I’ keys, while negative words were categorised with the opposite key. This block aims to assess the time participants take to associate physical activity with positive attributes.
2. Block 2: Physical Activity and Positivity

Block 2 had the same content and purpose as Block 1. Block 1 was for practice, whereas Block 2's data was used for analysis.

3. Block 3: Physical Activity and Negativity (Practice)

   In this condition, participants had to categorise physical activity words and negative words using the ‘E’ and ‘I’ keys, while positive words were categorised with the opposite key. This block aims to assess the ease with which the participants associate physical activity with negative attributes.

4. Block 4: Physical Activity and Negativity

   Block 4 had the same content and purpose as Block 3. Block 3 was for practice, whereas Block 4's data was used for analysis.

In all blocks, one word at a time appeared in the centre of the screen, and participants had to quickly match it with the appropriate category using the ‘E’ and ‘I’ keys. The response time (latency) and accuracy of each classification were recorded. Reaction times were recorded and used to infer implicit preferences, with faster responses suggesting stronger automatic associations (Greenwald et al., 1998). In this research, a D-score can be calculated by subtracting the mean response time of Block 2 from Block 4 and dividing by the pooled standard deviation. This standardised score reflects the direction and strength of the participant’s implicit association with physical activity (Greenwald et al., 2003).

In this research, the SC-IAT was generated using SoSci Survey and was accessible through www.soscisurvey.de. The Single Category Implicit Association Test (SC-IAT) has demonstrated acceptable levels of internal reliability across different applications. Based on results from four studies using six different SC-IAT variations (Karpinski & Steinman, 2006), the internal consistency coefficients were generally strong, with an average correlation of .69, and individual coefficients ranging from .55 to .85. These values are comparable to the internal consistency found in traditional IATs. These findings suggest that the SC-IAT possesses a sufficient level of measurement reliability. In terms of validity, the SC-IAT has consistent correlations with related explicit measures. In the domain of brand preferences, SC-IAT scores correlated significantly with explicit attitude ratings, such as a correlation of $r = .29$ ($p = .04$) between SC-IAT scores and overall soda preference (Karpinski & Steinman, 2006). Similar correlations were observed for brand-specific attitudes, including $r = .27$ for Coke and $r = .26$ for Pepsi. In the area of self-esteem, the SC-IAT correlated with explicit self-esteem at $r = .38$ ($p = .01$), while the traditional IAT did not show a significant relationship ($r = .01$, $p = .93$). These results demonstrate that the SC-IAT captures meaningful individual differences in implicit attitudes, supporting its construct validity.

CBM Training in the TIIM Application

The Twente Intervention Interaction Machine (TIIM) application was used to carry out the Cognitive Behaviour Modification training. This application is developed by the Behavioural, Management, and Social Sciences (BMS) Lab at the University of Twente (Van 't Klooster et al., 2024). TIIM is a free mobile app available on both the iOS App Store and the Android Play Store, although it has restricted access. The app enables students, researchers, and faculty at the University of Twente to create surveys, long-term studies, and interventions. In this particular study, TIIM was used to administer the CBM training through the response latency platform of the application.

Participants were asked twice a day, for three days, to complete the CBM training. The aim was to reduce the implicit bias they had towards physical activity. During a CBM training, participants had to swipe certain words that appeared in the middle of the screen either downwards to positivity/physical activity, or upwards to negativity. They were the same words used in the SC-IAT in the SoSci Survey, which can be found in Appendix A, consisting of physical activity words (target category) and positive and negative evaluative words. There were a total of 90 trials per session, which were presented in a randomised order. When participants swiped the word to the wrong side of the screen, the label turned red. If they swiped it to the right side of the screen, it appeared green. In addition to the training sessions, the app featured a welcome message and daily instructions. Participants were also sent notifications as reminders to complete their training sessions.

Procedures

Participants received a link to the SoSci Survey, additional information about the research, and informed consent at the start of the study, which can be found in Appendix B. On the first day, participants completed a baseline assessment in SoSci Survey. This includes questions about demographic information, a Single Category Implicit Association Test (SC-IAT) and the Profile of Mood States (POMS) questionnaire. The information about the SC-IAT and the Profile of Mood States questionnaire can be found in Appendices C and D. The other questionnaires included in the baseline assessment are not of importance for this research. After completing the baseline assessment, participants were asked to download the TIIM application on their device. After downloading the TIIM application and creating an account, participants could start with the first session of the CBM training. Two hours after the first session, they received a notification to start the second session of day one. 24 hours after the first session of day one, participants received a notification for the first session of day two, followed by the second session two hours later. 48 hours after the first session of day one, they received a notification to start the first session of day three, followed by the second session two hours later. After three days of using the TIIM application, participants had to wait four more days to receive an email with the link to the post-intervention assessment. This assessment included the same measurements as the baseline assessment: a Single Category Implicit Association Test (SC-IAT), the Profile of Mood States (POMS) questionnaire, and other questionnaires that are not of importance for this research.

Data Analysis

Data analysis was conducted using version 4.2.2 of RStudio. The following R packages were used: tidyverse (mutate, filter, select, group_by, summarise, ggplot), readxl (read_excel), janitor (clean_names), here (here), stringr (str_detect, str_replace_all), forcats (fct_recode, fct_collapse), lme4, lmeTest, (lmer()), and effsize. Additionally, base R functions such as read.csv, table, prop.table, ifelse, unique, length, which, and write.csv were used for data handling and basic operations. Furthermore, sapply, lapply, factor, as.numeric, rowSums, data.frame, rep, and logical subsetting ([-c()], [,]) were also used to preprocess and structure the data.

RQ1: Can Cognitive Bias Modification enhance implicit perceptions of physical activity?

To answer the first research question about the effect of Cognitive Bias Modification (CBM) on cognitive bias towards physical activity, as measured by the Single Category Implicit Association Test (SC-IAT), a pre- and post-training comparison of response times in d-scores was conducted. R Studio was used to analyse the data and determine whether there was a significant difference in response times on the IAT before and after the CBM training. Descriptive statistics, such as the response times before and after the CBM training, were calculated. Visual inspection of data distributions was performed via histograms to determine the normality of distribution of the response time. To determine the appropriate statistical test, normality of the pre- and post-training response times was checked using histograms and the Shapiro-Wilk test. Based on the normality test results, a paired t-test was used to compare pre- and post-training response times. To visualise the data, histograms were plotted for both the pre- and post-training response times to inspect their distributions. Additionally, boxplots were created to compare the pre- and post-training response times, which highlight any differences in central tendency and spread of the data.

RQ2: How does cognitive bias against physical activity differ between individuals with varying levels of depressive symptoms at baseline?

To evaluate the second research question, a linear relationship between baseline levels of depressive symptoms and cognitive biases toward physical activity was examined. Depressive symptoms from the baseline scores from the POMS (Profile of Mood States) questionnaire were used, and cognitive bias was measured using the pre-scores of the SC-IAT. The distribution of both variables was visualised using histograms and density plots to check for normality. The Spearman rank correlation was conducted to assess the linear relationship between depressive symptoms and cognitive bias. Additionally, a scatterplot was created to visualise the relationship between depressive symptoms and SC-IAT scores. A regression line was added to the plot to illustrate the direction and strength of the association.

RQ3: What effect do depressive symptoms have on the effectiveness of Cognitive Bias Modification in altering bias toward physical activity?

To answer the third research question, a moderation analysis was conducted to explore whether depressive symptoms influence how effective Cognitive Bias Modification (CBM) is in shifting cognitive biases related to physical activity. The d-score was measured from pre- to post-intervention. Depressive symptoms were assessed using the baseline scores from the Profile of Mood States (POMS) questionnaire. Histograms and density plots were examined to check the distribution of these variables. A linear mixed-effects model (LME) was used to test whether depressive symptoms moderate the effect of CBM over time. In this model, time (pre- vs. post-training) was included as a within-subject fixed effect, depressive symptoms as a continuous between-subject predictor, and their interaction to examine moderation. Taking into account the repeated-measures structure of the data, a random intercept for each participant was included. This model allowed for the use of all available data points, taking into account individual differences in baseline response times and depressive symptoms, and avoids the need to categorise continuous variables. A scatterplot with a regression line was created to illustrate how the effectiveness of CBM varies across different levels of depressive symptoms.

Results

Descriptive Statistics

The first results gathered were the descriptive statistics. These results can be found in Table 1, which shows the d-scores of both the pre- and post-SC-IAT, as well as the POMS depression scores.

Table 1

Descriptive Statistics (N=19)

Test	***M***	***SD***	***Range***
d-score T0	*0.30*	*0.31*	*1.23*
d-score T7	*0.67*	*0.32*	*1.17*
POMS depression score T0	*2.36*	*3.10*	*12*

Note: M = Mean; SD = Standard Deviation. D-scores represent implicit associations measured with the Single Category Implicit Association Test (SC-IAT) before (T0) and after (T7) the intervention. POMS = Profile of Mood States (baseline measure)

RQ1: Can Cognitive Bias Modification enhance implicit perceptions of physical activity?

In order to answer this first research question about the effect of Cognitive Bias Modification (CBM) on cognitive bias towards physical activity, as measured by the Single Category Implicit Association Test (SC-IAT), a pre- and post-training comparison of response times in d-scores was conducted. Beforehand, normality was checked using the Shapiro-Wilk test, which showed a p-value of .944 for the pre-SC-IAT and a p-value of .605 for the post-SC-IAT (Table 2). This means the data were normally distributed, which can also be seen in Appendix F.

Table 2

Shapiro-Wilk test for pre- and post-SC-IAT

Variable	W statistic	p-value	Interpretation
Pre-SC-IAT	0.980	0.944	Normally distributed
Post-SC-IAT	0.962	0.605	Normally distributed

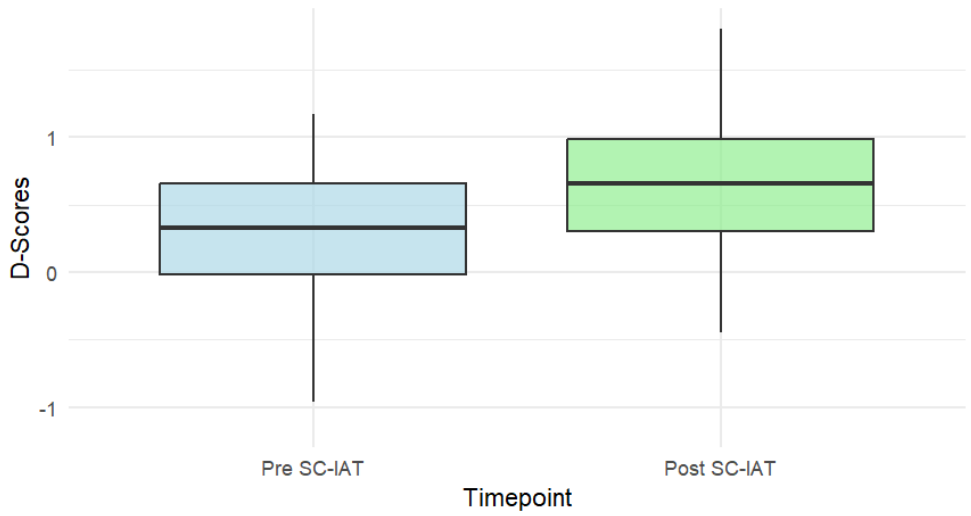
Note: Results of the Shapiro-Wilk test indicate that both the pre- and post-intervention SC-IAT d-scores were normally distributed ($p > .05$), justifying the use of parametric statistical analyses, N=19.

The paired t-test showed that participants' mean d-score significantly increased in the pre-to-post intervention from 0.30 to 0.67. Furthermore, it showed an increase with a mean difference of 0.37 (95% CI: -0.58 to -0.17), and a p-value < .001. This result corresponds to a large effect size, *Cohen's d* = –1.19, 95% CI [–1.99, –0.38]. This indicates that the observed difference was not only statistically significant but also substantial in magnitude. The negative t-value (-3.90) and the confidence interval indicate a significant change in implicit attitudes, with a confidence interval that does not include zero, further suggesting that the observed change is not due to random chance.

Based on these findings, it can be concluded that Hypothesis 1, which stated that participants will have a decrease in cognitive bias against physical activity after participating in the Cognitive Bias Modification Intervention, can be accepted. The difference between pre- and post-SC-IAT d-scores can also be seen in the boxplots of Figure 1.

Figure 1

Boxplot of Pre- and Post-SC-IAT d-scores



Note: d-score: <0 =negative bias, >0 = positive bias, N=19

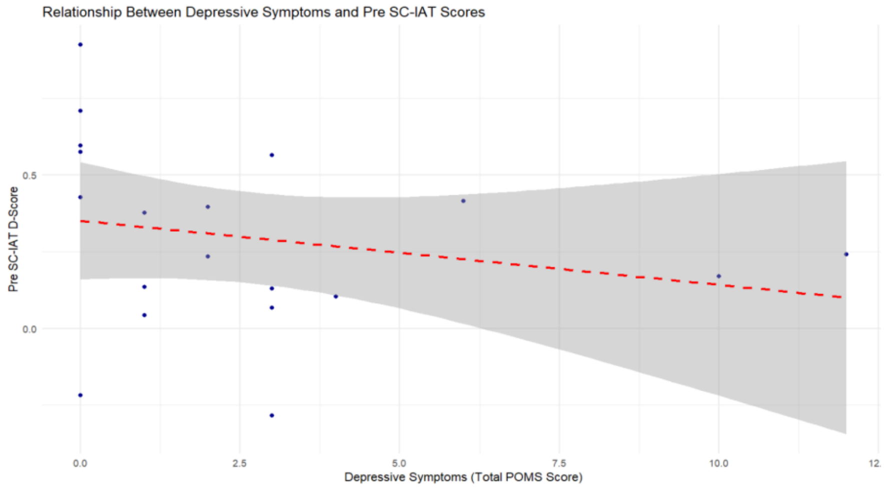
RQ2: How does cognitive bias against physical activity differ between individuals with varying levels of depressive symptoms at baseline?

To answer the second research question, a linear relationship was examined between baseline levels of depressive symptoms and cognitive biases toward physical activity. Beforehand, normality was checked using histograms with density plots, which showed that the data of the pre-SC-IAT were normally distributed. However, the data of the POMS depression scores were not normally distributed. Both can be found in Appendix F. Accordingly, a non-parametric Spearman Rank correlation was carried out.

Results indicated a moderate negative correlation ($\rho = -.40$, $p = .087$), which was only marginally significant. This suggests a trend where individuals with higher depressive symptoms may hold less positive implicit attitudes toward physical activity, although the evidence is not strong enough to confirm this relationship. The relationship between pre-SC-IAT scores and POMS depressive symptoms can be found in Figure 2. In this figure, it can be seen that there are two outliers with high depressive symptom scores, compared to the rest of the values.

Figure 2

Relationship between Depressive Symptoms and Pre-SC-IAT D-scores (N=19)



Note: Total Depressive Score (Range: 0-12). d-score: <0 =negative bias, >0 = positive bias. The grey coloured area represents the 95% CI.

To further explore the initial findings, a post-hoc Spearman rank correlation was conducted, excluding two identified outliers with exceptionally high depressive symptom scores (Appendix E). After removal, results remained largely unchanged with the strength of the association of similar strength, and again only marginally significant, $\rho = -.45$, $p = .068$.

Based on these findings, it can be concluded that Hypothesis 2, which stated that participants with depressive symptoms will have greater cognitive bias against physical activity, can be partially accepted. However, this finding was not significant, and therefore, the hypothesis cannot be completely accepted.

RQ3: What effect do depressive symptoms have on the effectiveness of Cognitive Bias Modification in altering bias toward physical activity?

To answer the last research question about the effect of depressive symptoms on Cognitive Bias Modification, a moderation analysis was conducted. The normality of the depressive symptoms, the pre-SC-IAT and the post-SC-IAT were tested and can be found in Appendix F. A linear mixed-effects model (LME) was used to test whether depressive symptoms moderate the effect of CBM over time (Tables 3 and 4).

Table 3

Linear Mixed-effects Model

Fixed Effect	Estimate	Std. Error	df	t-value	p-value
(Intercept)	0.689	0.094	33.64	7.29	< .001
Time (Pre vs. Post)	-0.337	0.127	17.00	-2.67	.016
Depressive Score (POMS)	-0.007	0.022	33.64	-0.32	.752
Time x Depressive Score	-0.014	0.030	17.00	-0.46	.649

Note: SC-IAT = Single Category Implicit Association Test; POMS = Profile of Mood States. The model examines the effect of time, depressive symptoms, and their interaction on SC-IAT d-scores. A significant main effect of time was found ($p = .016$), while depressive symptoms and the interaction were not significant, N=19.

Table 4

Linear Mixed-effects model: Random effects

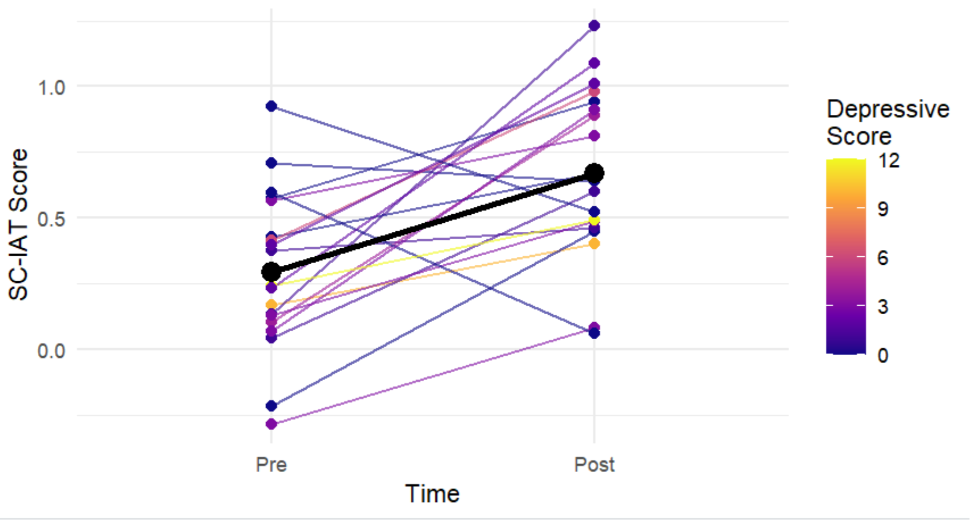
Group	Effect	Variance	Std. Deviation
Participant	Intercept	0.0105	0.102
Residual	-	0.0914	0.302

Note: Intercepts were included for each participant to account for within-subject variability. Variance and standard deviation reflect variability between participants and residual error, N=19.

The linear mixed model revealed a significant main effect over time, as expected given the paired t-test above, indicating that participants' implicit attitudes towards physical activity improved following CBM training ($p = .016$). However, depressive symptoms, measured via baseline POMS scores, did not significantly predict SC-IAT d-scores ($p = .75$), nor did they moderate the effect of CBM over time (interaction $p = .65$). Figure 3 illustrates the change in SC-IAT d-scores from pre- to post-intervention for each participant, with lines colour-coded based on baseline depressive symptoms (POMS scores). While the overall trend, represented by the thick black line, indicates a reduction in implicit bias following the intervention, there is substantial variability in individual trajectories. Specifically, participants with higher pre-test SC-IAT scores tend to show larger decreases, whereas those with lower initial scores occasionally exhibit increases.

Figure 3

Change in SC-IAT d-scores by Depressive Symptoms (N=19)

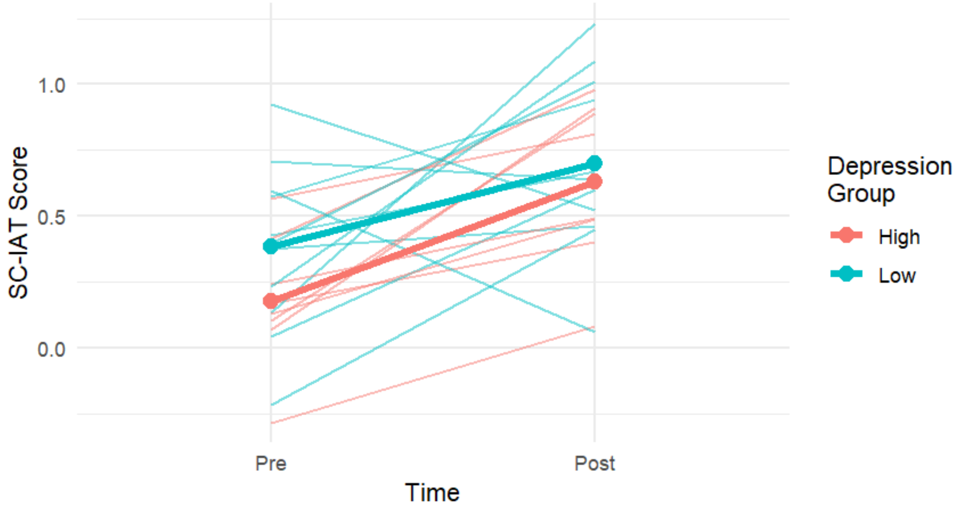


Note: d-score: <0 =negative bias, >0 = positive bias. Time represents pre- and post-intervention measurements.

To further investigate whether depressive symptoms moderated the effect of Cognitive Bias Modification (CBM), an additional analysis was conducted. While the initial model used continuous depression scores, this approach may have masked potential non-linear patterns. Therefore, depressive symptoms were reclassified into two categories (Low vs. High) using a median split to explore whether the change in SC-IAT scores over time differed more clearly between groups (Figure 4). The linear mixed model with categorised depression scores showed a significant main effect of Time, indicating that SC-IAT scores decreased from pre- to post-intervention ($p = .007$). However, the interaction between Time and Depression Group was not significant ($p = .49$), suggesting that the degree of change in implicit attitudes did not differ significantly between individuals with high and low depressive symptoms. These results are consistent with the previous model using continuous scores and support the conclusion that depressive symptoms did not significantly moderate the effect of CBM.

Figure 4

SC-IAT Score Changes from Pre- to Post-Intervention by Depression Group (Low vs. High) (N=19)



Note: d-score: <0 =negative bias, >0 = positive bias. Time represents pre- and post-intervention measurements. Groups are based on depressive symptom levels (low and high). The bold lines represent group means.

Based on these findings, it can be concluded that Hypothesis 3, which entails participants experiencing depressive symptoms will have greater decreases between pre- and post-measurements, cannot be accepted.

Discussion

This study aimed to investigate the effect of CBM training in the TIIM app on cognitive bias against physical activity. The first finding of this study concerns the effect of CBM on cognitive bias against physical activity. After the data analysis, it was concluded that participants showed a significant increase in SC-IAT d-scores from pre- to post-intervention. This indicates that CBM was successful in increasing the bias towards favouring physical activity. Furthermore, the data analysis revealed a relationship between depressive symptoms and cognitive biases. According to the data analysis, a moderate negative correlation was found between the two variables; however, this was not statistically significant. This suggests that higher levels of depressive symptoms are likely to be associated with less positive implicit attitudes, but further research is needed to confirm this. Finally, this study does not support the idea that depressive symptoms moderate the effectiveness of CBM. Participants improved their implicit attitudes towards exercise after the intervention, but depressive symptoms did not significantly moderate the effect of CBM over time. This means that those with higher depressive symptoms did not improve any more or any less than those with lower symptoms.

Effectiveness of CBM

The findings of the first research question are consistent with previous studies demonstrating the effectiveness of CBM in modifying automatic cognitive processes. For example, Jones and Sharpe (2017) reported consistent short-term reductions in anxiety-related cognitive biases across multiple meta-analyses. Moreover, Van der Baan (2023) found that CBM reduced attentional bias for alcohol in a sham-controlled study. These findings support the idea that CBM can effectively alter implicit biases. Although these studies focused on different domains, the current findings extend the literature by suggesting that CBM may also be effective in reducing implicit biases against physical activity. However, several methodological differences limit direct comparisons. First, while previous studies often included control groups, the present study used a single-group pre-post design, which may lead to an overestimation of effects. Additionally, many CBM interventions focus on attentional or interpretational biases, whereas the current study targeted memory bias using an IAT-based task that also incorporated elements of approach-avoidance training (TIIM). Furthermore, most prior studies assessed long-term effects through follow-up measures, while the present study only evaluated immediate post-intervention outcomes. The study population also differed, as previous research typically involved clinical samples, whereas this study was conducted in a non-clinical setting. Finally, the training was completed online at home, which may affect engagement and standardization compared to in-clinic delivery. These differences highlight the need for caution when interpreting the results in light of existing CBM literature, but they also point to the potential for broader applicability of CBM outside clinical environments.

Depressive Symptoms and Cognitive Bias

The correlation of the second research question did not reach statistical significance. Previous research supports the notion that depressive symptoms can influence attitudes and behaviours related to physical activity. For example, Jung et al. (2017) reported that individuals with depressive symptoms engaged in significantly less light-intensity physical activity (LPA) compared to those without such symptoms. Furthermore, as Caballo (1998) explains, individuals experiencing depression often process information through a negatively biased cognitive view. Certain cognitive patterns may lead to avoidance of physical activity, as exercise is perceived as demanding or unachievable. As a result, depressive symptoms may contribute to increased sedentary behaviour, reinforcing a cycle of inactivity and deteriorating mental health. Although the correlation in the current study did not reach statistical significance, the pattern is consistent with previous literature suggesting that depressive symptoms are associated with more negative cognitive ratings of physical activity. An interesting point to consider is that the sample in the current study consisted of individuals with relatively low depressive symptom scores. This could mean that the full range of possible associations between depressive symptoms and cognitive bias may not have been captured. It is possible that a stronger or more consistent relationship would emerge in a sample with a wider and more evenly distributed range of depressive symptoms. However, the findings did approach significance, and a moderately strong correlation coefficient was observed, which is even more suggestive in a small sample of 19 participants. Therefore, this study adds to the growing evidence that cognitive biases shaped by depressive symptoms may play a role in how individuals perceive physical activity.

The effect of depressive symptoms on CBM

The final research question had to be rejected. This result was unexpected, as the hypothesis was based on an assumption developed within the context of this research. The reasoning was that individuals with higher depressive symptoms tend to exhibit stronger negative cognitive biases and, therefore, might have more potential for change (Caballo, 1998). From this perspective, it was assumed that CBM would be more effective for individuals with higher baseline bias, as they start further from the desired outcome. However, the data showed that baseline depressive symptoms were only weakly related to baseline implicit bias, which undermines the rationale behind the hypothesis. If individuals with higher depressive symptoms do not necessarily begin with stronger biases, there is less reason to expect that they would benefit more from CBM. Although this rationale was not grounded in prior empirical research specifically linking CBM effectiveness to depression severity, it was proposed as a possible mechanism by which CBM could be particularly beneficial in this subgroup. This contradictory finding can be explained by the fact that individuals with higher depressive symptoms may have engaged less actively with the CBM task due to lower motivation or reduced cognitive energy, which are common symptoms of depression. According to the DSM-5 (American Psychiatric Association, 2013), one of the symptoms of depression is a markedly diminished interest or pleasure in most activities. This could mean that people with depressive symptoms are also less interested in the CBM intervention itself. When someone is less interested, they are likely to feel less motivated to engage with the task. As a result, individuals with more depressive symptoms may have put in less effort or attention during the CBM training, which could explain why the intervention was not more effective for this group. In addition, previous research has shown that individuals with depressive symptoms generally have more difficulty responding to psychological interventions. For example, De Carlo et al. (2016) found a correlation between depressive symptoms and non-response, suggesting that reduced motivation to change may hinder the effectiveness of interventions like CBM in this group.

Strengths and Limitations

This study has several strengths that contribute to the validity and relevance of its findings. First, using a within-subject design allowed direct comparisons of participants' implicit attitudes before and after the intervention, which improved internal validity by controlling for individual differences and made the research statistically powerful (Montoya, 2022). Furthermore, this study used validated instruments, such as the Single Category Implicit Association Test (SC-IAT) and the POMS depression scale, both of which are widely used and psychometrically validated tools for assessing psychological constructs such as implicit attitudes and mood-related depressive symptoms. A key strength of this research is the development and use of a tailored Cognitive Bias Modification (CBM) intervention specifically designed to address negative implicit attitudes towards physical activity. This domain-specific approach is relatively new and is an important development in adapting CBM methods to health-related behaviours. The intervention showed positive effects on reducing cognitive biases against physical activity, supporting its potential value and highlighting an emerging area of applied psychological research. Given the relatively limited amount of work focused on CBM in the context of physical activity, this study makes an important contribution and can be used as a basis for future research. In addition, this study focused on the possible moderating role of depressive symptoms in the effectiveness of CBM, another underexplored area. Although no statistically significant moderation effects were found, including this analysis is noteworthy as it begins to address a research gap. This research can guide future studies by highlighting factors that may be relevant to the responsiveness of interventions. Exploring such mechanisms is important given that CBM continues to be adapted for different psychological domains. Using visual data representations such as histograms, scatterplots, and line graphs improved the interpretability of the results.

However, there were also several limitations that should be taken into account. The small sample size (N = 19) limited statistical power, which may have contributed to the lack of significant findings regarding depressive symptoms (Faber & Fonseca, 2014). The sample consisted mainly of young adults, most of whom were female and highly educated, with different nationalities and levels of depressive symptoms. The small sample size also created another limitation, namely the absence of a control group. Therefore, it is not possible to conclude that changes in bias were due exclusively to the intervention and not to repeated testing or other factors. One possible explanation is a training effect, where performance on cognitive tasks improves simply due to repeated exposure to the same or similar test materials (McCaffrey et al., 2000). Another possible explanation is that it is unclear whether all participants used the TIIM app. During data collection, it was not possible to link the SC-IAT data to the CBM via the TIIM app, so it is unclear whether all participants attended all CBM sessions. The final point to mention regarding the sample size is the participants who dropped out. It is possible that this group had certain characteristics. Were they totally unmotivated to complete the intervention, or were there other reasons for their dropout? It is possible that their dropout impacted the outcomes of this study, so it is important to bear this in mind.

Next to that, the range of depressive symptoms in the sample was relatively limited, which may have reduced the ability to detect meaningful moderation effects. This small range limits the statistical sensitivity of the moderation analysis and may explain why no significant interaction between depressive symptoms and the CBM effect was found. A broader distribution of depressive symptom scores, including more participants with moderate to severe symptoms, would be necessary to more accurately assess whether depression levels influence responsiveness to CBM. The novelty of the CBM intervention is another limitation that should be taken into account. Although this tailored design is a strength, it also means that the effectiveness and reliability of this physical activity-focused CBM have not yet been tested in other studies. As a result, the outcomes should be interpreted with some caution, since the intervention has not yet been fully validated within this context. Furthermore, the meta-analysis by Cristea et al. (2016) found that while CBM interventions can modify cognitive biases, they do not have significant effects on actual behavioural outcomes. This raises questions about the clinical usefulness of CBM and suggests that altering cognitive biases alone may change behaviour. This limitation also applies to the current study, as a direct behavioural outcome measure, such as physical activity levels, was not included. Therefore, it remains unclear whether changes in implicit attitudes observed here would translate into real-world behavioural change.

Moreover, despite the limited power due to the small sample size, post-hoc analyses excluding outliers confirmed the main results. This suggests that excluding outliers did not bias the findings and supports the robustness of the conclusions.

Lastly, despite the validation of the instrument, the SC-IAT can also be viewed as a limitation. The Implicit Association Test (IAT) has faced substantial criticism regarding its validity and reliability. According to Gawronski (2019), its test–retest reliability is low, suggesting it may measure temporary associations rather than stable attitudes. Moreover, its predictive validity is weak, with only small correlations between IAT scores and actual behaviour, especially when explicit attitudes are controlled (Oswald et al., 2013). In this research, the SC-IAT was used to specifically measure bias related to physical activity. However, it is important to acknowledge that a bias towards sedentary behaviour may still exist. The SC-IAT was chosen instead of the traditional IAT for several reasons, such as the fact that sedentary time is not simply the opposite of physical activity. Although this decision was justified, it did not fully consider that by excluding sedentary behaviour as the counterpart to physical activity, the CBM intervention may not have addressed sedentary behaviour bias, which could therefore still be present.

Implications for future research

The findings of this study highlight multiple important directions for future research. One of these is the promising outcome of the newly developed CBM intervention, which was specifically designed to reduce cognitive bias against physical activity. This domain-specific approach appears to be effective and is worth exploring further. Future studies should aim to replicate and validate this intervention across larger and more diverse samples to better assess its reliability and generalisability. In addition, future research would benefit from the inclusion of a control group and the use of behavioural outcome measures, such as actual changes in physical activity levels. Combining implicit measures (like the SC-IAT) with observable behaviour would provide a more complete picture of the real-world impact of CBM interventions and clarify whether changes in bias translate into lasting behaviour change. Another limitation in the current study was the limited variability in depressive symptoms among participants. To better understand the role of depressive symptoms as a moderator, future studies should aim to include individuals with a broader range of symptom severity. Moreover, in future research, it is essential to link data from the SC-IAT to data from the CBM via the TIIM app. This way, it is possible to determine whether each participant actually attended the intervention. Finally, as this remains a relatively new area of research, further investigation into the mechanisms behind CBM is needed. Future studies should examine under which conditions CBM is most effective, how individual differences influence its impact, and whether different formats (e.g., standard IAT vs. SC-IAT) yield similar results.

Overall, these directions can help to refine CBM as a psychological tool for improving health-related behaviours such as physical activity.

Conclusion

In conclusion, the CBM training appeared to be effective in reducing negative cognitive bias against physical activity, as shown by a significant increase in SC-IAT d-scores from pre- to post-intervention. Although no significant moderation effect of depressive symptoms was found, and the correlation between depressive symptoms and implicit attitudes did not reach significance, there was a noticeable trend suggesting that higher levels of depressive symptoms may be linked to more negative cognitive bias. They provide a starting point for future research on CBM targeting physical activity-related behaviours and on the role depressive symptoms might play in this. Future research could build on this by using larger, more diverse samples, including behavioural outcomes, and testing different CBM formats. This study contributes to the emerging field of CBM and offers a foundation for further investigation into how implicit attitudes toward physical activity can be changed and what factors may influence that process.

References

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). https://doi.org/10.1176/appi.books.9780890425596

Caballo, V. E. (1998). Cognitive Therapy and Depression. In *International Handbook of Cognitive and Behavioural Treatments for Psychological Disorders* (2nd ed.). https://doi.org/10.1016/b978-0-08-043433-9.x5000-7

Chevance, G., Héraud, N., Guerrieri, A., Rebar, A., & Boiché, J. (2017). Measuring implicit attitudes toward physical activity and sedentary behaviors: Test-retest reliability of three scoring algorithms of the Implicit Association Test and Single Category-Implicit Association Test. *Psychology of Sport and Exercise*, *31*, 70–78. https://doi.org/10.1016/j.psychsport.2017.04.007

Conroy, D. E., Hyde, A. L., Doerksen, S. E., & Ribeiro, N. F. (2010). Implicit attitudes and explicit motivation prospectively predict physical activity. *Annals of Behavioral Medicine*, *39*(2), 112–118. https://doi.org/10.1007/s12160-010-9161-0

Cristea, I. (2015). Data for Cristea, Kok, Cuijpers.cmaData for Cristea, I.A., Kok, R.N., Cuijpers, P. (2015) The Effectiveness of Cognitive Bias Modification Interventions for Substance Addictions: A Meta-Analysis. PLoS one [Dataset]. In *Figshare*. https://doi.org/10.6084/m9.figshare.2059137

De Carlo, V., Calati, R., & Serretti, A. (2016). Socio-demographic and clinical predictors of non-response/non-remission in treatment resistant depressed patients: A systematic review. *Psychiatry Research*, *240*, 421–430. https://doi.org/10.1016/j.psychres.2016.04.034

Faber, J., & Fonseca, L. M. (2014). How sample size influences research outcomes. *Dental Press Journal of Orthodontics*, *19*(4), 27–29. https://doi.org/10.1590/2176-9451.19.4.027-029.ebo

Gawronski, B. (2019). Six lessons for a cogent science of implicit bias and its criticism. *Perspectives on Psychological Science*, *14*(4), 574–595. https://doi.org/10.1177/1745691619826015

Gotlib, I. H., & Joormann, J. (2010). Cognition and Depression: Current status and future directions. *Annual Review of Clinical Psychology*, *6*(1), 285–312. https://doi.org/10.1146/annurev.clinpsy.121208.131305

Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. K. (1998). Measuring individual differences in implicit cognition: The implicit association test. *Journal of Personality and Social Psychology*, *74*(6), 1464–1480. https://doi.org/10.1037/0022-3514.74.6.1464

Greenwald, A. G., Nosek, B. A., & Banaji, M. R. (2003). Understanding and using the Implicit Association Test: I. An improved scoring algorithm. *Journal of Personality and Social Psychology*, *85*(2), 197–216. https://doi.org/10.1037/0022-3514.85.2.197

Grove, R., & Prapavessis, H. (1992). *Preliminary evidence for the reliability and validity of an abbreviated Profile of Mood States*. *International Journal of Sport Psychology, 23*(2), 93–109. https://www.researchgate.net/publication/232536671

Hyde, A. L., Doerksen, S. E., Ribeiro, N. F., & Conroy, D. E. (2010). The independence of implicit and explicit attitudes toward physical activity: Introspective access and attitudinal concordance. *Psychology of Sport and Exercise*, *11*(5), 387–393. https://doi.org/10.1016/j.psychsport.2010.04.008

Jones, E. B., & Sharpe, L. (2017). Cognitive bias modification: A review of meta-analyses. *Journal of Affective Disorders*, *223*, 175–183. https://doi.org/10.1016/j.jad.2017.07.034

Jung, S., Lee, S., Lee, S., Bae, S., Imaoka, M., Harada, K., & Shimada, H. (2017). Relationship between physical activity levels and depressive symptoms in community-dwelling older Japanese adults. *Geriatrics and Gerontology International/Geriatrics & Gerontology International*, *18*(3), 421–427. https://doi.org/10.1111/ggi.13195

Karpinski, A., & Steinman, R. B. (2006). The Single Category Implicit Association Test as a measure of implicit social cognition. *Journal of Personality and Social Psychology*, *91*(1), 16–32. https://doi.org/10.1037/0022-3514.91.1.16

MacLeod, C., & Mathews, A. (2012). Cognitive Bias modification approaches to anxiety. *Annual Review of Clinical Psychology*, *8*(1), 189–217. https://doi.org/10.1146/annurev-clinpsy-032511-143052

Martins, L. C. G., De Oliveira Lopes, M. V., Diniz, C. M., & Guedes, N. G. (2020). The factors related to a sedentary lifestyle: A meta-analysis review. *Journal of Advanced Nursing*, *77*(3), 1188–1205. https://doi.org/10.1111/jan.14669

McCaffrey, R. J., Duff, K., & Westervelt, H. J. (2000). Practitioner's Guide to Evaluating Change with Neuropsychological Assessment Instruments. In *Critical issues in neuropsychology*. https://doi.org/10.1007/978-1-4615-4233-9

McNair, D. M., Lorr, M., & Droppleman, L. F. (1971). *Profile of Mood States manual*. Educational and Industrial Testing Service.

Monni, A., Olivier, E., Morin, A., Belardinelli, M. O., Mulvihill, K., & Scalas, L. (2020). Approach and avoidance in Gray's, Higgins', and Elliot's perspectives: A theoretical comparison and integration of approach-avoidance in motivated behavior. *Personality and Individual Differences*, *166*, 110163. https://doi.org/10.1016/j.paid.2020.110163

Montoya, A. K. (2022). Selecting a Within- or Between-Subject design for mediation: validity, causality, and statistical power. *Multivariate Behavioral Research*, *58*(3), 616–636. https://doi.org/10.1080/00273171.2022.2077287

Muschalik, C., Elfeddali, I., Candel, M. J. J. M., Crutzen, R., & De Vries, H. (2019). Does the discrepancy between implicit and explicit attitudes moderate the relationships between explicit attitude and (intention to) being physically active? *BMC Psychology*, *7*(1). https://doi.org/10.1186/s40359-019-0322-z

Nielsen, L., & Reiss, D. (2012). *Motivation and Aging: Toward the Next Generation of Behavioral Interventions*. Division of Behavioral and Social Research, National Institute on Aging. https://www.nia.nih.gov/sites/default/files/d7/background.pdf

Oswald, F. L., Mitchell, G., Blanton, H., Jaccard, J., & Tetlock, P. E. (2013). Predicting ethnic and racial discrimination: A meta-analysis of IAT criterion studies. *Journal of Personality and Social Psychology*, *105*(2), 171–192. https://doi.org/10.1037/a0032734

Park, J. H., Moon, J. H., Kim, H. J., Kong, M. H., & Oh, Y. H. (2020). Sedentary Lifestyle: Overview of updated evidence of potential health risks. *Korean Journal of Family Medicine*, *41*(6), 365–373. https://doi.org/10.4082/kjfm.20.0165

Rhodes, R. E., Janssen, I., Bredin, S. S., Warburton, D. E., & Bauman, A. (2017). Physical activity: Health impact, prevalence, correlates and interventions. *Psychology And Health*, *32*(8), 942–975. https://doi.org/10.1080/08870446.2017.1325486

Rydell, R. J., & McConnell, A. R. (2006). Understanding implicit and explicit attitude change: A systems of reasoning analysis. *Journal of Personality and Social Psychology*, *91*(6), 995–1008. https://doi.org/10.1037/0022-3514.91.6.995

Sedentary Behaviour Research Network. (2012). Letter to the Editor: Standardized use of the terms "sedentary" and "sedentary behaviours." *Applied Physiology Nutrition and Metabolism*, *37*(3), 540–542. https://doi.org/10.1139/h2012-024

Stenner, B. J., Buckley, J. D., & Mosewich, A. D. (2019). Reasons why older adults play sport: A systematic review. *Journal of Sport and Health Science/Journal of Sport and Health Science*, *9*(6), 530–541. https://doi.org/10.1016/j.jshs.2019.11.003

Strack, F., & Deutsch, R. (2004). Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review*, *8*(3), 220–247. https://doi.org/10.1207/s15327957pspr0803_1

Strack, F., & Deutsch, R. (2014). The reflective—Impulsive model. In J. W. Sherman, B. Gawronski, & Y. Trope (Eds.), *Dual-process theories of the social mind* (pp. 92–104). The Guilford Press.

Tremblay, M. S., & Willms, J. D. (2003). Is the Canadian childhood obesity epidemic related to physical inactivity? *International Journal of Obesity*, *27*(9), 1100–1105. https://doi.org/10.1038/sj.ijo.0802376

Tremblay, M. S., Aubert, S., Barnes, J. D., Saunders, T. J., Carson, V., Latimer-Cheung, A. E., Chastin, S. F., Altenburg, T. M., & Chinapaw, M. J. (2017). Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1). https://doi.org/10.1186/s12966-017-0525-8

Tversky, A., & Kahneman, D. (1974). Judgment under Uncertainty: Heuristics and Biases. Science, 185(4157), 1124–1131. https://doi.org/10.1126/science.185.4157.1124

Van Der Baan, H. S., D'Escury-Koenigs, A. L. C., & Wiers, R. W. (2023). The effectiveness of cognitive bias modification in reducing substance use in detained juveniles: An RCT. *Journal of Behavior Therapy and Experimental Psychiatry*, *82*, 101916. https://doi.org/10.1016/j.jbtep.2023.101916

Van 't Klooster, J. J. R., Mayer, L. M. R., Klaassen, B., & Kelders, S. M. (2024). Challenges and opportunities in mobile e-coaching. *Frontiers in Digital Health*, *5*. https://doi.org/10.3389/fdgth.2023.1304089

Warburton, D. E., & Bredin, S. S. (2016). Reflections on Physical Activity and Health: What Should We Recommend? *Canadian Journal of Cardiology*, *32*(4), 495–504. https://doi.org/10.1016/j.cjca.2016.01.024

Webb, O. J., Benjamin, C. C., Gammon, C., McKee, H. C., & Biddle, S. J. (2012). Physical activity, sedentary behaviour and physical self-perceptions in adolescent girls: A mediation analysis. *Mental Health and Physical Activity*, *6*(1), 24–29. https://doi.org/10.1016/j.mhpa.2012.08.005

White, R. L., Babic, M. J., Parker, P. D., Lubans, D. R., Astell-Burt, T., & Lonsdale, C. (2017). Domain-Specific Physical Activity and Mental Health: A Meta-analysis. *American Journal of Preventive Medicine*, *52*(5), 653–666. https://doi.org/10.1016/j.amepre.2016.12.008

White, R. L., Vella, S., Biddle, S., Sutcliffe, J., Guagliano, J. M., Uddin, R., Burgin, A., Apostolopoulos, M., Nguyen, T., Young, C., Taylor, N., Lilley, S., & Teychenne, M. (2024). Physical activity and mental health: a systematic review and best-evidence synthesis of mediation and moderation studies. *International Journal of Behavioral Nutrition and Physical Activity*, *21*(1). https://doi.org/10.1186/s12966-024-01676-6

Zou, L., Wang, T., Herold, F., Ludyga, S., Liu, W., Zhang, Y., Healy, S., Zhang, Z., Kuang, J., Taylor, A., Kramer, A. F., Chen, S., Tremblay, M. S., & Hossain, M. M. (2022). Associations between sedentary behavior and negative emotions in adolescents during home confinement: Mediating role of social support and sleep quality. *International Journal of Clinical and Health Psychology*, *23*(1), 100337. https://doi.org/10.1016/j.ijchp.2022.100337

Appendices

During the preparation of this work, I used ChatGPT and DeepL to improve sentence structure and find suitable synonyms for words.

Appendix A

List of Stimuli Used in the Experiment

List of Physical Activity Stimuli

- Biking
- Running
- Hiking
- Swimming
- Basketball
- Football
- Volleyball

List of Positive Stimuli

- Confidence
- Happy
- Optimistic
- Comfortable
- Joyful
- Energising
- Healthy
- Balanced
- Capable
- Relaxed
- Fulfilling
- Freedom

List of Negative Stimuli

- Frustration
- Sad
- Pessimistic
- Anxious
- Miserable
- Exhausting
- Unhealthy

- Overwhelmed
- Struggling
- Stressed
- Wasteful
- Burden

Appendix B

Informed Consent

Study Info

Dear participant,

Thank you for your participation in this study!

Before the survey proceeds, I kindly ask you to fill out an informed consent form. This form ensures that you understand the purpose of the study, your rights as a participant, and any potential risks or benefits involved.

Once you have completed the informed consent form, I will ask you a series of questions regarding your demographics. Afterwards, you will be requested to complete questionnaires about different topics: physical activity, depressive symptoms, and external variables. I will remind you taking breaks in between. :) You are also able to pause the questionnaire at any time and resume later, by using the button in the bottom left corner.

After the completion of the questionnaires, you will be directed to a short game. You can either use your laptop with physical keyboard (preferred method) or your phone.

Once you have finished the game you may close the window. In the next phase, you will receive an email with further instructions and steps to follow.

If you have any questions or concerns throughout the study, please do not hesitate to reach out to us. You can find our contact information in the informed consent form.

Thank you in advance for your participation. Your contribution to this study is greatly appreciated.

Informed consent

Training physical activity bias using the TIIM app

Thank you for signing up to participate in our study on **reducing physical activity bias using the TIIM app**. This research explores implicit bias against physical activity using questionnaires and a short game through the TIIM app, which you can download from the Apple App Store or Google Play Store.

In this research we aim to test a novel method for assessing implicit bias against physical activity using a single category Implicit Association Test (SC-IAT). Further, we will examine the effect of training implicit associations towards physical activity. This will be done in two groups, the experimental group and the control group. Both groups start with completing self-report assessments related to physical activity, depressive symptoms and external variables. The completion of the first questionnaires including the SC-IAT, the Profile of Mood States (POMS) Questionnaire, and the demographics will take around **30** minutes. Following this, the experimental group will receive an email invitation to play a short game in the TIIM app twice a day for the next three days. Each game takes about **5** minutes. A day after the last training, both groups will be invited to complete a final assessment by completing the SC-IAT and the initial questionnaire. This will take approximately around **30** minutes. After the end of the study, the control group will also get access to the training so that this group can also try it out.

This study is conducted by **Roos Lensink and Vasiliki Sokratous**, currently undergoing their Bachelor thesis in Health Psychology and Technology in the Faculty of Behavioural, Management, and Social Sciences (BMS) at the University of Twente under the supervision of **Marcel E. Pieterse and Annemarie Braakman-Jansen**.

The research has been reviewed and approved by the BMS Ethics Committee/domain Humanities & Social Sciences.

Participation in this study involves minimal burdens and risks. Although completing the questionnaires is unlikely to cause psychological discomfort, you may experience occasional technical issues. To address this, several pilot tests were conducted beforehand. If you encounter any troubles, you can contact the research team for support.

Your participation in this study is completely voluntary, and you can **withdraw at any time** without any negative consequences or need to provide an explanation. **All data collected will remain anonymous, securely stored and will be deleted once the study is completed.**

If you have any questions or concerns about your rights as a research participant, or if you wish to discuss any aspect of this study, please contact the Secretary of the Ethics Committee

of the Faculty of Behavioural, Management, and Social Sciences at the University of Twente via ethicscommittee-bms@utwente.nl.

For further information or any questions, please feel free to reach out to Roos Lensink and Vasiliki Sokratous.

Thank you for helping us with this research!

Best regards,

Roos Lensink and Vasiliki Sokratous

Bachelor's Programme, Faculty of Behavioural, Management and Social Sciences
University of Twente

Appendix C

Abbreviated POMS (Revised Version)

Name: ______________________________ Date:

Below is a list of words that describe feelings people have. Please **CIRCLE THE NUMBER THAT BEST DESCRIBES HOW YOU FEEL RIGHT NOW**.

	Not At All	A Little	Moderately	Quite a lot	Extremely
Tense	0	1	2	3	4
Angry	0	1	2	3	4
Worn Out	0	1	2	3	4
Unhappy	0	1	2	3	4
Proud	0	1	2	3	4
Lively	0	1	2	3	4
Confused	0	1	2	3	4
Sad	0	1	2	3	4
Active	0	1	2	3	4
On-edge	0	1	2	3	4
Grouchy	0	1	2	3	4
Ashamed	0	1	2	3	4
Energetic	0	1	2	3	4
Hopeless	0	1	2	3	4
Uneasy	0	1	2	3	4
Restless	0	1	2	3	4
Unable to concentrate	0	1	2	3	4
Fatigued	0	1	2	3	4
Competent	0	1	2	3	4
Annoyed	0	1	2	3	4
Discouraged	0	1	2	3	4

Resentful	0	1	2	3	4
Nervous	0	1	2	3	4
Miserable	0	1	2	3	4

PLEASE CONTINUE WITH THE ITEMS ON THE NEXT PAGE

	Not At All	**A Little**	**Moderately**	**Quite a lot**	**Extremely**
Confident	0	1	2	3	4
Bitter	0	1	2	3	4
Exhausted	0	1	2	3	4
Anxious	0	1	2	3	4
Helpless	0	1	2	3	4
Weary	0	1	2	3	4
Satisfied	0	1	2	3	4
Bewildered	0	1	2	3	4
Furious	0	1	2	3	4
Full of Pep	0	1	2	3	4
Worthless	0	1	2	3	4
Forgetful	0	1	2	3	4
Vigorous	0	1	2	3	4
Uncertain about things	0	1	2	3	4
Bushed	0	1	2	3	4
Embarrassed	0	1	2	3	4

THANK YOU FOR YOUR COOPERATION

PLEASE BE SURE YOU HAVE ANSWERED EVERY ITEM

POMS SCORING KEY

Scores for the seven subscales in the abbreviated POMS are calculated by summing the numerical ratings for items that contribute to each subscale. The correspondence between items and subscales is shown below.

Item	**Scale**	Not At All	A Little	Moderate	Quite a lot	Extremely
Tense	**TEN**	0	1	2	3	4
Angry	**ANG**	0	1	2	3	4
Worn Out	**FAT**	0	1	2	3	4
Unhappy	**DEP**	0	1	2	3	4
Proud	**ERA**	0	1	2	3	4
Lively	**VIG**	0	1	2	3	4
Confused	**CON**	0	1	2	3	4
Sad	**DEP**	0	1	2	3	4
Active	**VIG**	0	1	2	3	4
On-edge	**TEN**	0	1	2	3	4
Grouchy	**ANG**	0	1	2	3	4
Ashamed	**ERA**	Reverse-score this item [0 = 4, 1 = 3, 2 = 2, 3 = 1, 4 = 0]				
Energetic	**VIG**	0	1	2	3	4
Hopeless	**DEP**	0	1	2	3	4
Uneasy	**TEN**	0	1	2	3	4
Restless	**TEN**	0	1	2	3	4
Can’t concentrate	**CON**	0	1	2	3	4
Fatigued	**FAT**	0	1	2	3	4
Competent	**ERA**	0	1	2	3	4
Annoyed	**ANG**	0	1	2	3	4
Discouraged	**DEP**	0	1	2	3	4

Resentful	**ANG**	0	1	2	3	4
Nervous	**TEN**	0	1	2	3	4
Miserable	**DEP**	0	1	2	3	4

Item	**Scale**	Not At All	A Little	Moderate	Quite a lot	Extremely
Confident	**ERA**	0	1	2	3	4
Bitter	**ANG**	0	1	2	3	4
Exhausted	**FAT**	0	1	2	3	4
Anxious	**TEN**	0	1	2	3	4
Helpless	**DEP**	0	1	2	3	4
Weary	**FAT**	0	1	2	3	4
Satisfied	**ERA**	0	1	2	3	4
Bewildered	**CON**	0	1	2	3	4
Furious	**ANG**	0	1	2	3	4
Full of Pep	**VIG**	0	1	2	3	4
Worthless	**DEP**	0	1	2	3	4
Forgetful	**CON**	0	1	2	3	4
Vigorous	**VIG**	0	1	2	3	4
Uncertain…	**CON**	0	1	2	3	4
Bushed	**FAT**	0	1	2	3	4
Embarrassed	**ERA**	Reverse-score this item [0 = 4, 1 = 3, 2 = 2, 3 = 1, 4 = 0]				

TEN = Tension	Note that 2 of the items on the Esteem-related Affect (ERA) subscale are reverse-scored prior to being combined with the other items.
ANG = Anger	
FAT = Fatigue	**Total Mood Disturbance (TMD)** is calculated by summing the totals for the

DEP = Depression	negative subscales and then subtracting the totals for the positive subscales: TMD = [TEN+DEP+ANG+FAT+CON] – [VIG+ERA]. A constant (e.g., 100) can be added to the TMD formula in order to eliminate negative scores.
ERA = Esteem-related Affect	
VIG = Vigour	
CON = Confusion	

Appendix D

Single Category IAT

Instructions:

E

I

Physical Activity

or

Positive

Negative

Put your middle or index fingers on the **E** and **I** keys of your keyboard. Words or images (items) representing the categories below will appear one-by-one in the middle of the screen. When the item belongs to a category on the left, press the **E** key; when the item belongs to a category on the right, press the **I** key. Items belong to only one category.

If you pressed the correct button, a green circle will appear. If you pressed the wrong button, a red cross will appear.

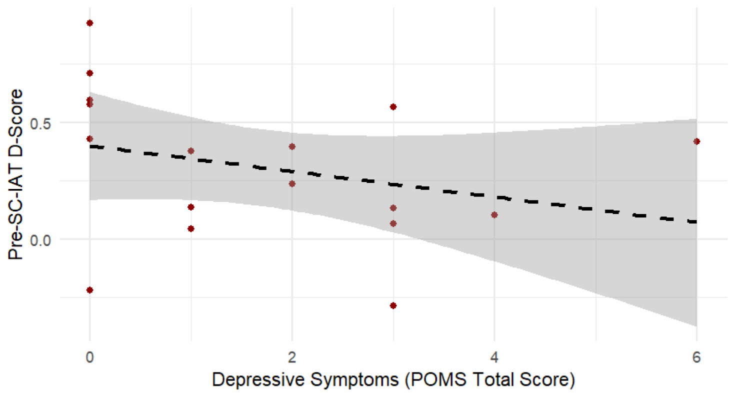
This is a times sorting task. **GO AS FAST AS YOU CAN** while making as few mistakes as possible. Going too slow or making too many errors will result in an uninterpretable score. This task will take about 3 minutes to complete.

Press the **space bar** to begin.

Appendix E

Post-hoc

Post-hoc: Relationship between Depressive Symptoms and Pre-SC-IAT Scores (N=17)



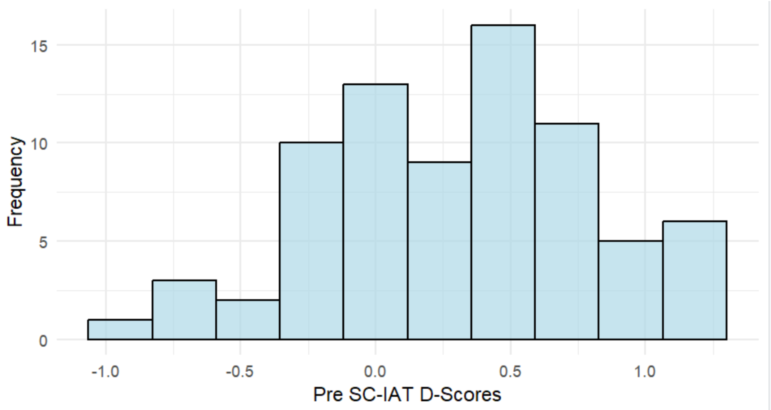
Note: This post-hoc figure presents the same relationship as shown in Figure 6, but excludes two outliers with unusually high depressive symptom scores. Total Depressive Score (Range: 0-6). d-score: <0 =negative bias, >0 = positive bias. The grey coloured area represents the 95% CI.

Appendix F

Normality Testing

Figure 1

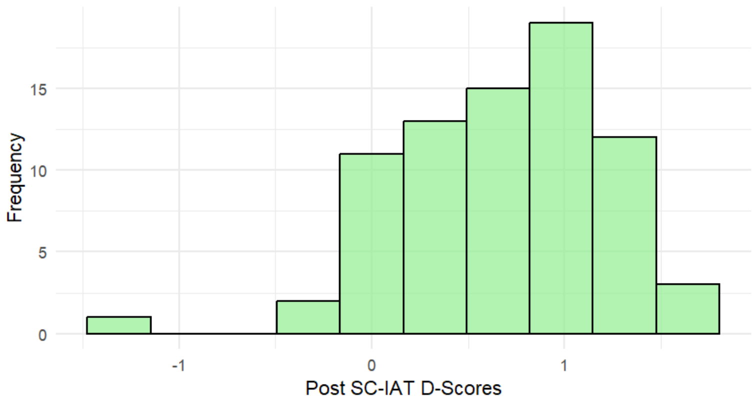
Histogram of Pre-SC-IAT d-scores



Note: d-score: <0 =negative bias, >0 = positive bias, N=19

Figure 2

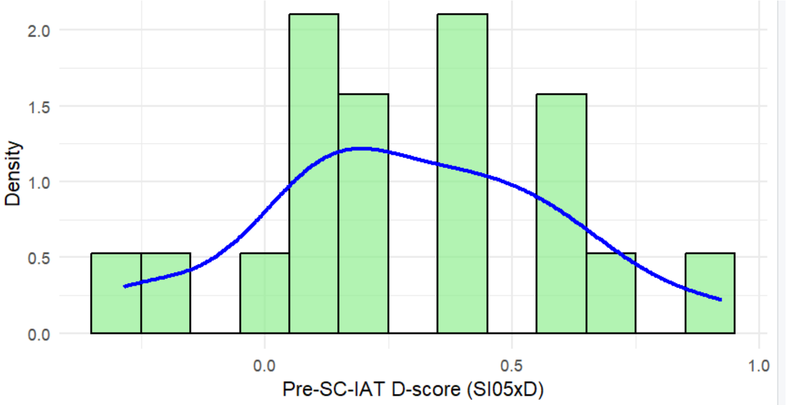
Histogram of Post-SC-IAT d-scores



Note: d-score: <0 =negative bias, >0 = positive bias, N=19

Figure 3

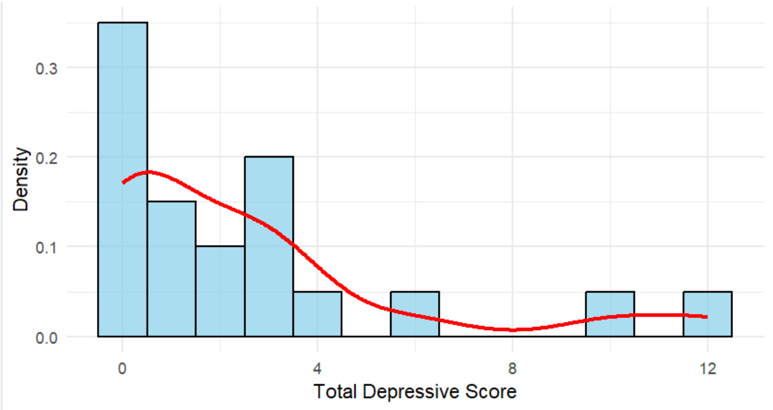
Distribution of Pre-SC-IAT d-scores



Note: d-score: <0 =negative bias, >0 = positive bias, N=19

Figure 4

Distribution of POMS Depressive Symptom Scores (N=19)



Note: Total Depressive Score (Range: 0-12). Higher scores indicate more severe depressive symptoms. Based on seven POMS items rated from 0 ("not at all") to 4 ("extremely").