Investigating the Effectiveness of IVY+: Combining Implicit Cognitive Bias Modification with Explicit Sleep Hygiene Training to Decrease Fatigue in University Students

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Abstract

Background: Fatigue is a widespread health problem significantly impairing individuals' daily lives and well-being. Attention is directed to the role of a fatigue self-concept bias in maintaining fatigue. Recent evidence supports the effectiveness of cognitive bias modification (CBM) in correcting such cognitive bias. The Dual Process Model and empirical evidence endorse the additional value of combining CBM with an explicit method to decrease fatigue.

Objective: The present study aimed to investigate the effectiveness of combining implicit CBM with explicit sleep hygiene training to decrease implicit and explicit fatigue in university students.

Methods: This semi-experimental pretest-posttest design study included university students (n = 27) from Germany and the Netherlands. Outcomes on implicit fatigue self-concept bias (IAT), explicit fatigue self-report (CIS), and sleep quality self-report (SQS) were assessed at baseline and directly after the 5-day IVY+ eHealth intervention. Paired sample t-tests (or Wilcoxon signed rank tests) were conducted to determine the differences between pre- and post-test scores.

Results: The results indicate significant reductions in fatigue self-concept bias (p = .001) and fatigue self-report (p = .012) after completion of the IVY+ intervention. No difference was found between pre- and post-scores on sleep quality (p =.302).

Conclusions: The findings show that IVY+ effectively decreased implicit and explicit fatigue. The study provides support for a combined implicit-explicit approach to target fatigue comprehensively. This small-scale study provides a starting point for future research to explore the effectiveness of combined intervention approaches for fatigue and other mental health issues.

Keywords: cognitive bias modification, implicit fatigue, explicit fatigue, self-concept bias, dual process model, sleep hygiene, sleep quality

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Introduction

Feelings of tiredness, weakness, and exhaustion are experiences that nearly everyone occasionally encounters, especially after a long workday or intense workout. In most cases, such fatigue symptoms are of short duration, representing a protective physiological response to safeguard against overexertion (Jason et al., 2010). But fatigue can also manifest more concerningly, presenting itself as a pathological health condition. In this regard, symptoms are experienced with greater intensity and extended duration, persisting for a minimum of one month (prolonged fatigue) or even for more than six months (chronic fatigue) (Jason et al., 2010). Ream and Richardson (1996) define fatigue as a “subjective, unpleasant symptom which incorporates total body feelings ranging from tiredness to exhaustion creating an unrelenting overall condition which interferes with individuals’ ability to function to their normal capacity” (p. 527). Persistent fatigue strains the lives of many individuals by interfering with daily activities concerned with employment, mobility, social life, and housework (Theander & Unosson, 2004).

Pathological fatigue is a global healthcare problem. Approximately 5-20% of the general population experience persistent fatigue. In primary care, fatigue complaints constitute 5-10% of all presentations (Connolly et al., 2013). Its prolonged appearance has especially been recognised as a main symptom in medical and psychiatric conditions (e.g., cancer, inflammatory rheumatic diseases, and depression) (Davies et al., 2021; Ma et al., 2020). However, enduring fatigue symptoms are also commonly experienced among healthy individuals in relation to lifestyle factors such as disturbed or inadequate sleep, high workload, and lack of physical activity (Caldwell et al., 2019; Frederick et al., 2022; Galland-Decker et al., 2019). Fatigue can be considered a silent enemy undermining individuals’ potential to perform best at school, work, and everyday life, causing continuous frustration in those suffering from it.

Fatigue in University Students

The prevalence of fatigue in university students has raised concern. Approximately half of the Dutch university students suffered from psychological complaints during their studies in 2013, with fatigue, stress, and depression being the most commonly addressed (Landelijke Studentenvakbond, 2013). This number is anticipated to rise further (de Vries et al., 2016). Fatigue is strongly associated with stress (Doerr et al., 2015), sleep quality (Kangas & Montgomery, 2011), and depression (Shim et al., 2018). Especially, periods of high academic stress, such as finals, are critical in prompting fatigue symptoms (Dittner et al., 2011; Doerr et al., 2015; Holm-Hadulla et al., 2021). Fatigue can negatively impact students' academic performance and overall well-being. Students may be restricted in their cognitive ability, making it harder to focus, absorb information, remember studied materials, and think critically (Ryan et al., 2007; Smith, 2018). The high prevalence of fatigue in university students and its negative consequences raise the urge to intervene.

Cognitive Biases and Illness Self-Concept

While the experience of fatigue symptoms generally arises from a complex interplay of biological, psychological, and socio-environmental factors, Hughes et al. (2016) specifically emphasise the role of illness representations, which are individuals' beliefs about their illness. Conscious and unconscious beliefs drive illness representations. Implicitly, negative illness representations may perpetuate symptoms by influencing how they are perceived and interpreted (Hughes et al., 2016). Such distortions in information processing are cognitive biases that operate beneath conscious awareness, unknowingly altering one's cognitions (Orbell & Phillips, 2018). Advances in implicit measurement techniques allow for examining automatic processes that occur outside of awareness and are not purposively provided. The Implicit Association Test developed by Greenwald et al. (1998) is the most popular implicit measurement instrument (Znanewitz et al., 2018). It can reveal cognitive biases by assessing the strength of mental associations between concepts in memory (Greenwald et al., 1998).

Numerous studies have found evidence for cognitive biases toward illness-related information in the context of fatigue (Hughes et al., 2017; Moss-Morris, 2003; Orbell & Phillips, 2018). For instance, Hughes et al. (2017) found that individuals with chronic fatigue syndrome showed an attentional bias for fatigue-related information and were more inclined to interpret ambiguous terms in a fatigue-related way compared to healthy controls. Consequently, such attentional and interpretative biases reinforce dysfunctional illness beliefs, maintaining and intensifying fatigue symptoms (Hughes et al., 2017).

Likewise, fatigued individuals may be at risk of developing a fatigue self-concept bias, which describes the extent to which one's self-concept is enmeshed with illness symptoms (Van Bulck et al., 2018). In this case, one is more likely to associate fatigue characteristics such as "tired" and "weak" with the self. Drawing on cognitive science, cognitive processes are guided by schemata, which are mental structures that help organise and interpret knowledge by categorising objects and events according to shared aspects. The Schema Enmeshment Model of pain proposes that the simultaneous activation of illness-, symptom-, and self-schemata results in enmeshment of such schemata, consequently leading to a bias in the way that somatic experiences are overly seen as a part of the self (Pincus & Morley, 2001). Assuming that this model is equally applicable to fatigue, individuals may come to label themselves as fatigued. Consequently, this can lead to an intensified perception of fatigue symptoms, which might foster counterproductive resting behaviours that subsequently contribute to the experience of more symptoms of fatigue. Thus, due to self-imposed limitations, feelings of fatigue may endure long after initial stressors have subsided. This counterproductive cycle of cognitions and behaviours may be overcome through Cognitive Bias Modification (CBM) training.

CBM and IVY

CBM is a promising approach to modifying the implicit fatigue self-concept bias. It seeks to directly interfere with implicitly activated cognitive processes by asking individuals to repeatedly perform simple tasks. These tasks function by counteracting existing biases and replacing them with more favourable thinking patterns. The repeated practice of such tasks strengthens the manifestation of recently acquired responses in place of previous, maladaptive ones (Koster et al., 2009). It is expected that CBM can directly alter cognition and thereby may indirectly decrease fatigue symptoms (Wells & Beevers, 2010). Training in CBM seems particularly promising for treating addictions (Kakoschke et al., 2017; Wiers et al., 2011) and has also been considered beneficial in reducing anxiety (Mobini et al., 2012) and depression (Becker et al., 2019; Vrijsen et al., 2018).

The recently designed eHealth app “IVY” uses CBM for self-concept bias modification. IVY aims to decrease fatigue by targeting two mechanisms. While an implicit association test paradigm intends to recondition unconscious associations between mental representations in memory, an approach-avoidance paradigm adds an active embodiment function. In the daily training, users develop action tendencies by swiping vitality-associated words down and thereby towards the body (approach mechanism) and swiping fatigue-associated words up and thereby away from the body (avoidance mechanism). A zooming effect is implemented by enlarging words when swiped downward and decreasing them when swiped upward, further enhancing approach-avoidance sensations (Wiers et al., 2011). In this way, IVY aims to strengthen mental associations between the self and words like “fit” and weaken associations between the self and words like “weak”.

Next to decreasing the implicit fatigue self-concept bias, IVY also focuses on strengthening a vitality-related self-concept. The underlying notion is that a self-concept focused on vitality might function as a buffer to mitigate or even offset symptoms of fatigue.

Studies have recognised the potential of vitality to operate as a fatigue resilience mechanism through which symptoms of fatigue may not only be decreased but may even prevent symptoms from developing in the future (Martin-Cuellar et al., 2019). Hence, next to reducing the fatigue self-concept bias, strengthening a vitality-related self-concept seems beneficial in creating more robust self-concept modifications. Training with IVY seems promising, as preliminary results demonstrate effects in decreasing implicit fatigue self-concept bias in breast cancer patients (Geerts et al., 2022). Additionally, a modification in the implicit fatigue self-concept bias is expected to reduce self-reported fatigue. However, this effect has not yet been shown (Geerts et al., 2022).

Dual Process Model and Empirical Evidence

The fact that IVY targets implicit processes of human functioning is a major advancement compared to more traditional intervention methods. For now, the function of the CBM training within IVY is to modify the implicit fatigue self-concept bias to ultimately decrease fatigue symptoms. As no effect of fatigue self-concept bias modification on fatigue self-report has been found yet (Geerts et al., 2022), it can be questioned whether solely intervening on an implicit level is enough to decrease fatigue symptoms. Forscher et al. (2019) call for caution in presuming that interventions exclusively changing implicit biases will translate into the desired changes in explicit measures or behaviour. Lacking proof of a direct impact of CBM on fatigue self-report warrants a broader perspective on mechanisms of human cognition.

Accordingly, the Dual Process Model highlights that human cognition is controlled by two systems following distinct operational principles. The impulsive system operates on an unconscious level and uses associative links in memory and mental shortcuts for guidance. It is fast, effortless, and automatic. It functions outside of conscious awareness and is prone to biases and errors. IVY training focuses on this system by weakening associative links between “fatigue” and the “self”, thereby targeting the unconscious self-concept. Meanwhile, the reflective system operates on a conscious level and uses syllogistic rules and causal attributions to elicit an informed decision. It is slow, effortful, and deliberate (Strack & Deutsch, 2004). Strack & Deutsch (2004) argue that the two systems should not be regarded in isolation; rather they are mutually interacting systems possibly cooperating or conflicting with each other.

The findings of Asendorpf et al. (2002) contradict the claim of a mutual interaction between the systems. Building on the Dual Process Model, they suggest that individuals have an implicit personality self-concept and an explicit personality self-concept, with the former being associated with the impulsive system and spontaneous behaviour, and the latter being associated with the reflective system and controlled behaviour. In their study, Asendorpf et al. (2002) examined the relationship between explicit and implicit measures of personality self-concepts and their ability to predict behaviour. Their findings support a double dissociation between spontaneous behaviour and controlled behaviour, which indicates that a change in the implicit self-concept uniquely impacts spontaneous behaviour, whereas a change in the explicit self-concept uniquely impacts controlled behaviour (Asendorpf et al., 2002).

Amidst conflicting findings on the interconnectivity of the impulsive and reflective system (Asendorpf et al., 2002; Strack & Deutsch, 2004), the Dual Process Model suggests that both the impulsive as well as the reflective system need to be considered to address the whole range of factors influencing cognition. While only altering associative links in the impulsive system may produce imbalances with conscious intentions from the reflective system, aligning the two systems can bring added value. Theoretically, it is proposed that compatible impulsive and reflective processes facilitate the activation of schemata and subsequent behaviour. Furthermore, less cognitive effort may be required to control and promote desirable cognitions and behaviours (Strack & Deutsch, 2004). Drawing from empirical evidence, Wiers et al. (2011) administered CBM training as an adjunct to regular alcohol use disorder treatment. They found improved clinical outcomes in comparison to patients only receiving regular treatment or placebo training. Wiers et al. (2011) described addictive behaviours as being controlled by an imbalance between impulsive reactions to alcohol-related cues and reflective processes, making individuals susceptible to alcohol-reaching impulses. This might be especially true in emotionally charged situations, leaving little room for controlled and reflective decisions. Their findings suggest that the CBM training helped to establish a balance between impulsive and reflective processes. Speculating on the working mechanism underlying the improved clinical outcomes, the authors further hypothesised that CBM increased the benefits patients acquired from other treatment components (Wiers et al., 2011).

Similarly, a combined intervention targeting impulsive and reflective processes might be valuable in inducing sustained changes for fatigue management. While the CBM training within IVY seems promising in decreasing unconscious fatigue self-concept, it can be assumed that individuals might not be consciously aware of the changes. Conscious, reflective fatigue-inducing decisions may persist, possibly creating a conflict between impulsive and reflective processes. By establishing coherence between unconscious self-concept associations and conscious decisional processes, fatigue-resisting cognitions and behaviours are enhanced. Practically, this could be achieved by complementing the CBM training with an explicit technique involving conscious and intentional tasks.

Combining CBM Training with Sleep Hygiene Activities

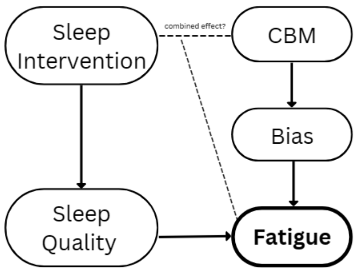
The reviewed literature sheds light on promising effects of combining IVY training with explicit methods to decrease fatigue. Next, research on user experience further supports the combined implicit and explicit intervention approach. Accordingly, Pooth (2020) investigated the suitability of combining implicit and explicit methods in eHealth interventions and reported overall favourable user perceptions. Following Pooth's (2020) suggestion to test the effectiveness of combined implicit and explicit methods empirically, this study aims to investigate the effectiveness of the CBM training in combination with explicit sleep hygiene training. While there are various ways to add an explicit intervention component to IVY, sleep hygiene training has been chosen due to its straightforwardness and easy implementation. The previously described IVY application is complemented with sleep hygiene modules (IVY+).

Poor sleep quality has been recognised as the most significant lifestyle factor contributing to fatigue in healthy individuals among different populations (Caldwell et al., 2019; Kangas & Montgomery, 2011; Samaha et al., 2007). Poor sleep is often related to poor sleep hygiene, which constitutes "a set of behavioral and environmental recommendations intended to promote healthy sleep" (Irish et al., 2015, p.23), such as creating a comfortable sleep environment, exercising regularly, and managing alcohol and caffeine consumption (Caldwell et al., 2019). While poor sleep health is a widely recognised public health issue, sleep problems are particularly prominent among university students (Becker et al., 2018). Disrupted sleep patterns are a common issue among students, as their lives are often characterised by the conflicting demands of following their academic pursuits while still maintaining an active student life. Consequently, students seem tempted to sacrifice sleep to study, stay updated on social media platforms, or attend late-night activities, often implying the consumption of alcohol (Dietrich et al., 2016). Several of these behaviours interfere with establishing healthy sleep patterns, as they are inconsistent with sleep hygiene practices. Interventions that explicitly educate students about sleep hygiene and guide them to enact these behaviours actively have been found to facilitate sleep quality (Brown et al., 2002; Brown et al., 2006; Dietrich et al., 2016; Zengin & Aylaz, 2019).

The sleep hygiene training for this study consists of several small activities that participants are asked to complete each day (e.g., going for a walk, shutting off electronic devices before bedtime) (Al-Kandari et al., 2017; Hewlett et al., 2019; Spahrkäs et al., 2020). To ensure a smooth integration of the sleep hygiene training to IVY, the sequences of the CBM training and sleep hygiene training are timed, resulting in a 5-day intervention consisting of one CBM training module and one sleep hygiene activity module each day. Both are integrated into the IVY+ application. Figure 1 represents the proposed theoretical model underlying the IVY+ intervention.

Figure 1

The Proposed Theoretical Model Underlying IVY+



Present Study

The purpose of this study is to investigate the effectiveness of the fatigue intervention IVY+. The original IVY intervention, exclusively comprising CBM training, effectively reduced individuals' fatigue self-concept bias. Contrary to predictions, no spill-over effect on explicit fatigue has been demonstrated (Geerts et al., 2022). Deriving from the Dual Process Model and empirical evidence, a combined implicit and explicit intervention approach may have added value. This is tested in the present study by comparing participants' scores on implicit fatigue and explicit fatigue before and after the IVY+ intervention. To further assess the specific impact of sleep hygiene training, the effect of the IVY+ intervention on participants' self-reported sleep quality is examined. By targeting both impulsive and reflective processes, IVY+ has the potential to comprehensively address the full range of mechanisms underlying fatigue. The results of the study will give special insights into the effectiveness of integrating CBM and sleep training in a fatigue intervention. In a more general sense, this study may have practical implications for combined implicit-explicit interventions.

Based on the provided background, the following research questions and corresponding hypotheses are investigated in this research:

RQ1: Is there an effect of the IVY+ intervention on students' implicit fatigue self-concept bias?

H1: There is a significant reduction in students' implicit fatigue self-concept bias between pre- and post-assessment measured with the IAT.

RQ2: Is there an effect of the IVY+ intervention on students' explicit fatigue self-report?

H2: There is a significant reduction in students' explicit fatigue self-report between pre- and post-assessment measured with the IAT.

RQ3: Is there an effect of the IVY+ intervention on students' sleep quality self-report?

H3: There is a significant increase in students' sleep quality self-report between pre- and post-assessment measured with the SQS.

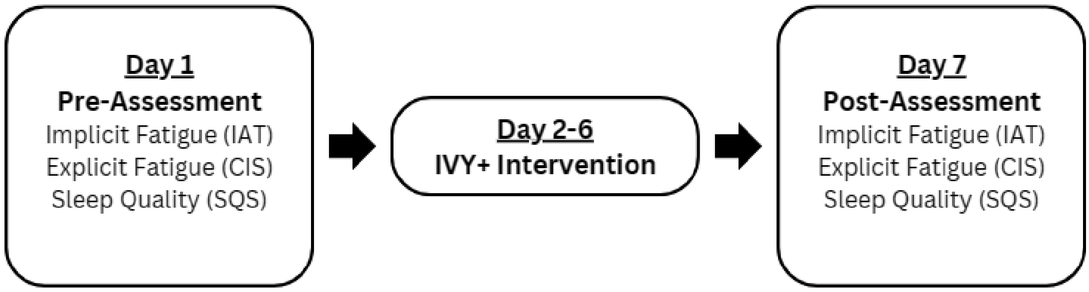
Methods

Design

A semi-experimental pretest-posttest design was employed. The study consisted of a pre-assessment, the 5-day IVY+ intervention, and a post-assessment (see Figure 2). The effect of the IVY+ intervention on the dependent variables implicit fatigue, explicit fatigue, and sleep quality was measured with the Implicit Association Test (IAT), Checklist Individual Strength (CIS), and Sleep Quality Scale (SQS), respectively.

Figure 2

Overview of the Study Design



Participants

Participants were recruited via convenience sampling by spreading the study throughout the researcher's network (via WhatsApp and e-mail). Inclusion criteria were being an adult (≥ 18 years), having a good command of the English language, and being a university student. Furthermore, a smartphone was required to access IVY+ through the TIIM application, and a computer or laptop was needed to complete the pre- and post-assessment. 11 participants were excluded from the study as they did not finish the entire intervention or due to errors in the IAT, resulting in a total of 27 participants in the final sample. The sample consisted of 19 (70.37%) females and 8 (29.63%) males. Respondents were aged between 18 and 32 years, with a mean age of 22.07. One participant was Dutch, and the remaining 26 participants were German. All participants were university students, with 8 of them pursuing a study programme in psychology and the other participants following programmes related to business, medicine, engineering, and a range of other fields. This study was approved by the BMS Ethics Committee at the University of Twente (230394).

Materials

Pre- and post-assessment

For the pre- and post-assessment, two surveys were created with the software SoSci survey (https://www.soscisurvey.de), both consisting of the IAT, CIS, and SQS.

Implicit Association Test. The Implicit Association Test (IAT) measured implicit fatigue self-concept bias. Generally, an IAT consists of a computerised word-sorting task asking participants to assign a word as quickly and accurately as possible to one category pair by pressing one of two predetermined keys on the computer. Four different categories are usually presented from which two are assigned to a specific response key, forming the category pairs. The task consists of several blocks with varying category pairs assigned to the same response key. The underlying assumption is that individuals can respond faster to pairs of categories closely associated in their minds compared to less associated pairs. Hence, a faster response time indicates stronger mental associations (Greenwald et al., 1998). The IAT is the most commonly used indirect instrument to measure implicit self-concept (De Cuyper et al., 2017). The psychometric quality of the IAT is under debate. Hofmann & Schmitt (2008) report high internal consistency (α around .80) and modest test-retest reliability (r around .55). Using a Spearman-Brown correction, Houwer & Bruycker (2007) found a split-half reliability of $r = .88$ (in this study $r = .59$). Furthermore, low discriminant, convergent, and construct validity have been repeatedly mentioned (Schimmack, 2019). Nevertheless, other evidence supports the use of IATs for assessing implicit self-concepts (Suslow et al., 2014).

As the IAT is flexible in its application, it was adapted to measure implicit fatigue self-concept bias. In this regard, IAT scores demonstrated the extent to which individuals associated themselves more with fatigue or vitality. Specifically, two attribute categories (self and others) and two attitude categories (fatigue and vitality) were presented. The IAT consisted of seven blocks in total, comprising five practice blocks and two test blocks (block 4, block 7). See Table A1 for a detailed overview of all blocks and corresponding attitude and attribute category pairs. One by one, words such as “me”, “them”, “exhausted”, and “fit” appeared in the middle of the screen and needed to be assigned to the corresponding category. See Table A2 for a list of all words-to-be-assigned. Words belonging to a category on the left needed to be assigned using the response key ‘E’, while words belonging to a category on the right needed to be assigned using the response key ‘I’. Based on the average response times on the two test blocks (block 4, block 7), improved D-scores were calculated according to Greenwald et al. (2003). Scores could range between -2 and +2. Negative values indicated a stronger self-association with vitality-related words and hence a vitality bias (< 0), while positive values indicated a stronger self-association with fatigue-related words and hence a fatigue bias (≥ 0) (Greenwald et al., 2003).

Checklist Individual Strength. The CIS was applied to measure explicit fatigue (see Appendix B). It is a multidimensional self-report questionnaire consisting of 20 items scored on a 7-point Likert scale ranging from “yes, that is true” to “no, that is not true”, with respective scores from 1 to 7 for each item response. Four dimensions of fatigue are covered, namely fatigue severity (7 items, e.g., “I feel weak”), concentration (5 items, e.g., “I have trouble concentrating”), motivation (4 items, e.g., “I feel no desire to do anything”), and physical activity (3 items, “I do quite a lot within a day”). After reversing the scores for items 1, 3, 4, 9, 10, 13, 14, 16, 17, 18, and 19, the total score was calculated by summing up the scores of all item responses. Final scores ranged from 20 to 140, with higher scores indicating higher levels of fatigue severity and concentration issues and lower levels of motivation and physical activity. The cut-off score of 76 has frequently been used to classify individuals as fatigued or non-fatigued (Bültmann et al., 2000). The CIS is a reliable and valid questionnaire with high internal consistency with Cronbach’s α of .84-.95 (in this study, Cronbach’s α = .90), high test-retest reliability (r = .74 to .86), and good concurrent, convergent, and discriminant validity (Beurskens, 2000; De Vries, 2003; Worm-Smeitink et al., 2017). Even though the CIS was initially developed to measure chronic fatigue syndrome, it is also applicable to healthy populations (Beurskens, 2000).

Sleep Quality Scale. The SQS assessed participants’ sleep quality before and after the intervention (see Appendix C). It was created by Yi et al. (2008) to evaluate sleep quality of adults in the general population. The questionnaire consists of 28 self-rated items measuring six sleep quality domains: sleep satisfaction, daytime symptoms, problems initiating and maintaining sleep, restoration after sleep, and difficulty waking up. Each item was rated on a

4-point Likert scale that ranged from rarely (None or 1-3 times a month), sometimes (1-2 times a week), often (3-5 times a week), to almost always (6-7 times a week), through which participants specified how frequently they have experienced the specific situation over the past month. As the IVY+ intervention only lasted for five days, this was adapted to the past week. An example item is "I wake up easily because of noise" (item 5). The total score was calculated by assigning scores to the response options ("Rarely" = 0, "Sometimes" = 1, "Often" = 2, "Almost always" = 3) and summing them up according to the individual responses. Items belonging to the domains restoration after sleep and sleep satisfaction (items 2, 8, 13, 16, 18, 20, 27) were reversed before all item scores were summated. Overall scores could fall between 0 to 84, with higher scores indicating lower sleep quality (Yi et al., 2008).

Regarding psychometric properties, the reliability and validity of the SQS have been shown in the general population. The developers of the scale reported high internal consistency with a Cronbach's alpha of α .92 (in this study, Cronbach's $\alpha = .87$), high test-retest reliability ($r = .81$), as well as construct validity ($t = -13.8$, $p = .00$). Furthermore, a significant correlation with the widely used Pittsburgh Sleep Quality Index was observed, confirming the concurrent validity of the SQS (Yi et al., 2006). Studies evaluating the psychometric properties of the SQS in patients with insomnia and depression (Snyder et al., 2018) and in a Turkish student sample (Önder et al., 2016) underline its reliability and validity.

IVY+ Intervention

The IVY+ intervention integrated the CBM training and sleep hygiene training into one platform. It was incorporated in TIIM (University of Twente Intervention and Interaction InstruMent) and is available for IOS and Android.

CBM Training. The CBM training aimed to retrain the implicit fatigue self-concept bias. The 5-day training consisted of one session per day asking participants to swipe fatigue-related words (e.g., exhausted, weak, slow, dull), vitality-related words (e.g., fit, energetic, lively, attentive), self-related words (e.g., my, I, self), and others-related words (e.g., them, another, your) to corresponding poles. The pole at the top of the screen incorporated the categories "fatigued" and "others", while the pole at the bottom of the screen consisted of the categories "vital" and "me". Participants were instructed to swipe fatigue-related words up, and thereby away from the self and towards others, and vitality-related words down, and thereby towards the self. Each training session included 120 stimuli and took approximately three to five minutes. Additionally, participants had access to a "Frequently Asked

Questions" section, giving answers to common questions that could occur throughout the training. See Appendix D for example screens during the training with IVY.

Sleep Hygiene Training. The 5-day sleep hygiene training included daily activities that participants completed throughout the day. Table 1 displays the specific activities included. The activity of the day was communicated via a text section, additionally including a short psychoeducation paragraph explaining the activities' contribution to improved sleep quality and potential risks of counterproductive behaviours to sleep (see Appendix E for detailed descriptions and instructions of the sleep hygiene activities). Lastly, a conclusion session asked participants about their effort to complete the separate activities. They indicated their answer on a number slider, ranging from 1 to 10. The training finished by thanking the participants for their participation.

Table 1

Sleep Hygiene Activities

Number	**Activity**
Activity 1	Read Information about sleep hygiene
Activity 2	Go for a 20-minute walk
Activity 3	Watch and follow the guided muscle relaxation video
Activity 4	Shut off electronic devices 1 hour before bed and instead read, stretch, take a hot shower
Activity 5	Exercise for 30 minutes

Procedure

Individuals were invited to participate in the study by being personally contacted by the researcher. Participants received a link via e-mail that referred them to the web-based survey tool SoSci. Participants were briefly introduced to the study and given information on what participation entails. Before the actual start of the study, they were asked to give their consent to take part, which they could withdraw at any time (see Appendix F). After that, participants answered demographic questions on gender, age, nationality, and study programme. Then subjects proceeded with the pre-assessment, which included the completion of the CIS, SQS, and IAT. After completing the pre-assessment, they were given more information about the procedure of the upcoming days via e-mail. Participants were asked to download the TIIM application and were given the code to access the IVY+ intervention. The next five days comprised the actual training with IVY+. Each day in the morning, around 9 am, participants received two messages from TIIM on their phones notifying them to complete both the CBM training and the sleep hygiene training for the day. After the 5-day intervention, participants received an e-mail asking them to complete the post-assessment, which once again consisted of completing the CIS, SQS, and IAT.

Data Analysis

All data analyses were conducted using the statistical software RStudio. The dataset was prepared by excluding data with missing values. 27 participants remained, representing the final sample. To get a broad overview of the sample characteristics, descriptive statistics were performed. The mean and standard deviation of the variable age, as well as the frequencies and percentages of the variables gender, nationality, and study programme, were calculated.

In the next step, pre- and post-scores on implicit fatigue, explicit fatigue, and sleep quality were calculated. For the IAT, D-scores were directly calculated by SoSci survey. For the CIS and SQS, reversed-polarity items were first recoded, and then participants' overall sum scores were calculated for the pre- and post-assessment. It was checked for outliers. Next, the overall sample means and standard deviations of the IAT, CIS, and SQS were calculated, for the pre- and post-assessment, respectively. Furthermore, the difference scores between pre- and post-test were computed.

Individual baseline scores were categorised into two groups, for each primary outcome distinctively. For the IAT, participants were grouped into vitality bias baseline (< 0) and fatigue bias baseline (≥ 0). Regarding the CIS, participants were categorised in low fatigue baseline (< 76) and high fatigue baseline (≥ 76) (Bültmann et al., 2000). As there has not yet been a published norm for categorising the SQS scores, a cut-off score of 42 was chosen to categorise participant scores in high sleep quality (SQ) (< 42) and low sleep quality (SQ) (≥ 42).

The means, standard deviations, and difference scores were calculated for each group. To further regard inter-group changes from pre-to post-measurement, individual shifts between the groups were analysed by checking whether the cut-off scores for group categorisation were surpassed.

The first, second, and third hypotheses were tested by examining the mean difference between the average pre- and post-assessment scores on the IAT, CIS, and SQS, respectively.

First, it was checked whether the data was suitable for the parametric paired sample t-test or whether the non-parametric Wilcoxon signed rank test needed to be conducted. The mean difference was tested with a Wilcoxon signed rank test for the first and second hypotheses. The third hypothesis was tested with a paired sample *t*-test.

In preparation for a post hoc analysis concerning the second hypothesis, participants' difference scores on the IAT were split into bias improvement (≥ 0.25) and bias maintenance (< 0.25). The mean difference in CIS scores in the bias maintenance group was tested with a Wilcoxon signed rank test. The mean difference in CIS scores in the bias improvement group was tested with a Wilcoxon signed rank test and a paired sample- t-test.

Results

Table 2

Descriptives per Baseline Group and of the Overall Sample and p-value of the Overall Sample Differences for Implicit Fatigue, Explicit Fatigue, and Sleep Quality

		Pre-test		**Post-test**		**Mean Difference**	***p***
		M	***SD***	***M***	***SD***		
Implicit Fatigue	Vitality Bias Baseline (*n* = 24)	-0.40	0.28	-0.61	0.30	-0.21	–
	Fatigue Bias Baseline (*n* = 3)	0.28	0.16	-0.73	0.10	-1.01	–
	Total (*n* = 27)	**-0.32**	**0.34**	**-0.62**	**0.29**	**-0.30**	**.001**
Explicit Fatigue	Low Fatigue Baseline (*n* = 17)	60.47	10.67	53.18	15.24	-7.29	–
	High Fatigue Baseline (*n* = 10)	83	6.88	75.70	15.82	-7.30	–
	Total (*n* = 27)	**68.81**	**14.47**	**61.52**	**18.77**	**-7.29**	**.012**
Sleep Quality	High SQ Baseline (*n* = 22)	28.41	6.82	27.23	9.15	-1.18	–
	Low SQ Baseline (*n* = 5)	48.20	7.73	44.80	8.76	-3.40	–
	Total (*n* = 27)	**32.07**	**10.40**	**30.48**	**11.31**	**-1.59**	**.302**

Baseline Groups and Individual Shifts

Individual baseline scores were categorised into two groups, for each primary outcome distinctively. Thereby, the data was simplified, allowing to detect general trends within the sample. Means, standard deviations, and difference scores per baseline groups and of the overall sample for implicit fatigue, explicit fatigue, and sleep quality are displayed in Table 2.

Implicit Fatigue

At baseline, 24 participants were assigned to the vitality bias group (< 0), and 3 participants were assigned to the fatigue bias group (≥ 0). The mean difference between pre- and post-scores for both groups indicated a change towards a vitality bias after the intervention. The change was greater for the fatigue bias baseline group. Regarding individual shifts between the two groups, 3 participants assigned to the fatigue bias baseline group were assigned to the vitality bias group at post-measurement. 1 participant previously assigned to the vitality bias baseline group was assigned to the fatigue bias group at post-measurement. In summary, at pre-test 3 (11.1%) participants were classified as fatigue bias, and at post-test 1 (3.7%) participant was classified as fatigue bias.

Explicit Fatigue

17 participants were assigned to the low fatigue baseline group (<76), while 10 participants were assigned to the high fatigue baseline group (≥ 76). At post-measurement, the scores of both groups decreased toward low fatigue. The post-test mean score of the high fatigue baseline group was slightly below 76, indicating a classification as low fatigue after the intervention, as opposed to before the intervention. Therefore, both groups were classified as low fatigue after the intervention. Concerning individual transitions between the two groups, 5 participants from the high fatigue baseline group were categorised as low fatigue at post-measurement, while 1 participant from the low fatigue baseline group was classified as high fatigue at post-measurement. Conclusively, while 10 (13.2%) participants were classified as high fatigue at pre-test, only 6 (7.9%) participants were classified as high fatigue at post-test.

Sleep Quality

At baseline, 22 participants were allocated to the high sleep quality (SQ) group (< 42), while 5 participants were allocated to the low SQ group (≥ 42). The mean difference between pre- and post-scores for both groups indicated a change towards high SQ at post-test. However, the post-measurement mean score of the low SQ baseline group was above 42, still indicating a classification as low SQ after the intervention. Regarding individual shifts between the two groups, 2 participants assigned to the low SQ baseline group were assigned to the high SQ baseline group at post-test. 1 participant previously assigned to the high SQ baseline group was assigned to the low SQ baseline group at post-test. In summary, at pre-measurement 5 (18.5%) participants were classified as low SQ, and at post-test 4 (14.8%) participants were classified as low SQ.

Hypothesis Testing

The effect of IVY+ on implicit fatigue was tested with a Wilcoxon signed rank test. There was a significant difference between pre-measurement D-scores and post-measurement D-scores, (V = 59, p = .001). D-scores decreased, suggesting a weaker self-association with fatigue-related words after the intervention compared to before the intervention. Therefore, the first hypothesis, which states a significant reduction in students' implicit fatigue bias between pre- and post-assessment measured with the IAT, was accepted.

To determine the effect of IVY+ on explicit fatigue, a Wilcoxon signed rank test was conducted. It showed a significant difference from pre-measurement to post-measurement, (V = 84, p = .012). The mean CIS score decreased, suggesting a reduction in explicit fatigue self-report. As a result, the second hypothesis, stating that there is a significant reduction in students' explicit fatigue between pre- and post-test measured with the CIS, was accepted.

To gain a deeper insight into the relationship between implicit fatigue and explicit fatigue, a post hoc analysis was conducted. It aimed to explore the extent to which the effect of IVY+ on explicit fatigue may vary depending on different bias levels.

14 participants were assigned to the bias improvement group (≥ 0.25), while 13 participants were assigned to the bias maintenance group (< 0.25). Regarding the bias maintenance group, a Wilcoxon signed rank test suggested no significant difference in CIS scores from pre-measurement (M = 71.46, SD = 12.61) to post-measurement (M = 63.77, SD = 17.03), (V = 22, p = .108). Concerning the bias improvement group, a Wilcoxon signed rank test also suggested no significant difference in CIS scores from pre-measurement (M = 66.36, SD = 16.07) to post-measurement (M = 59.43, SD = 20.68), (V = 23, p = .068). However, as the data is on the edge of being normally distributed, a paired sample t-test was additionally conducted, indicating a significant difference in scores from pre-measurement to post-measurement (t (13) = -2.18, p = .048, 95% CI [-13.78, -0.08)). Even though no conclusive judgement on whether the pre- and post-CIS scores are significantly different in

the bias improvement group can be made, the findings suggest a trend for a significant difference.

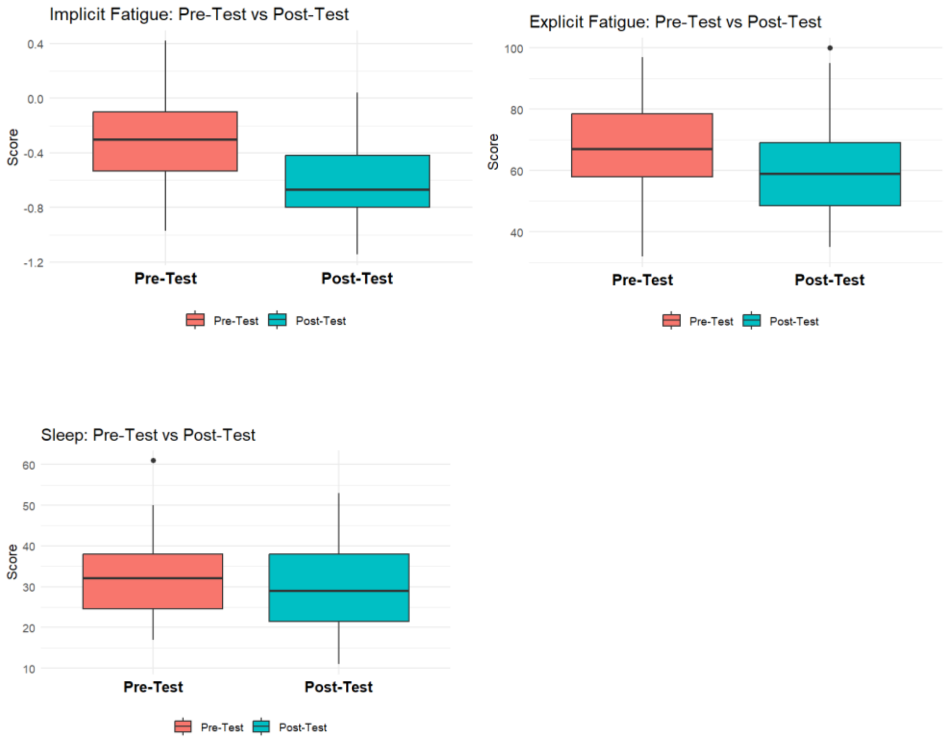
Conclusively, some support was found for the assumption that the effect of IVY+ on explicit fatigue varies depending on the extent to which implicit bias improved. No significant difference in CIS scores between pre- and post-measurement was found in the bias maintenance group, while there are indications for a significant difference in CIS scores in the bias improvement group. This suggests a correlation between the change in implicit fatigue and the change in explicit fatigue.

For the third hypothesis, a paired sample t-test was used to assess the effect of IVY+ on sleep quality. It showed no significant difference between pre-measurement and post-measurement, (t (26) = -1.05, p = .302, 95% CI [-4.7, 1.5])). Therefore, the third hypothesis, stating a significant increase in students' sleep quality self-report between pre- and post-assessment measured with the SQS, was rejected.

In summary, a significant reduction in implicit fatigue bias and explicit fatigue self-report was found from pre-to post-measurement. Post hoc analysis findings indicated that the significant reduction in explicit fatigue correlated with implicit bias improvement. No significant increase in sleep quality self-report was found. The p-values of the pre- and post-differences in implicit fatigue, explicit fatigue, and sleep quality are displayed in Table 2. Figure 3 shows boxplots for the pre- and post-scores in implicit fatigue, explicit fatigue, and sleep quality.

Figure 3

Boxplots for Pre- and Post-Scores in Implicit Fatigue, Explicit Fatigue, and Sleep Quality



Discussion

This study aimed to investigate the effectiveness of the innovative fatigue intervention IVY+ in reducing fatigue among university students. By combining implicit CBM training with explicit sleep hygiene training, it was theorised that the IVY+ intervention might be effective in comprehensively targeting fatigue, thereby decreasing implicit fatigue bias and explicit fatigue self-report. Additionally, the effect of IVY+ on sleep quality was tested.

Overall, the results showed a significant reduction in implicit fatigue self-concept bias and explicit fatigue self-report between pre- and post-assessment. However, no significant increase in sleep quality was found. At first sight, the results seem in line with previously discussed indications of the Dual Process Model and empirical evidence that a combined implicit and explicit intervention approach could be effective in addressing a wider range of cognitions underlying fatigue. As participants' implicit fatigue bias and explicit fatigue self-report decreased after the intervention, there is support for the effectiveness of IVY+. Interestingly, IVY+ did not positively influence sleep quality. This finding raises doubts about the contribution of the explicit sleep hygiene training. On the one hand, the addition of the explicit component might have contributed to the effectiveness of IVY+. On the other hand, the insignificant effect on sleep quality suggests that the sleep hygiene training did not function as intended with regard to specifically sleep hygiene. Possible interpretations of all findings will be discussed in the following.

Before embarking on a more in-depth exploration of the results, one major limitation of the study design needs to be highlighted in advance. Due to the single-group study design, it cannot be claimed whether the significant changes in implicit and explicit fatigue should be attributed to the implicit CBM component, explicit sleep training, both intervention components or other contextual influences. This limitation substantially strains the interpretability of the results.

Impact of the Intervention on Implicit Fatigue

The results of the first hypothesis demonstrate a significant reduction in implicit fatigue self-concept bias from pre-to- post-measurement. This suggests that participants associated themselves more strongly with vitality and less with fatigue as compared to before the intervention. This finding is consistent with an earlier study reporting a decrease in implicit fatigue self-concept bias (Geerts et al., 2022). Geerts et al. (2002) found a pre-to post-test shift in D-scores of -0.54, while this study found a shift of -0.3. Particularly, in this study, a D-score of -0.32 was found at baseline, indicating a stronger orientation towards a vitality self-concept bias before the intervention. After the intervention, the D-score decreased further to -0.62, with reductions found in the vitality bias baseline group and the fatigue bias baseline group. These findings advocate the functioning of IVY+ as both a fatigue-preventive intervention and a therapeutic tool for managing fatigue. As CBM has been found to directly target cognitive biases (Koster et al., 2009; Wells & Beevers, 2010), significant reductions in fatigue self-concept bias can be mainly attributed to the implicit CBM training component of the IVY+ intervention. However, regarding the single study design, a conclusive judgement cannot be made.

Furthermore, it can be questioned whether the IAT reliably measured cognitive bias modifications. It has been widely presented as a measurement instrument that can reveal implicit real-life biases based on reaction times. On the one hand, there is support for using IATs in the assessment of implicit self-concepts (Suslow et al., 2014). On the other hand, the modest test-retest reliability (r = .55) reported by Hofmann & Schmitt (2008), as well as the modest split-half reliability (r = .59) found in the present study compromise its ability to make robust inferences on changes in cognitive biases in a pre-post study design. In light of the differential findings, careful inferences should be made based on IAT results.

In summary, the significant reduction in participants’ fatigue self-concept bias scores, in combination with previous indications of successful CBM training, espouse the effectiveness of IVY+ in decreasing implicit fatigue. However, further research should adopt stronger study designs to expand the exploration of CBM intervention potentials.

Impact of the Intervention on Explicit Fatigue

Regarding the results of the second hypothesis, the significant reduction in participants’ fatigue self-report from pre- to post-measurement suggests that IVY+ effectively decreased explicit fatigue. Once again, this finding cannot be traced back to a specific component of the IVY+ intervention. Yet, the post hoc analysis results help to better understand connections between changes in implicit and explicit fatigue.

A post hoc analysis assessed whether a modification in self-concept bias linked to changes in fatigue self-report. The findings revealed a trend for a correlation between a change in bias and fatigue symptoms, as participants demonstrating greater improvements in implicit fatigue reported larger decreases in explicit fatigue from pre-to post-test, compared to lower or no improvements. This aligns with research arguing that symptoms are widely influenced by unconscious processes (Mathews & MacLeod, 2005; Cunningham et al., 2007). Additionally, the findings are consistent with the studies by Mogoaşe et al. (2014) and Hakamata et al. (2010), also reporting a positive correlation between bias modification and symptom change. Even though the results of the post hoc moderation analysis indicate a relationship between changes in implicit and explicit fatigue, the findings are insufficient for claiming a direct causal pathway, as suggested by a spill-over effect. Mediation analyses have been conducted in this context, discovering only a mediation effect in subgroups (Price et al., 2016) or no effect at all (Mogoaşe et al., 2014, Wiers et al., 2011). Hence, while there is evidence for linking bias modifications with changes in explicit fatigue self-report, further research is needed to substantiate a spill-over effect. Nevertheless, the post hoc analysis findings suggest that the implicit CBM training contributed to reductions in explicit fatigue self-report.

Furthermore, the combined intervention approach might have also played a role in decreasing explicit fatigue. While the intervention study exclusively incorporating CBM training within IVY did not find an effect on self-reported fatigue (Geerts et al., 2022), the present study found a significant reduction in fatigue self-report. Accordingly, it is conceivable that an added value of the combined intervention promoted this outcome. From a theoretical perspective, Strack & Deutsch (2004) argue for a synergic effect of compatible impulsive and reflective processes. Specifically, they say that if both processes align, the targeted cognitive schemata and subsequent behaviour are promoted, even requiring less cognitive effort. They further argue that this has significant motivational implications (Strack & Deutsch, 2004). Expanding on this reasoning, complementing the CBM training with explicit sleep hygiene training might have promoted fatigue-resisting cognitions and behaviours to an extent that would not have been achievable with CBM training alone. This argumentation is in line with the assumption of Wiers et al. (2011) that one intervention component increased the benefits patients derived from another treatment component (Wiers et al., 2011). Therefore, it can be hypothesised that one mechanism underlying the added value of the combined intervention approach in the present study is that the two components reinforced each other. This synergic effect might have contributed to reductions in fatigue self-report. However, it needs to be acknowledged that this assumption is solely based on a vague line of reasoning, necessitating research to further investigate the mechanisms underlying a combined effect.

To conclude, the significant results of the second hypothesis indicate that IVY+ was effective in reducing participants' fatigue self-report. While the CBM training might have largely contributed to the significant findings, it is also conceivable that the combined intervention approach promoted this outcome through a synergic effect. Lacking traceability of the findings to specific parts of the intervention hampers the ability to reach a definite conclusion on specific mechanisms underlying this outcome.

Impact of the Intervention on Sleep Quality

Coming to the third hypothesis, no significant increase in participants' sleep quality was found. The sleep training was specifically targeted at improving sleep quality by providing participants with guidance to implement sleep hygiene practices into their daily routines. It served as the explicit component of the IVY+ intervention. As individuals' sleep quality did not increase as a result of the intervention, it seems that the sleep hygiene training did not serve its function in terms of sleep quality improvement. However, it is also plausible that the sleep hygiene training induced hidden changes in other facets of sleep not noticeable in the SQS scores. Regarding the explicit role of the sleep hygiene training within IVY+, it can be postulated that reflective processes were targeted latently (Strack & Deutsch, 2004). Nevertheless, such assumptions remain speculative.

There are several plausible explanations for the insignificant findings on sleep quality. Firstly, the sample scored exceptionally high on sleep quality prior to the intervention. This finding opposes existing literature consistently reporting poor sleep quality in university students (Becker et al., 2018; Brown et al., 2006). While overall SQS scores could fall between 0 and 84, the average score was 32. No final judgement can be made as there are no norm scores to categorise SQS scores. However, the average score of 32 seems to be relatively low, indicating that the sample already had high sleep quality before the intervention. This baseline characteristic may have induced a ceiling effect, limiting the ability to capture further improvements. Furthermore, the items within the SQS were created to measure sleep quality for the past month. As the SQS pre- and post-measurements were only five days apart, this might have substantially influenced the test outcomes. Nevertheless, as all popular sleep questionnaires (e.g., PSQI) ask respondents to reflect upon the past month, this limitation could hardly be avoided.

Additionally, the 5-day length of the intervention might have been insufficient. Research suggests habitual change to be a time-taking process in which health-promoting behaviours require long-term repetitions to yield meaningful health improvements (Gardner et al., 2021). Hence, it is conceivable that the development of new sleep habits and subsequent noticeable changes in sleep quality requires more time than was given within the framework of the intervention. The SQS is a self-report measurement exclusively assessing sleep quality. Alternatively, behavioural measurements assessing sleep hygiene behaviours might have been able to detect more subtle, earlier changes in sleep. However, this was outside the scope of the present study.

Lastly, it should be emphasised that the sleep hygiene training programme is only one way to integrate an explicit component into the IVY+ intervention. In this study, it was chosen for the sake of simplicity and ease of implementation. Correlations between fatigue and, e.g., stress, anxiety, depression, life satisfaction, emotional stability, conscientiousness, and self-efficacy have also been reported (Zdun-Ryzewska et al., 2021). For instance, an alternative method feasible as an explicit adjunct to CBM is self-regulation training, e.g., including action planning activities (Pooth, 2020). Thus, further research might combine CBM training with another explicit intervention component.

Strengths, Limitations, and Future Implications

Some substantial limitations possibly affecting all study-related outcomes necessitate further attention. As previously noted, the single-group study design considerably affected the results' interpretability in making inferences about the source of change in the outcomes. The significant changes were possibly the result of the implicit CBM component, explicit sleep hygiene training, or a combination of both intervention components. Furthermore, the study results might have been unintentionally influenced by confounding variables, potentially compromising the internal validity. For instance, external events such as upcoming exams and personal stressors might have affected reported fatigue and sleep levels. As no control group was included, it could not be ensured that the observed effects were caused by the intervention or influenced by alternative factors. Thus, future research should use a controlled study design to assess the differential effects of distinct and combined intervention components. For instance, the study design could include separate groups assigned to complete the implicit CBM training, the explicit intervention component, the combined intervention, or act as a control group only completing the pre- and post-test.

Moreover, another considerable limitation is the small sample size (n = 27). To have statistical power, a required sample size of 34 was calculated (desired effect size = 0.5, α = 0.05, power = 0.8). Several participants were excluded from the study as they did not finish the entire intervention or made too many errors in the IAT, resulting in only 27 participants in the final sample. Therefore, the study might not have optimal external validity, consequently limiting the generalisability of the outcomes. Apart from the small sample size, participants were collected via convenience sampling, introducing potential errors due to insufficient randomisation. In this regard, future research should collect a larger sample size, ideally recruited via random sampling.

Some procedural issues also occurred. For several participants, there was a time delay between ending the 5-day intervention and completing the post-assessment, violating the fidelity of implementation. Additionally, technical issues with the TIIM application were reported where participants were automatically logged out of the application and did not receive notifications to complete the next activities. To conclude, even though the outcomes suggest that the IVY+ intervention is an effective fatigue intervention, the findings of the study should be interpreted with caution.

Notwithstanding, the present research provided a solid basis for introducing an innovative approach to mitigate rising fatigue problems among university students. Until now, no documented attempts have been made to test the effectiveness of a fatigue intervention combining implicit and explicit methods. While traditional interventions predominantly encompass either explicit or implicit strategies to combat fatigue, this study aimed at addressing unconscious as well as conscious processes underlying fatigue by taking a combined implicit-explicit approach. By applying the implications of the Dual Process Model to the notion of a fatigue self-concept, a unique perspective on fatigue was taken and applied to practice. Future research should take this study as inspiration to test the effectiveness of combined intervention approaches for fatigue further. In this regard, it might be interesting to combine the CBM training with different explicit techniques and to have diverse sample populations. Especially concerning clinical populations such as patients with chronic fatigue syndrome or cancer, the development of non-invasive alternatives relieving fatigue might improve the quality of life of many patients.

Conclusion

To summarise, the present study found promising evidence for the effectiveness of IVY+ as an innovative fatigue intervention in a non-clinical student sample. Significant reductions in implicit fatigue self-concept bias and explicit fatigue were found after the intervention. The combined implicit-explicit fatigue intervention approach seems promising, yet further research is needed to substantiate the findings and examine the specific contributions of the implicit and explicit training components.

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Appendices

Appendix A

Implicit Association Test

Table A1

IAT Blocks and Corresponding Attitude and Attribute Category Pairs

Block	Response number	Category assigned to left response key	Category assigned to right response key
1 (practice)	20	self	others
2 (practice)	20	fatigue	vitality
3 (practice)	20	self/fatigue	others/vitality
4 (test)	40	self/fatigue	others/vitality
5 (practice)	20	others	self
6 (practice)	20	others/fatigue	self/vitality
7 (test)	40	others/fatigue	self/vitality

Table A2

Attribute and Attitude Item Words in the IAT

Attribute Categories		**Attitude Categories**	
Category A	**Category B**	**Category C**	**Category D**
Self	***Others***	***Fatigue***	***Vitality***
Me	Them	Slow	Awake
Mine	Another	Tired	Strong
My	Your	Weary	Energetic
Self	Their	Weak	Vital
I	Others	Lifeless	Attentive
		Dull	Lively
		Exhausted	Fast
		Sleepy	Fit

Appendix B

Checklist Individual Strength

Below you will find 20 statements that relate to how you have felt during **the past week.**

If you feel that this statement is entirely true, tick the left box. If you feel that this statement is not true at all, tick the right box. If you feel that this statement is neither "yes, that is true", nor "no, that is not true", tick the box that is most in accordance with how you have felt.

I feel tired	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I feel very active	yes, that is true	○	○	○	○	○	○	○	no, that is not true
Thinking requires effort	yes, that is true	○	○	○	○	○	○	○	no, that is not true
Physically I feel exhausted	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I feel like doing all kinds of nice things	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I feel fit	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I do quite a lot within a day	yes, that is true	○	○	○	○	○	○	○	no, that is not true
When I am doing something, I can concentrate quite well	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I feel weak	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I don't do much during the day	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I can concentrate well	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I feel rested	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I have trouble concentrating	yes, that is true	○	○	○	○	○	○	○	no, that is not true
Physically I feel I am in a bad condition	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I am full of plans	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I get tired very quickly	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I have a low output	yes, that is true	○	○	○	○	○	○	○	no, that is not true
I feel no desire to do anything	yes, that is true	○	○	○	○	○	○	○	no, that is not true
My thoughts easily wander	yes, that is true	○	○	○	○	○	○	○	no, that is not true
Physically I feel I am in a good shape	yes, that is true	○	○	○	○	○	○	○	no, that is not true

Franziska Knüppe, University of Twente, NL – 2023

Appendix C

Sleep Quality Questionnaire

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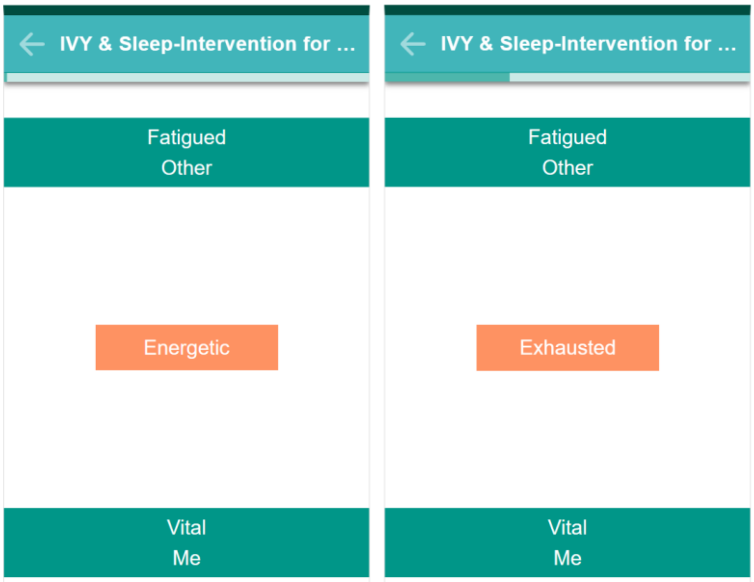
In the past week, how often have you experienced the following:

	rarely	sometimes	often	almost always
I have difficulty falling asleep	○	○	○	○
I fall into a deep sleep	○	○	○	○
I wake up while sleeping	○	○	○	○
I have difficulty getting back to sleep once I wake up in the middle of the night	○	○	○	○
I wake up easily because of noise	○	○	○	○
I toss and turn	○	○	○	○
I never go back to sleep after awakening during sleep	○	○	○	○
I feel refreshed after sleep	○	○	○	○
I feel unlikely to sleep after sleep	○	○	○	○
Poor sleep gives me headaches	○	○	○	○
Poor sleep makes me irritated	○	○	○	○
I would like to sleep more after waking up	○	○	○	○
My sleep hours are enough	○	○	○	○
Poor sleep makes me lose my appetite	○	○	○	○
Poor sleep makes it hard for me to think	○	○	○	○
I feel vigorous after sleep	○	○	○	○
Poor sleep makes me lose interest in work or others	○	○	○	○
My fatigue is relieved after sleep	○	○	○	○
Poor sleep causes me to make mistakes at work	○	○	○	○
I am satisfied with my sleep	○	○	○	○
Poor sleep makes me forget things more easily	○	○	○	○
Poor sleep makes it hard to concentrate at work	○	○	○	○
Sleepiness interferes with my daily life	○	○	○	○
Poor sleep makes me lose desire in all things	○	○	○	○
I have difficulty getting out of bed	○	○	○	○
Poor sleep makes me easily tired at work	○	○	○	○
I have a clear head after sleep	○	○	○	○
Poor sleep makes my life painful	○	○	○	○

Franziska Knüppe, University of Twente, NL – 2023

Appendix D

Screenshots of CBM Training within IVY+



Appendix E

Sleep Intervention

Activity	Text	Sources
Read Information about sleep hygiene	Day 1 Good morning! :) This is the first day of the 5-day sleep hygiene training. Every morning around 9 am you will receive a text about a particular task you are asked to complete throughout the day. You can find the text under the section "active modules". After reading the information within the module, you can click on ok. If you would like to reread it, you can find it in the section "finished modules". Please let me know if you have any questions regarding the sleep hygiene training by emailing f.knuppe@student.utwente.nl. Today's task is all about getting more familiar with strategies for sleep hygiene in general. For that, I ask you to **carefully read the following information on sleep hygiene** and reflect on whether you recognise some of the (counteractive) practises in your daily routine. ***What is sleep hygiene?*** Good sleep hygiene is all about setting yourself up for optimal sleep each and every night. Good sleep hygiene entails creating a sleeping setting as well as everyday habits that promote consistent, uninterrupted sleep. Maintaining a consistent sleep schedule, keeping your bedroom comfortable and distraction-free, following a relaxing pre-bed ritual, and developing healthy habits during the day are all beneficial for a good night of sleep. ***Why is sleep hygiene important?*** Persistent inadequate sleep can increase your risk for long-term health issues over time. It can also have an impact on how well you concentrate, think, react, learn, and memorise things. Among others, it might affect your mood, immune system, heart and circulatory system, and metabolism. Therefore, having healthy sleeping patterns are important for both, physical and mental health, and can improve your productivity and overall quality of life. ***What can you do to improve your sleep hygiene?*** There are many things you can do to practice good sleep hygiene: **Bedroom setting** • Avoid engaging in stimulating tasks in your bedroom, such as studying, eating, or viewing television. • Try not to use electronic devices right before going to sleep such as using computers, iPads, phones, or other electrical devices. • Try to keep your bedroom as dark as possible to keep out the light that might disrupt your sleep. • Have a comfortable mattress, sheets and pillow. **Routine** • Try to maintain a regular sleep schedule by getting up and going to bed at a similar time every day. • Get outside as soon as you can in the morning to take advantage of the natural light. • Try to avoid taking a nap during the day as it might make it harder to fall asleep at night. **Healthy habits** • Eat wisely to prevent nighttime hunger, but avoid heavy meals right before bedtime. • Try to engage in regular exercise such as aerobics and swimming, or just going for a walk. • Try to avoid smoking, as nicotine stimulates the body. • Try to reduce your alcohol consumption and try to avoid it later in the evening. Even though alcohol might make it easier for you to fall asleep, it reduces the quality of your sleep. • Try to avoid caffeine after midday, as it stimulates the body. ***Do you recognise any unhealthy sleeping patterns in your daily routine?*** These are just some recommendations to practise a good sleep hygiene. In the next couple of days, you will actively practice some of the mentioned recommendations. See you tomorrow!	Suni, E. (2020, August 14). *What is Sleep Hygiene?* (N. Vyas, Ed.). Sleep Foundation. https://www.sleepfoundation.org/sleep-hygiene National Heart, Lung, and Blood Institute. (2022, March 24). *How Sleep Works - Why Is Sleep Important? | NHLBI, NIH*. Www.nhlbi.nih.gov. https://www.nhlbi.nih.gov/health/sleep/why-sleep-important
Go for a 20-minute walk	Day 2 **Get more steps in** Good morning! :) The task of the day is to go for a **20-minute walk.** A quick walk around the neighborhood, the campus, or anywhere you like can already be sufficient and can be easily implemented between your daily activities. If you'd like to you can combine it with listening to music, a podcast, or inviting someone to join you for a walk, you can adjust this activity simply however it suits you best. Not only physical activities in the sense of exercising in a sport can help enhance your sleep but also a low-impact daily physical activity like taking a walk can help improve your sleep. Besides being more physically active in general, taking a walk brings further benefits like exposure to natural light which can help entrain a better circadian rhythm which can promote better sleep, and furthermore, it can reduce stress.	Sullivan Bisson, A. N., Robinson, S. A., & Lachman, M. E. (2019). Walk to a better night of sleep: testing the relationship between physical activity and sleep. *Sleep Health*, *5*(5), 487–494. https://doi.org/10.1016/j.sleh.2019.06.003 Wang, F., & Boros, S. (2020). The effect of daily walking exercise on sleep quality in healthy young adults. *Sport Sciences for Health*. https://doi.org/10.1007/s11332-020-00702-x*Want to Sleep Better? Go for a Walk | Psychology Today*. (n.d.). Www.psychologytoday.com. Retrieved April 5, 2023, from https://www.psychologytoday.com/intl/blog/think-act-be/201910/want-sleep-better-go-walk#:~:text=For%20example%2C%20being%20exposed%20to
Watch and follow the guided muscle relaxation video	Day 3 **Relaxation Exercise** Good morning! :) Today's activity is following a relaxation exercise. Although relaxation techniques do not necessarily help to improve sleep quality, the idea behind relaxation techniques is to help you fall asleep more easily. There are several reasons why these techniques can help to initiate sleep better such as that they can lower your heart rate and blood pressure, loosen the tensions in your muscles, and slow down your breathing. The breathing techniques of these exercises can generally make you feel more relaxed and create a sense of well-being. It is possible to teach yourself a relaxation exercise procedure that you can implement before you want to go to sleep, but as learning new techniques always takes time, for today's task you will just follow a guided progressive muscle relaxation video to get familiar with this technique. **This is the link to the video you are asked to follow today:** How to do Progressive Muscle Relaxation - YouTube It takes less than 7 minutes. Please make sure that you are in a comfortable, quiet environment while following the video. Relax! If you liked today's task there are also alternative relaxation techniques that might be interesting to have a look at such as autogenic training, guided imagery/visualisation, self-hypnosis, or only breathing exercises.	NCCIH. (2021, June). *Relaxation Techniques for Health*. NCCIH. https://www.nccih.nih.gov/health/relaxation-techniques-what-you-need-to-know Newsom, R. (2020, December 18). *Relaxation Exercises to Help Fall Asleep*. Sleep Foundation. https://www.sleepfoundation.org/sleep-hygiene/relaxation-exercises-to-help-fall-asleep
Shut off electronic devices 1 hour before bed and instead read, stretch, take a hot shower	Day 4 **Turn off Electronic Devices** Good morning! :) Your task for today is to **shut off electronic devices at least 1 hour before bedtime**. This includes watching TV, using the phone, laptop, tablet…Electronic devices should be avoided before sleeping for several reasons: 1. Blue light emitted by electronic displays can disrupt your circadian cycle and suppress melatonin production, a hormone that helps control sleep. 2. Electronic devices can be stimulating and keep your brain alert. When watching Netflix, scrolling through Instagram or TikTok, or playing video games, flows of new impressions need to be processed and fill your head with unnecessary stimuli which can make it more difficult for you to relax and fall asleep. 3. Electronic devices may keep you busy and thereby delay the time when you actually go to sleep, decreasing your overall sleep length. Due to the several, harmful effects that electronic devices may have on your sleep, they should be avoided, especially right before bedtime. Instead of using such devices, I advise you to engage in relaxing activities such as reading a book, stretching, or taking a hot shower.	Suni, E. (2020b, November 4). *Technology in the Bedroom*. Sleep Foundation. https://www.sleepfoundation.org/bedroom-environment/technology-in-the-bedroom#:~:text=Using%20devices%20tends%20to%20delay%20the%20time%20when Pacheco, D. (2020, November 6). *Can Electronics Affect Quality Sleep?* Sleep Foundation. https://www.sleepfoundation.org/how-sleep-works/how-electronics-affect-sleep
Exercise for 30 minutes	Day 5 **Physical activity** Good morning! :) Your task for today is to **exercise for at least 20 minutes**. This may entail various forms of physical activity, such as running, yoga, cycling…whatever you feel like doing! You can choose, depending on your preference and experience, the level of intensity for your exercise session. In the end, the most important thing is to get moving. I recommend planning your exercise session before the evening, as intense exercising too close to bedtime might make it more difficult for you to fall asleep. ***How does exercise impact sleep?*** There is strong scientific evidence for the benefits of exercise in improving sleep quality. It has been shown to reduce sleep onset time as well as awake time during the night and alleviate sleepiness during the day. Specifically, regular exercise has been shown to enhance sleep by releasing endorphins that foster feelings of happiness and relaxation and combat anxiety and stress, and by regulating natural sleep-wake cycles.	Drerup, M. (2020, November 11). *How Exercise Affects Your Sleep*. Health Essentials from Cleveland Clinic. https://health.clevelandclinic.org/how-exercise-affects-your-sleep/ Pacheco, D. (2021, January 22). *Exercise and Sleep*. Sleep Foundation. https://www.sleepfoundation.org/physical-activity/exercise-and-sleep

Appendix F

Introduction to Study and Informed Consent

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Before starting with the survey, I would like to give you some more information on this study and what participation entails. My research investigates the effectiveness of an intervention to improve sleep quality and decrease fatigue in students. The lives of many university students are often shaped by high academic demands, poor lifestyle choices, and high social pressures that can contribute to increased feelings of tiredness among students. In turn, this can decrease overall well-being and academic performance. The purpose of this research is to gather insight into the effects of the eHealth Application IVY+ as a tool to improve sleep quality and decrease fatigue.

You will be asked to complete two 15-minute surveys, one before and another one after the intervention. For the intervention, you will be asked to use the IVY+ application 5 days in a row. This entails completing a 3-minute association task and a sleep hygiene activity each day.

Please take time to carefully read the information on the next page before deciding whether or not to participate.

Franziska Knüppe, University of Twente, NL – 2023

UNIVERSITY OF TWENTE.

I am looking for participants who are at least 18 years old and currently study at a university.

Furthermore, participants need to have a good command of the English language and need to use a laptop as well as a smartphone.

Participation is completely voluntary, and you can withdraw at any time.

I believe there are no major risks associated with this study beyond the chance that some technical difficulties may occur, which are minimised by conducting multiple pilot tests beforehand. Please contact me in case you experience any difficulties throughout the study.

Prior to the analysis of the data, all personal data will be anonymised and will only be used for research purposes. The data will be stored in a secure way. Your answers will be treated confidentially; they will not be shared with other parties than the researcher and the supervisor. The data will be deleted after the final report is submitted.

The research is conducted by Franziska Knüppe (BSc Psychology student at the University of Twente).
The study is approved by the Ethics Committee of the Faculty of Behavioural, Management, and Social Science at the University of Twente.

Thank you in advance for your participation! Should you have any questions about this study, please feel free to contact me.

f.knuppe@student.utwente.nl

Franziska Knüppe, University of Twente, NL – 2023

UNIVERSITY OF TWENTE.

Informed Consent

- ○ 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.

Franziska Knüppe, University of Twente, NL – 2023