The Effects of a Mobile Cognitive Bias Modification Training on Implicit Positive Orientation and The Perceived Stress Levels of Students: A Quasi-Experimental Design

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Abstract

Stress is a frequently reported complaint amongst students, affecting their mental and physical well-being, as well as academic success. While traditional stress interventions focus on coping resources, an alternative approach to reducing stress involves the concept of Positive Orientation (PO). PO is the cognitive disposition to make positive judgements about one's self, life, and future. This can be seen as a positive self-concept bias. Following dual-processing theories, there is an unconscious implicit concept of PO and a conscious explicit counterpart. The increase of implicit PO might alter the appraisal of stressful situations of students. One intervention used to alter biases is Cognitive Bias Modification (CBM). The aim of this study is to investigate the effect of CBM training on the implicit PO levels and on the perceived stress levels of students. Besides that, in this study, it is investigated whether the relationship between CBM training and the perceived stress levels is mediated by implicit PO and moderated by baseline measures of implicit PO categorised as high or low.

For this study with a quasi-experimental design, a mobile CBM training intended to target implicit PO was developed to reduce the stress levels of students. The sample consisted of 50 students, divided into the intervention and control group. The intervention group received six sessions of CBM training using the TIIM App over three days. To measure the dependent variables implicit PO and perceived stress, both groups completed the PO-Implicit Association Test (IAT) and the Perceived Stress Scale-10 (PSS-10) at baseline and after three days.

The results show that the CBM training marginally significantly increased the implicit PO levels in the intervention group. However, no significant effect of CBM training on the perceived stress levels was found, and neither mediation nor moderation effects were found on this relationship.

These findings provide promising preliminary evidence that CBM training delivered with the TIIM App is effective in increasing the implicit PO levels of students. Future research is needed to explore the effectiveness of the CBM training in a highly stressful situation, such as an exam. This is because previous studies indicated that CBM training had a significant effect on perceived stress only when participants were exposed to a stressful situation, which might be similar for the CBM training targeting the positive self-concept bias. Additionally, future research is needed to develop a mobile CBM training to reduce stress amongst students using the attention paradigm. This is because previous studies have proven that attention plays a key role in the appraisal of stressful situations.

Introduction

Stress amongst Students

Stress is a frequently reported complaint amongst students worldwide. In 2022, 77.3% of students in the United States experienced moderate to high levels of stress in the past month (American College Health Association [ACHA], 2023). Even higher percentages were found amongst students in Canada (83.7%) (ACHA, 2022), Slovenia (82%) (Studo, 2023) and Germany and Austria (82%) (Studo & Instahelp, 2023). Stress is also a complaint amongst students in the Netherlands. According to Dopmeijer et al. (2021), 97% of all students in higher education in the Netherlands experience some amount of stress. More than 60% of them reported that the amount of stress was severe to extremely severe. Dopmeijer et al. (2021) conducted the first nationwide study in the Netherlands, which questioned 28.000 students about their perceived stress level in the past weeks and their mental well-being. Based on the findings of Dopmeijer et al. (2021), Trimbos Insituut is currently doing further research into stress and performance pressure amongst students in the Netherlands (Koopman, 2022). Nevertheless, it is already clear that stress is a serious complaint amongst students.

There are multiple causes for these high levels of stress. It was found that the main sources of (extremely) severe levels of stress amongst students are: study and academic performance, personal problems, finances, (job) future and daily duties (Dopmeijer et al., 2021; Garber et al., 2019; Pitt et al., 2018). However, when exposed to the same stressful situation, there are individual differences in how stressful students perceive the situation. This can be explained by Lazarus and Folkman's transactional model of stress and coping (1984), who define stress as "exposure to stimuli appraised as harmful, threatening, or challenging, that exceeds the individual's capacity to cope" (as cited in Biggs et al., 2017, p. 352). In this model, the subjective experience of the stressors by the individual and the perception to cope with these stressors are emphasized. Thus, if students do not perceive an event as challenging and believe they have the resources to cope with it, the event is not experienced as stressful. However, if students are not able to cope with a challenging situation, the perception of stress activates the psychological and physiological stress responses (Dandeneau et al., 2007).

Effects of Stress on Well-Being

The consequences of stress vary. First of all, stress can serve a beneficial purpose, as it helps to focus and perform well in short-term stressful situations (Bear et al., 2020). However, if individuals are unable to cope with the ongoing demands for a longer period of time, stress can transform into chronic stress, and the body starts releasing the stress hormone cortisol (Dandeneau et al., 2007). Cortisol causes bodily changes and affects both physical and mental health, leading to significant problems such as the increased risk for depression and cardiovascular diseases (Bear et al., 2020; Cooper & Quick, 2017). Thus, although experiencing stress can be helpful in short stressful situations, the consequences of chronic stress have a negative impact on well-being.

Amongst students, stress has notable mental effects. Those experiencing moderate to severe levels of stress are more likely to have lower mental well-being and suffer from mental complaints (Dopmeijer et al., 2021; Shankar & Park, 2016). Besides mental effects, stress affects physical well-being and academic success. Education-related stress influences health behaviours, such as reduced physical activity and unhealthy eating habits, which in turn increases the risk of developing physical health problems later in life (Pascoe et al., 2020; Shankar & Park, 2016). Lastly, stress can lead to reduced academic achievement, which causes an increase in the risk of dropping out of school (Pascoe et al., 2020). To conclude, stress affects student well-being across multiple dimensions.

Interventions to Reduce Stress

Since stress has a large impact across multiple dimensions and on both short-term and long-term health, interventions to reduce stress are essential. The traditional interventions that focus on reducing stress, have focused on gaining beneficial coping skills (Cooper & Quick, 2017; Pascoe et al., 2020). By obtaining the skills to engage in proactive and preventive coping behaviours, one's appraisal of resources increases and, thus, one feels able to cope with the demands (Biggs et al., 2017). Since the rise of positive psychology, more interventions to reduce stress have been developed. Positive psychology interventions focus on both strengthening the existing resources of the individual and reducing the perception of stress, including Mindfulness-Based Stress Reduction (MBSR) therapy, well-being therapy and writing about positive experiences (Cooper & Quick, 2017). For example, MBSR focuses on acknowledging and accepting the cognitions, emotions and bodily sensations that are present in the current moment through exercises, which reduces stress and improves well-being (Serpa et al., 2014, as cited in Cooper & Quick, 2017). Both traditional and positive psychological interventions have proven to be effective in reducing the stress levels of students.

Positive Orientation

Recently, the new concept of *Positive Orientation* (PO) has arisen in the field of positive psychology, which also provides a promising way to reduce stress. PO (previously known as "positive thinking" and "positivity") is a basic disposition consisting of the three constructs optimism, self-esteem, and life satisfaction (Caprara et al., 2010). It reflects the cognitive ability of the individual to make positive judgements about the self, life, and the future (Alessandri et al., 2012; Caprara et al., 2010; Caprara et al., 2012). PO is a cognitive component of well-being, and more specifically, PO can be seen as a *cognitive bias*. Cognitive biases are thought patterns that influence the interpretations of an individual about the world, which are learned based on people's beliefs and previous experiences (Kliegr et al., 2018). These interpretations influence cognitions, behaviours, and emotions. The PO bias causes people to process positive information quicker and more often than negative information (Becker et al., 2016; Hertel & Mathews, 2011). It is found that the majority of the people has a PO bias (Becker et al., 2016). This means that they have a distorted "positive" self-concept, which is a concept of themselves, their life and their future in their mind that is positive. In contrast, there is a small group of individuals, including individuals with emotional disorders such as anxiety and depression, who selectively attend more to negative information and interpret ambiguous stimuli as threatening (Mathews & MacLeod, 2005, as cited in Hertel & Mathews, 2011). These individuals are thought to have a "negative" self-concept and, thus, a negative orientation bias.

Although cognitive biases are a distorted view of reality, and, therefore, are often seen as something negative, certain biases have a protective function. These biases, known as self-serving biases, help people manage stress and negative emotions. The PO bias is such a self-serving bias. Individuals with high levels of PO use a more proactive coping style and maintain a more positive view (Park et al., 2021). This proactive coping style and positive view could support individuals to appraise situations as less challenging or easier to cope with, and, therefore, prevent or reduce the occurrence of stress amongst individuals with high PO. This could explain why PO is negatively correlated with the levels of stress that one experiences (Dymecka et al., 2023; Horiuchi et al., 2018; Park et al., 2021). Additionally, Caprara et al. (2010) found that adolescents who score higher on PO also reported high levels of physical, hedonic, and social well-being. Thus, PO is related to the perceived stress levels and the levels of well-being. Therefore, interventions targeting PO are promising in reducing the perceived stress levels of students.

Dual-Process Model

The concept of PO consists of two constructs that could be targeted, namely *explicit* PO and *implicit* PO. This can be explained by dual-process models (Bursell & Olsson, 2021; Frankish, 2010). Dual-process models state that there are two types of thinking, namely *System 1*, which is unconsciousness, intuitive and fast, and *System 2*, which is conscious, analytic, and slow (Bago & De Neys, 2020). System 1 consists of two types of responses: the "heuristic" intuitive response, which relies on people's stereotypes, prejudices and previous experiences, and the "logical" intuitive response, which relies on basic knowledge of probabilistic and logical principles (Bago & De Neys, 2020). System 1 is more sensitive to cognitive biases, due this the influence of prejudices and experiences in the heuristic response (Kahneman, 2011, as cited in Frankish, 2010). Because System 1 is fast and requires a relatively low cognitive load, people's judgements and behaviour often rely on this system. These unconscious and almost automatic thoughts and acts are called implicit constructs. This is in contrast to the reported and explicit constructs, which are often controlled by the slower and more conscious System 2. The activation of these two different systems can lead to discrepancies between implicit and explicit constructs. The construct of PO is also rooted in both systems, as it contains an associative aspect that one might be unaware of (Costantini et al., 2019). This means that PO can be investigated and targeted both explicitly and implicitly.

Measuring PO

Currently, most research has used self-report questionnaires to investigate the concept of PO (Dymecka et al., 2023; Horiuchi et al., 2018; Park et al., 2021). These measures rely on the conscious system of the individual and, therefore, measure the explicit construct of PO. However, this requires individuals to recall and introspectively reflect on their cognitions and attitudes, whereas people might be unaware of their biased "positive" self-concept. Biased self-concepts often act outside of one's awareness, on implicit levels (Wolbers et al., 2021). Thus, in order to investigate the biased self-concepts, the construct of PO should be measured and targeted implicitly.

In general, implicit constructs can be measured using the Implicit Association Test (IAT), which was first developed by Greenwald et al. (1998). The IAT includes four types of stimuli: two target categories (e.g., flower/insect) and two attribute categories (e.g., pleasant/unpleasant). The test consists of two parts and during the first part of the IAT, one needs to sort words of one target category (e.g., flower) in one attribute category (e.g., pleasant) and words of the other target category (e.g., insect) in the other attribute category (e.g., unpleasant). During the second part of the IAT, the sorting is reversed (Greenwald et al., 1998). During both parts of the test, the reaction time is measured. If the two target categories do not differ from each other, the individual would categorize both words at the same reaction speed (Kurdi et al., 2021). However, if one has a strong cognitive bias (e.g., sees insects as unpleasant), the response to sort items that are strongly associated is faster than that of the weakly associated items. That is because sorting these strongly associated items happens more automatically and activation of system 2 might be required for weakly associated items

(Greenwald & Banaji, 1995). Because of this difference in response time for strong and weak associations, cognitive biases can be measured by reaction time. Moreover, it is found that cognitive biases are better seen under time pressure and high cognitive load, as it reduces the activation of system 2 (Frankish, 2010). Implicit constructs that can be measured with the IAT are, for example, stereotypes, implicit personality traits and self-esteem (Back et al., 2009; Bosson et al., 2003; Kurdi et al., 2021).

To measure implicit PO, the PO-IAT was developed by Costantini et al. (2019). It requires participants to assign positive (e.g., high esteem) and negative (e.g., low esteem) items to the target categories “Me” and “Others”. Similar to the original IAT, the response time is measured for the PO-IAT. Thereby, it is expected that people with a PO bias have a significantly shorter reaction time (and are thus faster) when they assign the positive items to themselves and negative items to others, compared to assigning negative items to the self and positive items to others. Therefore, the PO-IAT can be used to measure the level of implicit PO, with a more positive score indicating a stronger PO bias.

Cognitive Bias Modification

One type of intervention to target implicit PO could be *Cognitive Bias Modification* (CBM) (Hertel & Mathews, 2011; Jones & Sharpe, 2017). CBM is a computer intervention that focuses on redirecting the cognitive bias in a certain direction (MacLeod & Mathews, 2012, as cited in Jones & Sharpe, 2017). CBM training was already found to be effective in reducing anxiety in the short-term and addiction in the long-term (Jones & Sharpe, 2017). More importantly, CBM training was found to be an effective intervention in reducing stress, when targeting attention and approach-avoidance biases (Becker et al., 2016; Dandeneau et al., 2007). This indicates that a CBM training to increase the self-concept PO might be beneficial in reducing the stress levels of students.

One particular application developed by the University of Twente and the Ziekenhuis Groep Twente (ZGT) to provide CBM as a mobile eHealth intervention is the IVY training (Pieterse & Bode, 2018; Wächtler, 2019; Wolbers et al., 2021). This training was provided mobile through the Twente Intervention Interaction Machine Application (TIIM App). The goal of the IVY training was to target the self-concept, in order to prevent chronic fatigue in breast cancer patients. It required patients to swipe words that should be associated with themselves (vitality) towards the bottom of the screen in the category “Me” (towards themselves), and words not associated with themselves (fatigue) towards the top of the screen in the category “Others” (away from themselves). Due to this, breast cancer patients might create a self-concept that focuses more on vitality, which would prevent them from the fatigue symptoms (Wolbers et al., 2021). It is yet unknown if the TIIM App could be used to train implicit PO, similar to the IVY training.

In the current study, an intervention with the TIIM App will be created where participants have to swipe positive words (e.g., high esteem) towards the bottom of the screen in the category "Me", whereas they swipe negative words (e.g., low esteem) towards the top of the screen in the category "Others". The words will be similar to the PO-IAT as developed by Costantini et al. (2019). Due to the CBM training, the implicit PO of participants is expected to increase. Additionally, the perceived stress levels of participants are expected to be indirectly reduced. If the intervention is found to be effective, students can benefit from the use of this CBM training with the TIIM App to decrease their perceived stress levels.

Moreover, it would be useful to know which students benefit most from the CBM training. In order to find that out, the difference in baseline measures of implicit PO will be used to test whether students with lower baseline measures of implicit PO (and thus negatively oriented) might have more benefit from the CBM training compared to students who are already more positively oriented at the start of the intervention. This is expected, because in previous studies, larger changes in bias were found in individuals of whom the degree of the bias is highest, and thus the possibility of reduction through the CBM was largest (Martinelli et al., 2022; Wiers et al., 2011). Since this intervention aims at increasing instead of decreasing bias, the largest changes are expected in individuals with the lowest degree of PO bias at baseline.

Research Goals and Hypotheses

The aim of the current study is to investigate the effect of CBM training with the TIIM App on the implicit PO levels and on the perceived stress levels of students. Besides that, this study aims to investigate whether the relationship between CBM training and the perceived stress levels is mediated by implicit PO and moderated by baseline measures of implicit PO. This will be tested in the current quasi-experimental study with pre- and post-tests between the intervention group, who receive CBM training with the TIIM App, and the control group. Therefore, the following research questions were proposed:

1. What is the effect of CBM training on the implicit PO levels of students?

Hypothesis 1: There is a significant increase in the implicit PO levels of students in the intervention group after the CBM training than at baseline, in comparison to the control group.

2. What is the effect of CBM training on the perceived stress levels of students?

Hypothesis 2: There is a significant decrease in the perceived stress levels of students in the intervention group after the CBM training than at baseline, in comparison to the control group.

3. To what extent is the effect of CBM training on the perceived stress levels of students mediated by implicit PO?

Hypothesis 3: The effect of CBM training on the perceived stress levels of students is mediated by implicit PO.

4. To what extent is the effect of CBM training on the perceived stress levels of students moderated by high versus low baseline measures of implicit PO?

Hypothesis 4: The effect of CBM training on the perceived stress levels is larger for students who have low baseline measures of implicit PO.

Method

Design

The study was approved by the University of Twente's Ethics Committee BMS/Domain Humanities and Social Science (request nr. 230191). Data collection took place in April 2023. The study involved a quasi-experimental design, comparing the participants' scores at both between-subject and within-subject levels. The effect of the CBM training in the TIIM App was measured on the dependent variables implicit PO and perceived stress.

Participants

The sample consisted of 54 participants. However, four participants were excluded from the analyses as they did not complete the first IAT and, thus, provided no useful data. Of these excluded participants, three were in the intervention group, while one was in the control group. Consequently, the final sample consisted of 50 participants, with 28 participants in the intervention group and 22 in the control group. Of these participants, eleven identified as male (22%), 37 as female (74%) and two as non-binary (4%). The age ranged from 19 to 31 years (M = 22.4, SD = 5.37). Furthermore, the sample consisted of 17 Dutch participants (34%), 29 German participants (58%) and four participants from other countries (8%). Regarding education level, one participant indicated secondary school (2%), two vocational education (4%), six University of Applied Sciences (12%), 31 University bachelor's degree (62%), and ten University master's degree (20%) as either their current or highest achieved education level. There were no noticeable differences in the demographics between the participants in the intervention group and the control group.

Participants were recruited via the SONA System, which is the test subject pool system of the University of Twente, as well as via convenience sampling of the researchers' networks. The eligibility criteria for this study were that participants needed to be at least 18 years old and have sufficient reading skills and an understanding of the English language. Besides that, they must have had access to a computer or laptop with a functioning keyboard in order to complete the tests. Before starting the pre-tests, participants had to give clear consent and it was made sure that they understood that participating in the research was voluntary (see Appendix A).

Materials

CBM Training in the TIIM App

To provide the CBM training to participants in the experimental group, the TIIM App was used. The TIIM App is a tool created by the Behavioural, Management and Social Sciences (BMS) Lab at the University of Twente (BMS Lab, 2023). It is a free mobile app available on both the IOS App Store and the Android Play Store, although with restricted access. The TIIM App allows students, researchers, and teachers at the University of Twente to design surveys, long-term studies, or interventions. In this study, the app was used to conduct the CBM training via the response latency platform of the TIIM App. As the response latency platform is a relatively new development, there is little research on its effectiveness yet. However, previous studies by Pieterse and Bode (2018) and Wächtler (2019) found significant results when using the TIIM App for the IVY training, aimed at reducing a fatigue bias. Furthermore, Wolbers et al. (2021) mentioned that it is a very convenient and inexpensive training tool, as participants can use the TIIM App at any time and place and because little mental effort and literacy are required for the use of this mobile CBM training app. This suggests that the platform of the TIIM App might be an effective tool for conducting CBM training.

During the developed CBM training in the TIIM App, words appeared in the middle of the screen, which users had to categorise by swiping either up or down on the screen. Positive words had to be swiped down on the screen (towards the user), in the category "Me/Positivity", and negative words had to be swiped upwards on the screen (away from the user), in the category "Others/Negativity". The words were the English translations of the Italian stimuli used in the original PO-IAT, as developed by Costantini et al. (2019) (see Appendix B for the list of stimuli used). For example, when the positive word "optimistic" appeared, it needed to be categorised as "Me/Positivity" as fast as possible. When the user swiped the word to the wrong category, the category label turned red, and the user was asked to swipe again until they categorised it correctly. When they swiped the words into the correct category, the category label turned green, and a positive chime confirmed their choice.

Furthermore, a zooming function was incorporated in the CBM training. When words were swiped down towards "Me/Positivity", the word on the screen became larger, stimulating a sensation of approach. Similarly, when the words were swiped away towards "Others/Negativity", the words became smaller, generating a feeling of avoidance (Wiers et al., 2010). One training session consisted of 20 words which were each presented five times in randomised order. The users completed the CBM training sessions twice a day for three days, to potentially strengthen the self-concept implicit PO. Besides the training sessions, the app included a welcome message and brief daily instructions. The users received notifications from the TIIM App as a reminder to complete their CBM training sessions.

Measuring Implicit PO with the PO-IAT

The dependent variable implicit PO was measured using the PO-IAT. The PO-IAT was generated using SoSci Survey (Leiner, 2016) and was made available to users via www.soscisurvey.de. The PO-IAT requires users to categorise words that are presented in the middle of the computer screen into the left or right categories as quickly and accurately as possible. Categorising had to be done by pressing the appropriate keys on the keyboard, namely “E” for the left categories and “I” for the right categories. The words that appeared on the screen were the same words that were used in the CBM training in the TIIM App (see Appendix B). First, the left side of the screen contained the categories “Me” and “Positivity”, and users had to categorize positive words (e.g., “Optimistic”) and pronouns such as “I” to the left. On the right side of the screen, the categories “Others” and “Negativity” were presented, and negative words (e.g., “Pessimistic”) and pronouns such as “Them” had to be categorised right. In case the word was falsely categorised by the user, a red “X” appeared, signalling that a mistake was made. The users needed to correct their mistake first by pressing the correct key to continue with the test. The first part of the PO-IAT contained three practice blocks and a fourth test block, in which the reaction time was measured. Then, in the second part of the PO-IAT, the categories were changed so that the left side of the screen included the categories “Others” and “Positivity”, and the right side included the categories "Me” and “Negativity”. This time, positive words and pronouns such as “Them” had to be categorised left, and negative words and pronouns such as “I” had to be categorised right. Again, the reaction time was measured in the practice blocks and the seventh block.

The PO-IAT results in a total *D*-score, as calculated by Greenwald et al. (2003). The total *D*-score includes both the response times of practice blocks 3 and 6, and the test blocks 4 and 7. The *D*-score was calculated by subtracting the average response times of block six and seven (Me/Negativity + Others/Positivity) from block three and four (Me/Positivity + Others/Negativity). Afterwards, values were individually standardised by dividing them by the standard deviations of response times of blocks three and four collectively, and blocks six and seven collectively. The resulting mean value of the two quotients is the *D*-score, which indicated the strength of the implicit association. Therefore, a positive *D*-score indicated that participants had a stronger association between themselves and positive concepts (shorter reaction times in block 3/4), while a negative *D*-score indicated a stronger association between themselves and negative concepts (shorter reaction times in block 6/7). The range of values for the *D*-score is not limited, which means that it can be less than -1 or greater than +1, depending on how much the reaction times differ. A *D*-score of zero indicated no stronger implicit association with either of the two concepts being tested (Nosek et al., 2005). Since the D-score is sensible for individual differences in reaction time, the D-score is most reliable when used as a group mean to compare between and within groups.

Perceived Stress Scale-10

The amount of stress that one perceives can be measured using the *Perceived Stress Scale* (PSS) (Cohen et al., 1983). The PSS is a self-report questionnaire about the subjective experience of stress. A subjective stress scale not only considers the amount and intensity of stressful events one experienced, but also personal and contextual factors, such as coping resources. Originally, the PSS contained 14 items. Later, the PSS-4 and PSS-10 were developed, which are shorter and faster to conduct than the original questionnaire (Cohen & Williamson, 1988). The 10-item questionnaire has the best psychometric qualities of the three versions (Cohen & Williamson, 1988; Lee, 2012). This is the reason why the PSS-10 is used in this study and will be further explained.

The PSS-10 contains questions about how often one has felt or thought a certain way in a timeframe of the past month, with the answer options on a 5-point Likert scale ranging from 0 (*never*) to 4 (*very often*). One question on the PSS-10 is: "*In the last month, how often have you been upset because of something that happened unexpectedly?*". Four items of the PSS-10 are positively phrased. For a total score, the positively-phrased items are reversed and then a sum of scores is calculated. The total score of the PSS-10 ranges from 0 to 40 with higher scores indicating higher levels of perceived stress. Cohen and Janicki-Deverts (2012) developed norm scores for the American population and found that perceived stress decreases when age increases. The average PSS-10 score was M = 16.78 in the age group of students (18-24 years old).

Lee (2012) found that the PSS-10 has a high internal consistency with a Cronbach's alpha ranging from α =.74 to α =.91. Moreover, the test-retest reliability of the PSS-10 is "*good*" to "*very good*" for 1-week (ICC = .86), 2-week (ICC = .90) and 4-week interval (ICC = .72 - .88) (Lee, 2012). A 24-hour timeframe was used by Kaskons (2022), who found a "*very good*" score (ICC =.91 - .93) among high school students. This indicates that the PSS-10 is a reliable measurement instrument. The construct validity was analysed with the factor analysis, which showed a two-factor structure accounting for 47.3% - 66.5% of the variance, identifying the constructs '*Perceived Helplessness*' and '*Perceived Self-Efficacy*' (Lee, 2012). The concurrent validity of the PSS-10 is good, with strong positive correlations between depression and anxiety measurements (Lee, 2012; Liu et al.,2020). The convergent validity of the PSS-10 was unsatisfactory, as Cohen and Williamson (1988) found that correlations with other measures of perceived stress were weak to moderate. Similar correlations were found between the PSS-10 and the amount and impact of life events on Chinese high school students (Liu et al., 2020). All in all, it can be said that the PSS-10 has acceptable psychometric qualities as a measurement instrument for perceived stress. For this study, the timeframe of the questions was adapted to “the past days” instead of the past month. The Cronbach’s alpha of the PSS-10 in this study was $\alpha = .88$. See Appendix C for the PSS-10 used in this study.

Procedure

After signing up via the SONA System, participants received a link to the SoSci website with information about the study and the informed consent form. This included a brief introduction to the purpose of the study and the procedure. Participants were informed that the effect of the CBM training and PO levels were measured, along with other aspects of mental well-being. Besides that, it was stated in the form that participation was entirely voluntary, withdrawal was possible at any time during the study, and the researchers could be contacted for further information or when experiencing problems. After giving consent, participants filled in demographic information, which included age, gender, nationality and current or highest achieved education level. Lastly, they filled in their email address to receive information about the next steps of the study. This email address was solely used for research purposes and not stored in the dataset or given to third parties.

The first 30 participants that signed up for the study were assigned to the intervention group and received an email with the link to start the pre-tests. The next participants were assigned to the control group and received another link to the pre-tests. Both groups filled in the pre-tests on the SoSci website, consisting of the PSS-10 and the PO-IAT test, together with the Patient Health Questionnaire - 9, the State-Trait Anxiety Inventory and Life Orientation Test-Revised, which were included in the research but not relevant for this thesis. After completing the pre-tests, the intervention group received instructions for downloading the TIIM App. After they downloaded the TIIM App and created an account, participants were assigned to the CBM training. Then, the participants could complete the first session, and the second session two hours after completing the first session of the day (see Table 1). The sessions could be done at any location and participants received a notification on their phone when the next session was available. If a session was not yet completed, participants received a reminder on their phones three and six hours after the session got available. After three days, the intervention and the control group received an email to complete the post-tests, which were identical to the pre-tests. If not completed, they received a reminder email to complete the post-tests after one day.

Table 1

Overview of sessions in the TIIM App

Session number	Days of the CBM training	Availability
Session 1	Day 1	Directly after filling in the pre-tests
Session 2	Day 1	2 hours after completing session 1
Session 3	Day 2	1 day after the start of the intervention
Session 4	Day 2	2 hours after completing session 3
Session 5	Day 3	2 days after the start of the intervention
Session 6	Day 3	2 hours after completing session 5

Data Analysis

Preparing Dataset

The collected data was downloaded from the SoSci server and stored as excel-file on the researcher's laptop and University of Twente student OneDrive. It was only available for the researcher and for research purposes. The file will be removed after the 31st of July 2023. The data analysis was conducted in R (version 4.2.3), using the packages *datarium* (Kassambara, 2019), *ez* (Lawrence, 2016), *ggpubr* (Kassambara, 2023a), *Hmisc* (Harrell & Dupont, 2023), *jtools* (Long, 2022), *mediation* (Tingley et al., 2019), *psych* (Revelle, 2023), *readxl* (Wickham & Bryan, 2023), *reshape* (Wickham, 2022), *Rmisc* (Hope, 2022), *rstatix* (Kassambara, 2023b), *tidyr* (Wickham et al., 2023), *tidyverse* (Wickham, 2023). The data was filtered so that only participants who completed the pre-test IAT (n = 50) and the variables relevant for this research were included in the dataset. Dropouts were included in the dataset for the pre-tests, but were left out of the post-tests. Next, the total scores for the PSS-10 were calculated. Then, the sample characteristics were analysed and the descriptive statistics for the *D*-scores and the PSS-10 scores were calculated for the total sample, and for the intervention group and control group separately. Finally, the data was ready to test the hypotheses. An alpha of $\alpha = .05$ was used to determine if the effects were significant. Additionally, it was decided to accept $p < .10$ as marginally significant, due to the explorative nature of the research and the small sample size.

Research Question 1: The Effect of CBM Training on Implicit PO

To test the first hypothesis "*There is a significant increase in the implicit PO levels of students in the intervention group after the CBM training than at baseline, in comparison to the control group*", a two-way repeated measures ANOVA was conducted. The within-subjects factor was 'time' (pre-test vs. post-test of the *D*-score) and the between-subjects factor was 'treatment' (CBM vs. control condition). A significant interaction between 'time' and 'treatment' would indicate that the improvement in the *D*-score, and, thus, an increase in the implicit PO levels, was greater for the intervention group than for the control group.

Prior to the two-way repeated measures ANOVA, the assumptions were checked, including sphericity using Mauchly's test and normality using the Shapiro-Wilk test. The Greenhouse-Geisser correction was used if the assumption of sphericity was violated. After conducting the two-way repeated measures ANOVA, post-hoc analyses were conducted when a (marginally) significant interaction effect was found. The post-hoc analyses included paired-samples *t*-tests and independent-samples *t*-tests to further investigate the effect of CBM training on the implicit PO levels of students.

Research Question 2: The Effect of CBM Training on Perceived Stress

To test the second hypothesis "*There is a significant decrease in the perceived stress levels of students in the intervention group after the CBM training than at baseline, in comparison to the control group*", again a two-way repeated measures ANOVA was conducted. Again, the within-subjects factor was 'time' (pre-test vs. post-test of the PSS-10) and the between-subjects factor was 'treatment' (CBM vs. control condition). A significant interaction between 'time' and 'treatment' would indicate that the improvement on the PSS-10, and, thus, a decrease in the perceived stress levels, was greater for the intervention group than for the control group.

Again, prior to the two-way repeated measures ANOVA, the assumptions were checked, including the Mauchly's test and the Shapiro-Wilk test. When the Mauchly's test was significant, the Greenhouse-Geisser correction was used. After conducting the two-way repeated measures ANOVA, post-hoc analyses were conducted when a (marginally) significant interaction effect was found. The post-hoc analyses included paired-samples *t*-tests and independent-samples *t*-tests to further investigate the effect of CBM training on the perceived stress levels.

Research Question 3: The Mediation Effect of Implicit PO

To test the third hypothesis "*The effect of CBM training on the perceived stress levels of students is mediated by implicit PO*", a mediation analysis via three linear regression models was conducted. Prior to the mediation analysis, the assumptions of normality, homoscedasticity, independence, and multicollinearity were checked. Then, the linear regression models were created to test the three pathways of the mediation analysis.

The first model tested the direct effect of 'treatment' (CBM vs. control condition) on the 'change in PSS-10 score' (post-test PSS-10 minus pre-test PSS-10). When a mediation effect exists, this path is significant. The second model tested the direct effect of treatment on the change in *D*-score. When a mediation effect exists, this path is also significant. The last model tested the indirect effect of treatment on the change in PSS-10 score through the change in *D*-score. When a mediation effect exists, the effect of CBM training on stress weakens or disappears when the implicit PO is included in the regression. A bootstrapping approach was used to estimate the indirect effect of CBM training on stress through implicit PO, with 500 bootstrap samples drawn from the data.

Research Question 4: The Moderation Effect of Baseline Measures of Implicit PO

To test the last hypothesis "*The effect of CBM training on the perceived stress levels is larger for students who have low baseline measures of implicit PO*", a linear regression analysis was conducted with an interaction term. The linear regression analysis contained the independent dichotomous variables 'treatment' (CBM vs control condition) and 'baseline implicit PO' (a dummy variable), and their interaction term (treatment * baseline implicit PO). The dependent variable was the 'change in PSS-10 score'. Before conducting the analysis, the dichotomous dummy variable 'baseline implicit PO' was created. This was done by splitting the groups into two categories, based on their pre-test *D*-score. The category 'low baseline implicit PO' included participants with a pre-test *D*-score below or including the cut-off point of the lower quartile (Q1) (≤ 0.2791). Ideally, the cut-off point would be ≤ 0. However, due to the small sample size and the expected pre-existing PO bias of the majority of the sample, the lower quartile of the pre-test *D*-score was chosen as the cut-off point. The other scores were categorised as 'high baseline implicit PO'. Next, the assumptions of normality of data, normality between groups and homogeneity of variance were checked.

Then, the linear regression analysis was conducted, and it was tested whether the interaction term was (marginally) significant. If so, this indicated a moderation effect of the baseline measures of implicit PO. Lastly, a simple slopes plot with the separate groups 'low baseline implicit PO' and 'high baseline implicit PO' was created to visualise the moderation effect.

Results

Descriptive Statistics

The average *D*-score on the IAT at baseline was $M = 0.56$ for the intervention group and $M = 0.47$ for the control group. After three days, the intervention group had an increased *D*-score ($M = 0.81$), while the *D*-score of the control group remained stable ($M = 0.49$). Besides that, the intervention group had an average score of $M = 16.25$ on the PSS-10 pre-test, with a decrease to $M = 14.5$ on the PSS-10 post-test. The control group had a score on the PSS-10 of $M = 17.86$ on the pre-test and $M = 19.13$ on the post-test. The PSS-10 scores of both groups at baseline were similar to the norm score of the American population under the age of 25 years old ($M = 16.78$). Table 2 shows a more detailed overview of the descriptive statistics for both the intervention and the control group. Due to dropouts, the number of participants in the post-tests was lower than in the pre-tests.

Table 2

Descriptive Statistics for the Intervention and Control Groups

	Intervention Group			Control Group			Total					
Question-naires	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	Min	Max	95% CI
D-score pre-test	28	0.56	0.35	22	0.47	0.40	50	0.52	0.37	-0.20	1.19	[0.42, 0.63]
D-score post-test	21	0.81	0.27	15	0.49	0.28	36	0.68	0.32	0.11	1.24	[0.59, 0.77]
PSS-10 pre-test	28	16.25	6.47	22	17.86	8.16	50	16.96	7.23	0	35	[14.9, 19.0]
PSS-10 post-test	22	14.5	6.78	16	19.13	8.82	38	16.45	7.94	2	37	[14.2, 18.7]

Note. Min = minimum score; Max = maximum score; CI = Confidence Interval; *D*-score = score of implicit PO on the PO-IAT; PSS-10 = Perceived Stress Scale (Min. 0, Max. 40).

Research Question 1: The Effect of CBM Training on Implicit PO

The first research question was "*What is the effect of CBM training on the implicit PO levels of students?*". The hypothesis was that there is a significant increase in the implicit PO levels of students in the intervention group after the CBM training than at baseline, in comparison to the control group. The assumptions for normality, homogeneity of variance and homogeneity of covariances were met (see Appendix D). There was one outlier, but no extreme values were observed. The assumption of sphericity was violated ($p < .001$ for intercept and $p = .030$ for treatment) based on Mauchly's test, so the correction method of Greenhouse-Geisser was applied to the two-way repeated measures ANOVA to ensure the output's reliability.

The results of the two-way repeated measures ANOVA showed that there was a significant main effect of treatment, $F(1, 34) = 5.16$, $p = .030$, indicating a significant difference in the mean *D*-scores between the intervention and control groups (see Table 3). The main effect of time was non-significant, $F(1, 34) = 1.03$, $p = .317$, suggesting that there was no significant difference in the mean *D*-score between the pre- and post-test measures across the sample. The interaction effect between treatment and time was marginally significant, $F(1, 34) = 3.35$, $p = .076$.

Table 3

Two-way Repeated Measures ANOVA output for the effects of treatment and time on D-score

Effect	DFn	DFd	*F*	*p*	$\eta \frac{2}{g}$
Treatment	1	34	5.16	.030*	.09
Time	1	34	1.03	.317	.01
Treatment x Time	1	34	3.35	.076	.03

Note. ANOVA = analysis of variance; DFn = degrees of freedom numerator; DFd = degrees of freedom denominator; $\eta \frac{2}{g}$= generalized eta squared

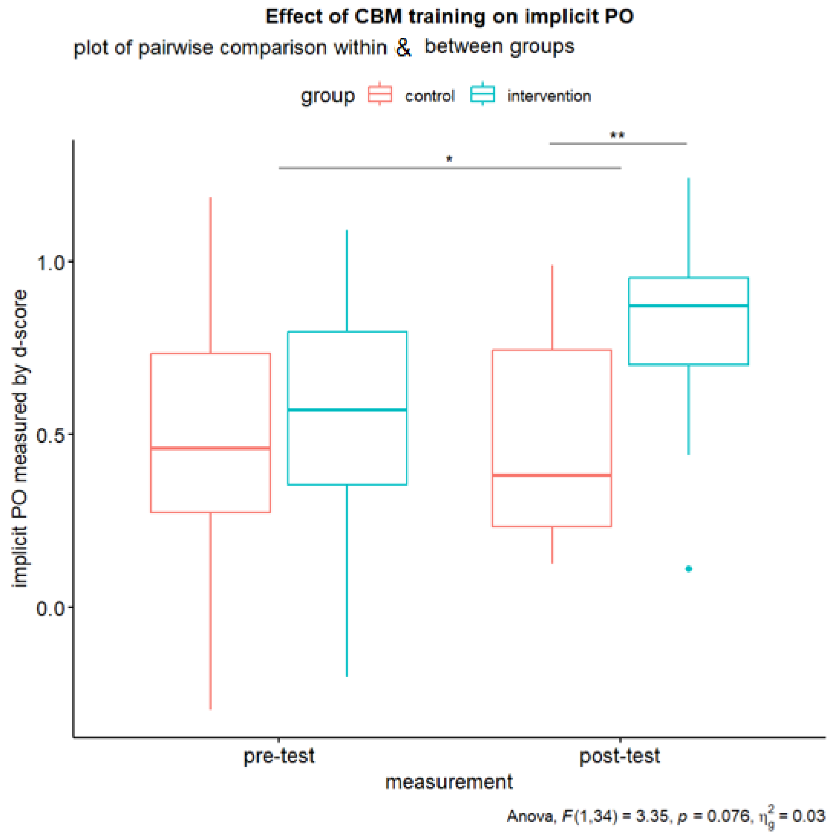
* $p < .05$

Due to the marginally significant interaction effect, the effect of treatment was analysed at both time points. The *p*-values were adjusted using the Bonferroni multiple-testing correction method. The post-hoc tests showed no difference between the intervention group and control group on the *D*-score at the pre-test ($p = .410$), but a significant difference at the post-test ($p = .002$). Pairwise comparisons indicated a significant difference between the pre-test and the post-test on the *D*-score in the intervention group ($p = .032$), but not in the control group ($p = .621$). See Figure 1 for a visualisation of the post-hoc tests.

Thus, the post-hoc tests showed a significant increase in the implicit PO levels in the intervention group after CBM training, but not for the control group. Nevertheless, the two-way repeated measures ANOVA showed that the interaction effect between treatment and time is only marginally significant. Therefore, the hypothesis that "*There is a significant* *increase in the implicit PO levels of students in the intervention group after the CBM training than at baseline, in comparison to the control group*" is partially accepted.

Figure 1

Boxplot of the post-hoc tests after ANOVA of implicit PO



Note. ANOVA = analysis of variance. The ANOVA statistics below refer to the marginally significant interaction effect. Number of participants per group: pre-test control $n = 22$; pre-test intervention $n = 28$; post-test control $n = 15$; post-test intervention $n = 21$.

* $p < .05$, ** $p < .01$.

Research Question 2: The Effect of CBM Training on Perceived Stress

The second research question was "*What is the effect of CBM training on the perceived stress levels of students?*". The hypothesis was that there is a significant decrease in the perceived stress levels of students after the CBM training than at baseline, in comparison to the control group. The assumptions for normality and homogeneity of variance were met (see Appendix D). There were no outliers or extreme values in the dataset. However, the assumption of homogeneity of covariances, measured by the Box's M-test (= 3.86 with $p = .0496$), was violated ($p < .05$), as well as the assumption of sphericity, measured by the Mauchly's test ($p < .001$ for the intercept). To address these violations, the correction method of Greenhouse–Geisser was applied to the calculation of the ANOVA table to ensure the output was reliable.

The results of the two-way repeated measures ANOVA indicated that there was no significant main effect of treatment or time, $F(1, 36) = 2.83$, $p = .101$ and $F(1, 36) = 0.08$, $p = .785$, respectively (see Table 4). This suggests that there was no significant difference in the mean stress scores between the two groups and no significant difference between the pre- and post-test measures across the sample. Moreover, the interaction effect between treatment and time was also not significant $F(1, 36) = 0.90$, $p = .350$. See Figure 2 for a visualisation.

Table 4

Two-way Repeated Measures ANOVA output for the effects of treatment and time on PSS-10 score.

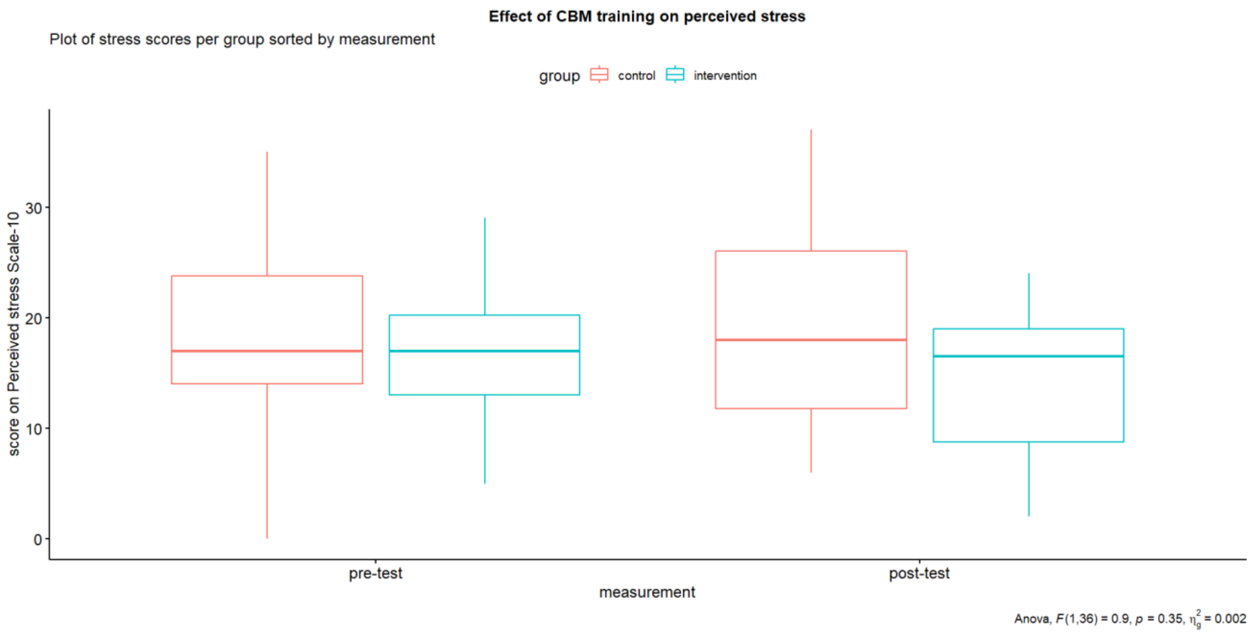
Effect	DFn	DFd	F	p	η_g^2
Treatment	1	36	2.83	.101	.06
Time	1	36	0.08	.785	<.01
Treatment x Time	1	36	0.90	.350	<.01

Note. ANOVA = analysis of variance; DFn = degrees of freedom numerator; DFd = degrees of freedom denominator; η_g^2 = generalized eta squared

As there were no significant effects, no post-hoc tests were performed. Additionally, the more cautious non-parametric Kruskal-Wallis test was conducted, due to the small violation of the assumption of homogeneity of covariances. Again, no significant difference between the average perceived stress levels in the groups was found. This confirmed the previous findings of the two-way repeated measures ANOVA. Based on these findings, the hypothesis that "*There is a significant decrease in the perceived stress levels of students in the intervention group after the CBM training than at baseline, in comparison to the control group*" is rejected.

Figure 2

Boxplot of perceived stress scores on the PSS-10



Note. ANOVA = analysis of variance. The ANOVA statistics below refer to the non-significant interaction effect. Number of participants per group: pre-test control n = 22; pre-test intervention n = 28; post-test control n = 16; post-test intervention n = 22.

Research Question 3: The Mediation Effect of Implicit PO

The third research question was "*To what extent is the effect of CBM training on the perceived stress levels of students mediated by implicit PO?*". The hypothesis was that the effect of CBM training on the perceived stress levels of students is mediated by implicit PO. The assumptions of normality of residuals, linearity, homoscedasticity, independence, and multicollinearity were met (see Appendix D). Besides that, no outliers were found.

The mediation analysis was conducted using three linear regression models to test the hypothesis (see Figure 3). The results of the first model showed that there was no significant effect of CBM training on the change in perceived stress (path c = -1.41, p = .350), which implies that there is no ground for a mediation effect of implicit PO. Further analysis confirmed this result, as the effect of CBM training on stress did not significantly weaken or disappear when implicit PO was included in the regression (path c' = -0.72, p = .662) (see Figure 3). The results of the nonparametric bootstrap analysis also suggest that CBM training does not affect stress directly, nor through implicit PO (see Table 5). Therefore, the hypothesis "*The effect of CBM training on the perceived stress levels of students is mediated by implicit PO*" is rejected.

Figure 3

Mediation analysis with pathway outcomes

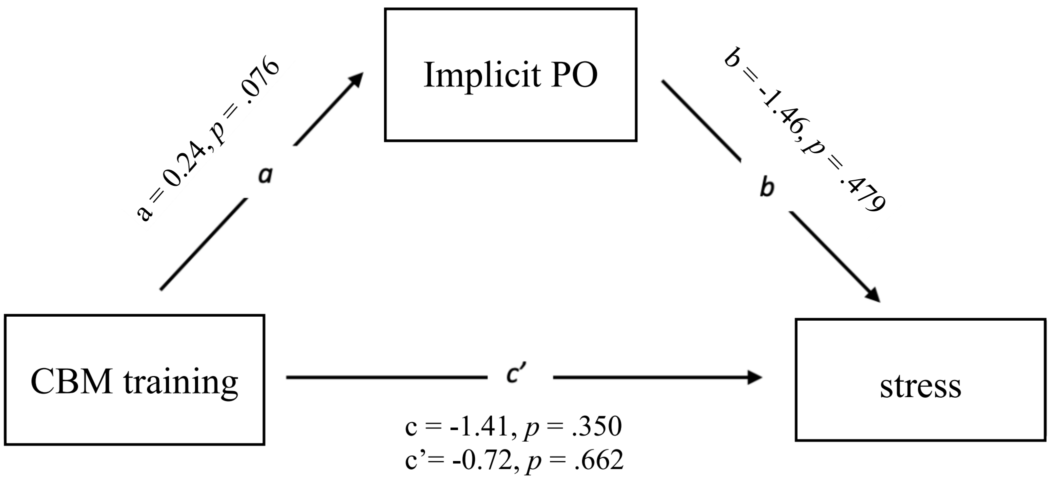


Table 5

Causal Mediation Analysis

	Estimate	95% CI	*p*
ACME	-0.35	[-1.32, 0.18]	.240
ADE	-0.72	[-3.41, 2.28]	.710
Total Effect	-1.07	[-3.92, 1.97]	.460
Prop. Mediated	0.33	[-2.93, 4.22]	.570

Note. CI = Confidence Interval; ACME = Average Causal Mediation Effect; ADE = Average Direct Effect; N = 36; Simulations = 500

Research Question 4: The Moderation Effect of Baseline Measures of Implicit PO

The last research question was "*To what extent is the effect of CBM training on the perceived stress levels of students moderated by high versus low baseline measures of implicit PO?*". The hypothesis was that the effect of CBM training on the perceived stress levels is larger for students who have low baseline measures of implicit PO. Therefore, the participants were split into two groups based on the *D*-score of the pre-test, compared to the lower quartile (*Q1*) of the pre-test *D*-score. Participants with a low implicit PO had a pre-test *D*-score ≤ 0.2791 (n = 8) and those with a high implicit PO had a pre-test *D*-score above that (n = 30).

The assumptions of normality of data, normality between groups and homogeneity of variance were met, with two outliers in the dataset but no extreme values (See Appendix D).

The results of the regression analysis indicated that the main effects of treatment and baseline implicit PO were not significant, meaning that neither of these variables had a significant effect on the change in PSS-10 scores (see Table 6). More importantly, the interaction effect between treatment and low baseline implicit PO was negative (β = - 2.39) and not significant (p = .529), suggesting that the effect of CBM training on the stress level did not differ significantly between participants with low and high baseline measures of implicit PO. Nevertheless, an interaction plot was created that showed the moderation effect of low baseline implicit PO (see Figure 4). Although non-significant, the interaction plot does suggest that students with low baseline measures of implicit PO might benefit more from the effect of CBM training on the perceived stress levels. However, based on the findings from the statistical tests, the hypothesis "*The effect of CBM training on the perceived stress levels is larger for students who have low baseline measures of implicit PO"* is rejected.

Table 6

Regression analysis including the dependent variable 'change in PSS-10 scores' and the binary predictor variables 'treatment', 'baseline PO' and the interaction term.

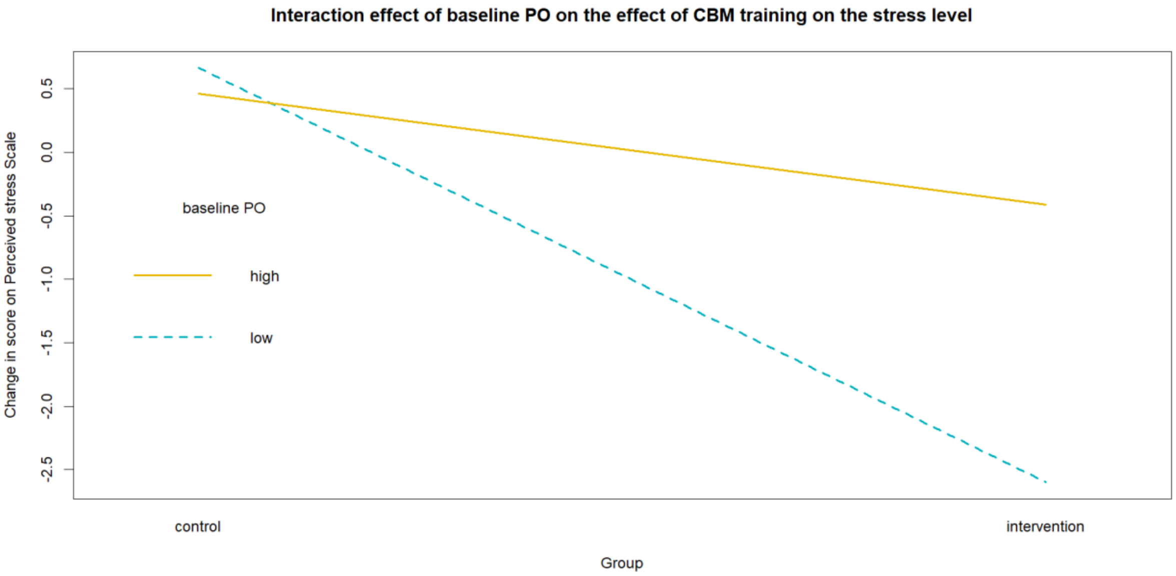
Coefficients	Estimate	SE	*t*	*p*
intercept	0.46	1.28	0.36	.720
Treatment	-0.87	1.69	-0.52	.610
Low baseline PO	0.21	2.95	0.07	.945
Treatment x low baseline PO	-2.39	3.76	-0.64	.529

Note. $F(3,34) = 0.583$, $p = .630$; $R^2 = 0.049$; Adj. $R^2 = -0.035$

* $p < .05$

Figure 4

Plot with moderation effect



Note. Non-significant interaction effect of (β = - 2.39, p = . 529) with n = 8 for low baseline PO and n = 30 for high baseline PO.

Discussion

Main Findings

The aim of this quasi-experimental study was to investigate the effect of CBM training on implicit PO and the perceived stress levels of students. The sample consisted of 54 participants, of whom 28 participants received six sessions of the CBM training and 22 participants were part of the control group. The CBM training in the TIIM App intended to strengthen the positive self-concept bias of students through association with positive rather than negative concepts. The increase in positive cognitions about one's self, life and future was expected to reduce the levels of perceived stress, which would benefit the mental and physical well-being of students, as well as their academic performance. Furthermore, it was investigated whether the relationship between CBM training and perceived stress is mediated by implicit PO, and if this relationship is moderated by the level of implicit PO at the start of the intervention.

The results show that there is a marginally significant effect of CBM training on implicit PO, which indicates that the CBM training has a positive effect on implicit PO. However, there is no effect of CBM training on perceived stress levels. The non-significant relationship between CBM training and perceived stress levels is not mediated through implicit PO, nor moderated by the level of implicit PO that students had before the intervention. Overall, the results of this study indicate that the use of CBM training in the TIIM App might be beneficial for increasing students' implicit PO bias, but it remains unclear whether this results in subjectively perceived changes of stress.

Research Question 1 and 2: The Effect of CBM Training on Implicit PO and Perceived Stress

The first research question was "*What is the effect of CBM training on the implicit PO levels of students?*". The results show that the intervention group improved marginally significantly more on implicit PO after the CBM training than the control group. This was confirmed by the post-hoc tests, which show a significant difference between pre- and post-measures within the intervention group only. Also, the post-hoc tests show a significant difference after the CBM training in the intervention group compared to the control group. Therefore, the first hypothesis was partially accepted. These findings provide promising preliminary evidence that brief CBM training can increase students' implicit PO bias. The second research question was "*What is the effect of CBM training on the perceived stress levels of students?*". Although there seemed to be a reduction in the average stress scores in the intervention group, the results show that there is no significant effect of CBM training on the perceived stress levels of students. Therefore, the second hypothesis was rejected.

The finding of the first research question is in line with previous literature reviews of Jones and Sharpe (2017) and Martinelli et al. (2022), as they concluded that CBM training is effective in altering biases. However, this is the first study that specifically focuses on the effect of CBM training on implicit PO bias. Therefore, it can be argued that this study contributes to previous work on the effect of CBM training on altering biases. Becker et al. (2016) also contributed to this field of research, as they found an effect of CBM training on general positivity bias. Nevertheless, the current study differs from the work of Becker et al. (2016), because they focused on a broader concept of general positivity, including images of animals, humans, and objects, rather than implicit PO bias. In short, the current study is related to previous literature on the effect of CBM training on altering biases but has a specific focus on implicit PO bias.

One possible explanation for the rejection of the second hypothesis is the CBM paradigm that was used. The CBM paradigm used in the current study differs from the CBM paradigm used in two other studies, in which a significant effect of CBM training on perceived stress levels was shown (Becker et al., 2016; Dandeneau et al., 2007). In the current study, the CBM training targeted the PO self-concept bias through the IAT paradigm, with a motoric approach-avoidance mechanism included. The goal of this CBM training is to increase participants' association between positive cues and themselves, and negative cues and others. In contrast, the CBM training in the aforementioned studies used attentional and approach-avoidance paradigms. For example, the goal of the attention paradigm is to avoid negative cues and redirect attention to positive cues. The effect of this paradigm on perceived stress levels can be explained by early attentional processes that influence the perception of stressful situations (Dandeneau et al., 2007). By paying attention to stimuli that are perceived as threatening, the physiological stress response gets activated. CBM training with the attention paradigm prevents this process from occurring, which significantly reduces perceived stress levels (Dandeneau et al., 2007). Thus, the attention paradigm seems to be more effective in reducing perceived stress levels than the current CBM training using the IAT paradigm to increase the PO self-concept bias.

Another possible explanation for rejecting the second hypothesis is that the effect of CBM training on stress can only be seen after participants are exposed to a highly stressful situation. For example, Dandeneau et al. (2007) found that there were no differences in perceived stress levels the days prior to an exam. However, the morning of the exam, participants who received CBM training reported significantly lower perceived stress levels, compared to the control group. Becker et al. (2016) found similar results after participants had to perform an anagram-task. However, this effect was only significant for dysphoric participants. In the current study, the sample consisted of healthy participants, who were not exposed to a stressful situation. Thus, a possible explanation for rejecting the second hypothesis is that participants were not exposed to a highly stressful situation during this study.

Research Question 3 and 4: The Mediation Effect of Implicit PO and the Moderation Effect of Baseline Measures of Implicit PO

The third research question was "*To what extent is the effect of CBM training on the perceived stress levels of students mediated by implicit PO?*". The results indicate that there is no mediation effect of implicit PO on the relationship between CBM training and the perceived stress levels of students. Therefore, the third hypothesis was rejected. Lastly, the fourth research question was "*To what extent is the effect of CBM training on the perceived stress levels of students moderated by high versus low baseline measures of implicit PO?*". Although the interaction plot seems to show larger differences for the group with low baseline measures of implicit PO, there is no significant moderation effect of baseline implicit PO on the relationship between CBM training and the perceived stress levels of students. Therefore, the fourth hypothesis was also rejected. Thus, the level of implicit PO bias that students have before starting the intervention does not influence the effect of CBM training on perceived stress levels.

The non-significant mediation effect of implicit PO in the third research question can be explained by the fact that there was no effect of CBM training on the perceived stress levels of students. However, there was also no significant path between implicit PO and perceived stress levels. This was not expected, because Dymecka et al. (2023), Horiuchi et al. (2018) and Park et al. (2021) all found that PO is correlated with perceived stress levels. Although these studies all used the PSS as the measurement instrument for stress, the difference with the current study is that in the aforementioned studies, PO was measured explicitly with the Positivity scale or by measuring the constructs of optimism, self-esteem, and life satisfaction separately. This difference between either implicit (the current study) or explicit (the aforementioned studies) measurements can be seen as an explanation for the non-significant result in this study. This could mean that only explicit PO is correlated with perceived stress levels, or that the implicit PO measurement used in this study (PO-IAT) was not valid.

The second reason for the non-significant mediation effect could be that the effect of CBM training on implicit PO was only marginally significant. Perhaps, in order for behavioural change to occur, the increase in implicit PO bias should be larger. Due to the marginally significant effect, no effects on the perceived stress levels were observed. The third reason for the non-significant mediation effect could be that the post-test was too close to the pre-test. This is because a delay between the change in implicit PO bias and the change in perceived stress levels may be expected.

The non-significant moderation effect in the fourth research question is in line with the findings of Becker et al. (2016). In their study, there was also no moderation effect of baseline positivity on the relationship between CBM and stress levels. However, in the study of Becker et al. (2016), baseline positivity was found to be a moderator on the stress levels of dysphoric participants, only after they were exposed to a highly stressful situation. Since the current study only consisted of healthy participants, this moderation effect could not be taken into consideration. Another aspect that should be taken into account is that, on average, participants already had high levels of implicit PO. This is similar to the finding of Becker et al. (2016), who found that the majority of participants had a pre-existing positivity bias. The high levels of implicit PO at baseline result in lacking participants in the 'low baseline implicit PO' group for the intervention. Due to practical reasons, the first quartile of baseline measures of implicit PO was used as a cut-off score. As a result, participants in the 'low baseline implicit PO' group already had high levels of implicit PO. Therefore, it is questionable whether this cut-off score was suitable.

Theoretical Implications

The findings of this study have several theoretical implications. First, a direction for future research is concerned with the moment of the post-test. It would be interesting to test whether a post-test later in time would show an effect on the perceived stress levels. This is because a delay between the change in implicit PO and behavioural change may be expected. Besides that, it could be investigated how long the increase in implicit PO bias remains visible after ending the intervention. This could be done by adding extra measurements later in time. Second, it would be relevant to test the effectiveness of the current CBM training on the perceived stress levels after a highly stressful situation, for example in a period of exams or deadlines (Becker et al., 2016; Dandeneau et al., 2007). Third, testing the effectiveness of the CBM training in another sample could be a direction for future research. For example, in a sample of students with high symptomatology, a larger effect of the CBM training is expected (Jones & Sharpe, 2017; Martinelli et al., 2022). Besides that, a larger sample could be used to find a more reliable effect size. Moreover, these samples are expected to include more participants with a neutral or negative orientation bias. This enables to investigate the moderation effect of baseline implicit PO again with a more reliable cut-off score.

Strengths and Limitations

One methodological strength is concerned with the use of different platforms for measurement and intervention. Specifically, the SoSci website was used for tests, while the TIIM App was employed for the CBM training. This approach involved the use of distinct devices (laptop/PC versus smartphone), different operating movements (pressing keys on a keyboard versus swiping on a screen), and presented words in different screen positions (left/right on SoSci versus top/bottom on TIIM). By implementing these variations, the likelihood of a motor practice-effect, where participants improve due to the practice of movements rather than an actual improvement on the test, is reduced (Friedman et al., 2022). Consequently, it can be argued that the findings are valid and robust. Additionally, Greenwald et al. (2003) found that practice effects caused a more neutral score on the IAT of participants who completed the IAT at least once before. This could undesirably affect the difference between pre- and post-test scores. Therefore, including a control group is a methodological strength of the study, as it helps to investigate the possibility of the practice-effect. Moreover, the control group helps to mitigate the influence of external events, such as exams or major global occurrences, which could potentially elevate stress levels. Consequently, the study demonstrates a high degree of generalizability and robustness, due to the usage of different platforms and control group.

On the other hand, there are two main limitations in this study. First, the validity of the PO-IAT was not thoroughly investigated. Costantini et al. (2019) recently developed this version of the IAT to measure implicit PO and found that the items had high internal consistency. Besides that, convergent validity with explicit PO and related constructs was good. However, implicit and explicit measures do not always correlate (Kurdi et al., 2021; Krause et al., 2011), and it remains unclear whether the measured response latencies reflect implicit PO bias. Second, the language used in this study can be considered a limitation. English was chosen because it is the teaching language at the University of Twente, thereby enabling participation from all university students. However, the demographics show that most participants were from Germany and the Netherlands. This suggests that English is not their native language. Previous research has shown that the effect of biases, including PO, is diminished when using a foreign language (Zhang et al., 2022). This limitation influences both measurement outcomes and training effects. Consequently, interventions aimed at enhancing self-protective mechanisms may be more effective if delivered in participants' native language.

Practical Implications

There are also two practical implications. First, in addition to regular treatments, the current CBM training could be used by (mental) health professionals to treat patients with depressive symptoms. Patients with depressive symptoms are expected to benefit from the current CBM training, as implicit PO was found to correlate with depressive symptoms (Costantini et al., 2019). However, the current CBM training only has a marginally significant effect on implicit PO. Therefore, a pilot study, in which the current CBM training is combined with regular treatments, is suggested to investigate the effects on implicit PO and depressive symptoms. Second, a mobile CBM training, using the attention paradigm instead of the PO self-concept bias, could be used as an intervention to reduce stress amongst students. This is because CBM training with the attention paradigm was found to significantly reduce the perceived stress levels of students (Dandeneau et al., 2007). This reduction in perceived stress levels of students improves their mental and physical well-being, as well as their academic performance (Pascoe et al., 2020; Shankar & Park, 2016). Study advisors and school psychologists could, therefore, recommend the mobile CBM training using the attention paradigm to students with stress complaints.

Conclusion

In summary, this study investigated the effect of CBM training on students' perceived stress levels and implicit PO, as well as the mediating role of implicit PO and the moderating role of baseline implicit PO. The results showed a marginally significant improvement in implicit PO, which suggests that CBM training in the TIIM App may be beneficial for enhancing the implicit PO levels of students. However, future research is needed to explore the effectiveness in different samples, including postponed or additional post-tests and stressful situations. Moreover, a pilot study, in which the current CBM training is combined with regular treatments, is suggested to investigate the effects on implicit PO and depressive symptoms. Furthermore, a mobile CBM training, using the attention paradigm instead of the PO self-concept bias, could be developed and tested as an intervention to reduce stress amongst students.

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Appendix

Appendix A: Informed Consent Form

Welcome.

You have been invited to participate in a study about the use of the mobile eHealth Application IVY as a tool to increase Positive Orientation in students. Positive orientation is the ability to have a positive view of yourself and your future. The purpose of this research is to gather insight into the current level of Positive Orientation of students and the effect of the IVY Application on Positive Orientation. Besides that, we are interested in the effect of the app on other aspects of mental well-being. The participants are distributed in two groups. Group 1 will be asked to answer the questionnaires twice, which will take approximately 90 minutes in total. Group 2 will be asked to answer questionnaires twice and additionally, use the IVY Application for 3 days in a row. This will take approximately 120 minutes in total. To inform you which group you are in, we will contact you by your given mail address. This study is conducted by the students Aishe Bingöl, Laureen Lhotak, Romy Nijhuis and Lytske Wijma from the Faculty of Behavioural, Management and Social Sciences at the University of Twente.

This research has been reviewed and approved by the BMS Ethics Committee/domain Humanities & Social Sciences. There are minimal burdens and risks associated with participation in this study. Filling in the questionnaires is not likely to cause any psychological discomfort. However, participants might experience some technical difficulties. These difficulties are minimised by having performed pilot tests with different phones beforehand. Besides that, participants can contact the researchers when experiencing troubles with the app.

Your participation in this study is entirely voluntary and you are allowed to withdraw at any time during the process without any negative consequences, and without providing any reasons. Additionally, you are free to ask any questions. During your participation in this study, you may be asked questions that you may experience as (very) personal. You are free to refuse to answer any questions you do not feel comfortable answering.

The nature and purpose of this study, including the data collection, are for educational purposes only. In order to obtain a clear picture of the participant sample of this study, you will be asked certain questions about your demographic information. The data that is gathered will be handled anonymously and stored in a folder that only the researchers of this study can access. The data will be deleted after the final report is submitted.

Study contact details for further information:

Name Researcher	*E-mail*
Aishe Bingöl	
Laureen Lhotak	
Romy Nijhuis	
Lytske Wijma	
Marcel Pieterse (supervisor)	

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-bms@utwente.nl

- I hereby confirm that I am 18 years old or older and have read and understood the information. My participation in this study is voluntary.
- No, I do not consent and will not participate in the study.

Appendix B: List of Stimuli Used in the Experiment

List of Positive Stimuli for Category 'Positivity'

- High esteem
- Confident
- Happy
- Satisfied
- Positive
- Optimistic

List of Negative Stimuli for Category 'Negativity'

- Low esteem
- Insecure
- Unhappy
- Dissatisfied
- Negative
- Pessimistic

List of Pronouns for Category 'Me'

- I
- Me
- Myself
- Mine

List of Pronouns for Category 'Others'

- Others
- Them
- They
- Their

Appendix C: Perceived Stress Scale-10

Figure 1

Items of the Perceived Stress Scale-10 as shown on the SoSci website

The questions in this scale ask you about your feelings and thoughts during the last days.
In each case, you will be asked to indicate by checking the box how often you felt or thought a certain way

In the last days, ...	**Never**	**Almost Never**	**Sometimes**	**Fairly Often**	**Very Often**
... how often have you been upset because of something that happened unexpectedly?	○	○	○	○	○
... how often have you felt that you were unable to control the important things in your life?	○	○	○	○	○
... how often have you felt nervous and "stressed"?	○	○	○	○	○
... how often have you felt confident about your ability to handle your personal problems?	○	○	○	○	○
... how often have you felt that things were going your way?	○	○	○	○	○
... how often have you found that you could not cope with all the things that you had to do?	○	○	○	○	○
... how often have you been able to control irritations in your life?	○	○	○	○	○
... how often have you felt that you were on top of things?	○	○	○	○	○
... how often have you been angered because of things that were outside of your control?	○	○	○	○	○
... how often have you felt difficulties were piling up so high that you could not overcome them?	○	○	○	○	○

Appendix D: Assumptions of Hypotheses

Assumptions hypothesis 1

The assumptions of hypothesis 1 were checked. The results are shown in Table 1 to 5 and Figure 2.

Table 1

Output Shapiro-Wilk test of normality for hypothesis 1

Treatment	Measurement	Variable	Statistic	*p*
0	*D*-score pre-test	Score	0.97	.811
1	*D*-score pre-test	Score	0.97	.503
0	*D*-score post-test	Score	0.92	.198
1	*D*-score post-test	score	0.96	.522

Note. Treatment 1 = intervention group, 0 = control group. If $p < .05$, the assumption of normality is violated.

Figure 2

QQ-plot to test normality for hypothesis 1

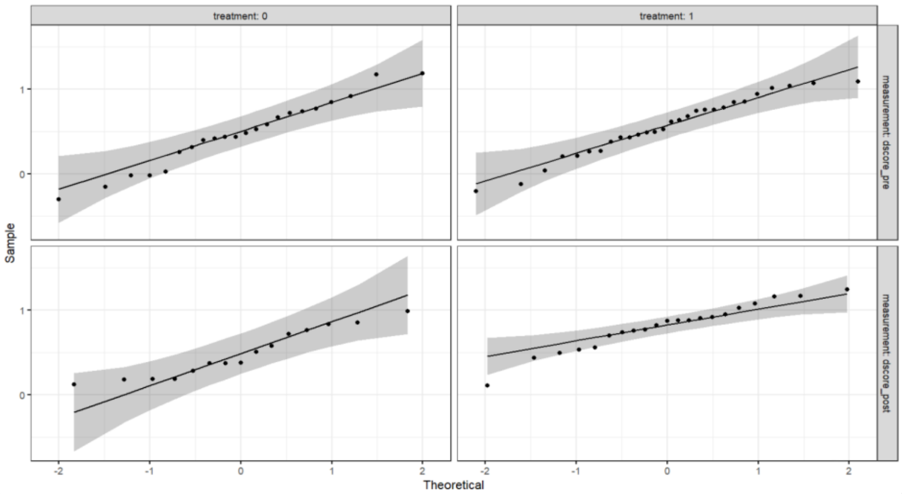


Table 2

Output Levene's test of homogeneity of variance for hypothesis 1

Measurement	Df1	Df2	Statistic	*p*
D-score pre-test	1	48	0.17	.681
D-score post-test	1	34	0.27	.609

Note. If $p < .05$, the assumption of homogeneity of variance is violated.

Table 3

Output Box's test of equality of covariance for hypothesis 1

Statistic	*p*	Parameter	Method
0.01	.915	1	Box's M-test

Note. If $p < .05$, the assumption of homogeneity of covariance is violated.

Table 4

Output Mauchly's test of sphericity for hypothesis 1

Effect	DFn	DFd	SSn	SSd	*F*	*p*	ges
Intercept	1	34	26.57	4.69	192.54	<.001*	.79
Treatment	1	34	0.71	4.69	5.16	.030*	.09
Time	1	34	0.08	2.53	1.03	.317	.01
Treatment:time	1	34	0.25	2.53	3.35	.076	.03

Note. If $p < .05$, the assumption of sphericity is violated.

Table 5

Table with outliers and extremes in hypothesis 1

Treatment	Measurement	Score	Outlier	Extreme
1	*D*-score post-test	0.11	true	false

Note. There is one outlier; no extremes.

Assumptions hypothesis 2

The assumptions of hypothesis 2 were checked. The results are shown in Table 6 to 9 and Figure 3.

Table 6

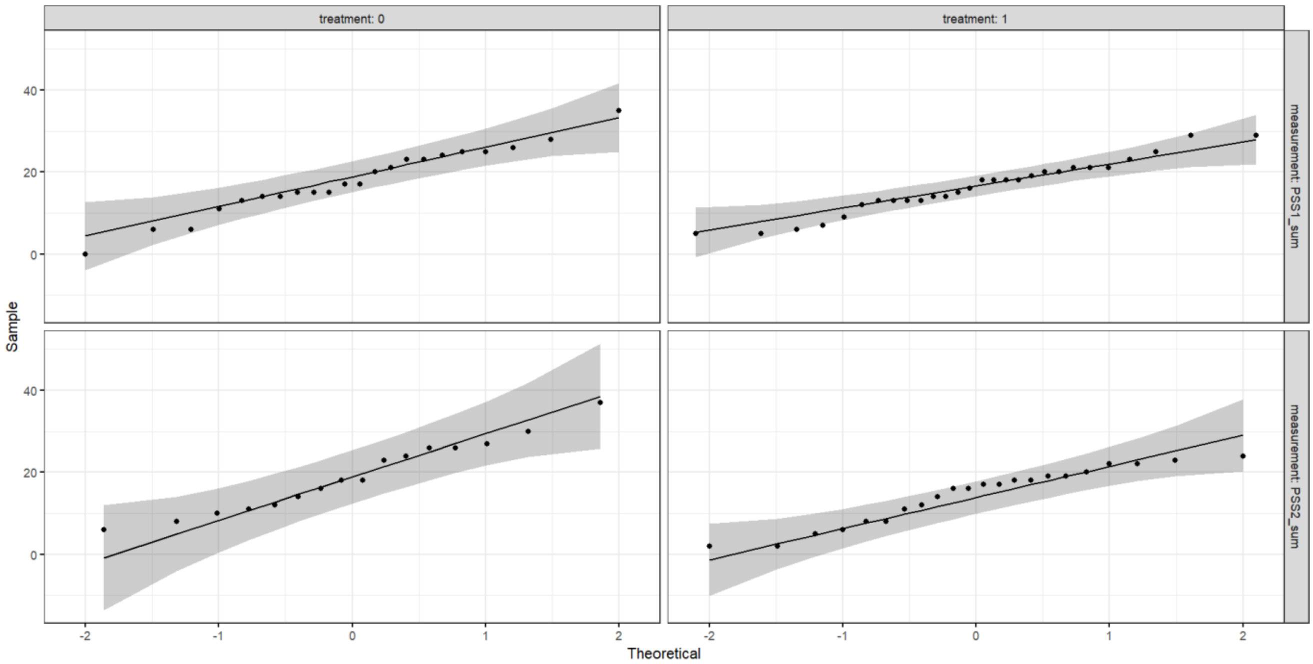
Output Shapiro-Wilk test of normality for hypothesis 2

Treatment	Measurement	Variable	Statistic	*p*
0	PSS-10 pre-test	Score	0.98	.907
1	PSS-10 pre-test	Score	0.97	.477
0	PSS-10 post-test	Score	0.96	.737
1	PSS-10 post-test	score	0.93	.115

Note. Treatment 1 = intervention group, 0 = control group. If p < .05, the assumption of normality is violated.

Figure 3

QQ-plot to test normality for hypothesis 2



Note. Treatment 1 = intervention group, 0 = control group.

Table 7

Output Levene's test of homogeneity of variance for hypothesis 2

Measurement	Df1	Df2	Statistic	*p*
PSS-10 pre-test	1	48	0.99	.325
PSS-10 post-test	1	36	1.49	.230

Note. If $p < .05$, the assumption of homogeneity of variance is violated.

Table 8

Output Box's test of equality of covariance for hypothesis 2

Statistic	*p*	Parameter	Method
3.86	.050	1	Box's M-test

Note. If $p < .05$, the assumption of homogeneity of covariance is violated.

Table 9

Output Mauchly's test of sphericity for hypothesis 2

Effect	DFn	DFd	SSn	SSd	*F*	*p*	ges
Intercept	1	36	2120.22	3617.41	211.00	<.001*	.84
Treatment	1	36	284.75	3617.41	2.83	.100	.06
Time	1	36	0.78	368.91	0.08	.785	<.01
Treatment:time	1	36	9.20	368.91	0.90	.350	<.01

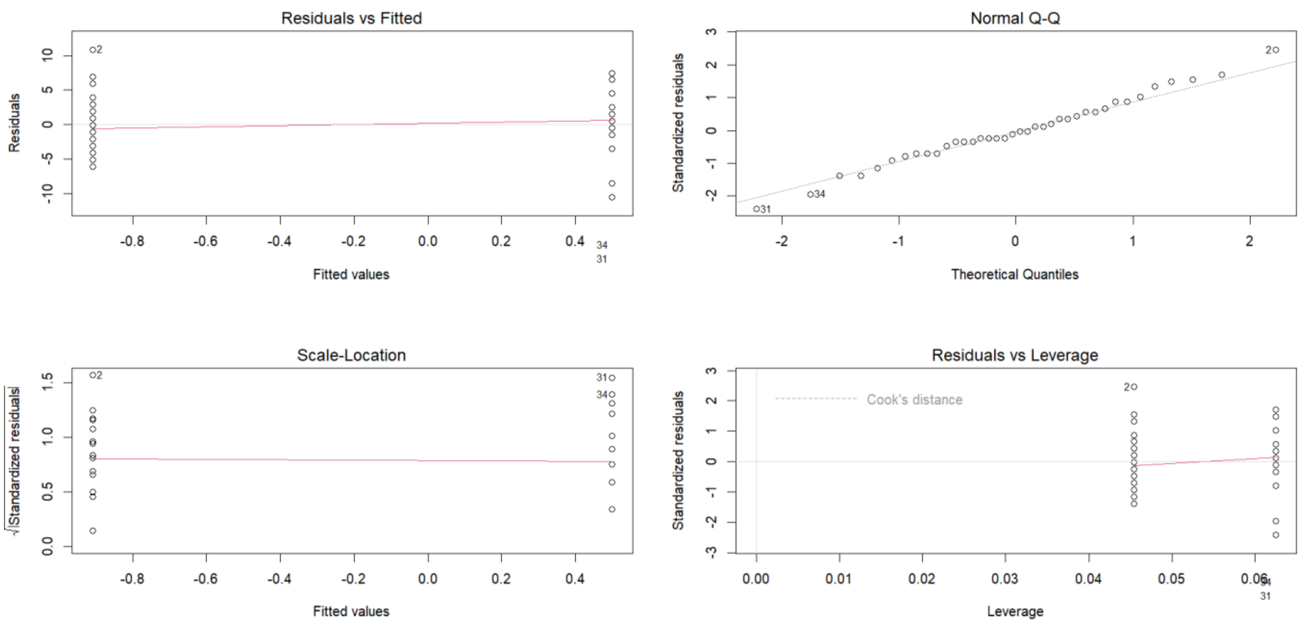
Note. If $p < .05$, the assumption of sphericity is violated.

Assumptions hypothesis 3

The assumptions of hypothesis 3 were checked. The results are shown in Figure 4.

Figure 4

Regression plot 'treatment' and 'change in D*-score' for hypothesis 3*



Assumptions hypothesis 4

The assumptions of hypothesis 4 were checked. The results are shown in Figure 5.

Figure 5

Regression plot 'change in PSS-10 score', 'baseline implicit PO', 'treatment' and the interaction term for hypothesis 4