Retraining Implicit Fatigue among University Students through CBM via an eHealth App

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Abstract

Introduction: Fatigue among university students has serious restraints on their functional abilities, emotional well-being and academic outcomes. It was suggested that affected individuals often hold a self-concept bias by which they associate themselves with fatigue and react quicker to related stimuli. Cognitive Bias Modification (CBM) has been used to retrain several cognitive biases, however improvement of CBM interventions, particularly lowering threshold of participation was proposed. Therefore, this study aimed at testing a CBM intervention applied via a smartphone app as a novel approach to retrain implicit self-concept biases in order to decrease fatigue among students.

Methods: This study included a sample of 56 participants who conducted pre- and post-measurements, including the IAT (implicit fatigue) and CIS (explicit fatigue), as well as an intervention. The intervention included the IVY Training App which is based on a CBM self-concept training aimed at decreasing implicit fatigue. Participants practiced with IVY for around five minutes on a daily basis for two weeks.

Results: Implicit as well as explicit fatigue scores were significantly lower after 14 days of practice with IVY. Higher effect sizes were revealed for implicit fatigue and for fatigue-biased participants at baseline measurement. However, adherence was not significantly correlated with the effect of the intervention on implicit fatigue. Among the feedback section, the app was mostly rated as "good" or "very good" and improvement for the IVY app was gathered.

Discussion: As participants revealed significantly lower implicit and explicit fatigue, lowered self-concept fatigue biases can be suggested. Results indicate that the IVY app seems to be able to serve as a tool to promote vitality among students by retraining implicit fatigue. However, revision of the app and further research involving a control group is necessary.

Keywords: CBM, fatigue, IAT, implicit self-concept bias, IVY Training App, students,

List of Acronyms

CBM	Cognitive Bias Modification
CBT	Cognitive-Behavioral Therapy
CIS	Checklist Individual Strength
EC	Ethics Committee
IAT	Implicit Association Test

List of Tables and Figures

Tables

Figures:

Table of Contents

1. Introduction

1.1 Vitality

Feeling "alive" is a common phrase people make use of after experiencing a positive sense of aliveness or energy (Ryan & Frederick, 1997). This feeling is often referred to as vitality. More recently it has been defined as a "positive energy state" and this "subjective experience of feeling alive, is beneficially associated with health functioning" (Hirsch, Molnar, Chan & Sirois, 2015, p. 1654). Concerning the latter, vitality has been found to be a dynamic reflection of well-being, which is affected by psychological as well as somatic factors. Higher vitality levels have been associated to self-reported quality of life (Hirsch et al., 2015). Vitality has also been characterized as being a "salient and dynamic state" (Nix, Ryan, Manly & Deci, 1999, p.266). Thus, the state of feeling vital can change. Once energy levels lower, a feeling of being drained can arise. Feeling drained or tired is often related to the concept of fatigue.

1.2 Fatigue

Fatigue is a common symptom that everyone experiences occasionally in daily life (Swain, 2000). Around 14%-22% of the general population is affected (Hendriks, Drent, Elfferich & de Vries, 2018; Conolly, O'Toole, Redmond & Smith, 2013), with students revealing higher levels of fatigue than other populations, e.g. the working population (Oginska and Pokorski, 2006). Of those fatigued, around 50% remain affected one year later (Conolly, O'Toole, Redmond & Smith, 2013). Thus, the symptom can be of shorter duration as it might be relieved by rest or of longer duration when not relieved by rest (Swain, 2000).

In general, fatigue involves physical tiredness, exhaustion, reduced motivation or impaired concentration (Ryan et al., 2007). On the one hand, it can occur on a physical perspective in which it is viewed as a sensation of weakness even in rest. On the other hand, it implies a psychological perspective appearing in e.g. lack of attention (Ryan et al., 2007). It can occur in daily life in order to prevent overexertion or to encourage healing. In addition, it is multifarious in its occurrence (Swain, 2000). Correspondingly, it does not solely involve 'feeling tired' but also complex interactions of biological, psychosocial as well as behavioral processes. It can be physiologic or pathologic, exercise-related or chronic, localized or generalized, treatable or non-treatable and lastly, can occur as a single symptom or conjointly with others (Finsterer & Mahjoub, 2014).

1.3 Fatigue Among Students

Due to serious restraints that fatigue has on functional abilities and emotional well-being the necessity of further attention was emphasized. A study by Oginska and Pokorski (2006) investigated the prevalence of fatigue symptoms among different populations. Contrary to expectations that fatigue is less common among university students, it revealed as a significant concern within this population. It was suggested that students' workload is challenging on a cognitive level and that "they are probably sensitive to and aware of vigilance, attention and memory deficits and thus, report more often cognitive problems and excessive drowsiness" (Oginska and Pokorski, 2006, p.1326).

A further study led by Shim, Noh, Yoon, Mun and Hahm (2018) outlined the significance of fatigue among students. They surveyed 243 UK undergraduate university students three times over a semester period and identified that almost half of the students reported high levels of fatigue. Symptoms affected their subjective health as well as academic outcomes. Thus, attention for fatigue symptoms among students was raised (Shim et al., 2018).

1.4 Approaches Towards Fatigue

Based on the prevalence as well as the significant impact of fatigue among students, several approaches to combat this symptom have been conceived. These approaches range from physical exercise to rather psychological approaches. Concerning the latter, Cognitive-Behavioral-Therapy (CBT) has been widely applied to combat fatigue symptoms. A meta-analysis evaluating CBT among fatigue patients, emphasized its effectiveness (Malouff, Thorsteinsson, Rooke, Bhullar, Schutte, 2007). However, among their meta-analysis they indicated that "considerable room for improvement in outcomes exists" and suggested to research into methods that reduce dropout rates (Malouff et al., 2007, p.742).

Adding onto the previous, a further study outlined that the majority of university students do not approach professional help (Uwatoko et al., 2018). Reasons for this have been presumed to involve lack of time as well as stigmatization of mental health. Therefore, further research on a novel, more feasible approach that is simple and offers a low threshold for participation was recommended (Uwatoko et al., 2018). A corresponding approach could be based on cognitive processes.

1.5 Approaches Based on Cognitive Processes

In order to decrease fatigue among students it can be referred to cognitive processes. Accordingly, cues in the environment that are related to the self are the ones that people are most captivated by (Asendorpf, Banse and Mücke, 2002). Adding onto this, people who associate themselves with a specific adjective, for instance “exhausted”, respond quicker to this adjective than people that do not associate themselves with it. This phenomenon is based on the self-concept as well as the dual-process theory.

Self-Concept

The self is viewed as a “particularly rich social knowledge structure, organized within an associative mental network” (de Cuyper, et al., 2017, p.9). The self-concept in turn is “the association of the concept of self with one or more (nonvalence) attribute concepts” (Greenwald et al., 2002, p.5), that describe one’s personality (Asendorpf, Banse and Mücke, 2002). More specifically, the self-concept and its associative network contain nodes. These nodes are related with the concept of self in different strengths, resulting in quicker or slower response rates. Correspondingly, someone who associates himself with “exhausted”, will have stronger nodes between this concept and his self-concept. Hence, this person will reveal a quicker response to a cue that displays exhaustion. This has also been defined as the self-concept bias.

Dual-Process Theory

The self-concept bias, described above, involves implicit and automatic responses towards a cue that is relevant to the self, which have been defined by the dual-process theory (Asendorpf et al., 2002). According to this theory, behavior is influenced by either reflective or automatic processes (Rhodes, McEwan & Rebar, 2018). Contrary to the reflective system in which behavior is based on intention, within automatic processes behavior is based on impulsive systems (Strack & Deutsch, 2004). Thus, behavior is rather a result of automatic activation of schemata from e.g. perceptual input.

When related to the self-concept, reflective and automatic processes can be compared to explicit and implicit self-concepts of personality. These can be illustrated by an iceberg (de Cuyper et al., 2017). Correspondingly, the visible part of an iceberg is related to explicit self-concepts, which involve reflective processes that are deliberative, effortful, explicit as well as intentional. The non-visible part represents automatic processes that are rather non-conscious, spontaneous, implicit and not as easy to control. These processes are most likely present in physical activity that is based on habits, automatic self-schemas or automatic motivation (de Cuyper et al., 2017).

1.6 Automatic Processes in Fatigue

Outlining the effects of automatic and implicit processes, a study by Hughes, Hirsch, Chalder and Moss-Morris (2016) found that people suffering from chronic fatigue, reveal attentional as well as interpretive biases towards illness-related information. Thus, they are affected by an information-processing bias which influences the way in which they attend to and interpret incoming information. More specifically, people suffering from Chronic Fatigue Syndrome hold a schema in which their illness is viewed as being significant, uncontrollable and long-lasting. Based on this schema, these people implicitly filter incoming information and thus, direct their attention to information that is in line with this schema (Hughes et al., 2016).

From the previous, it could be implicated that fatigue can be connected to self-concept biases as an effect of automatic processes. Correspondingly, it can be implied that next to attentional and interpretive-processing biases individuals affected by fatigue also reveal implicit self-concept biases. As they attend to and filter incoming information based on the schema about their illness, they are more likely to hold a self-concept highly associated with fatigue. Subsequently, they might implicitly react quicker towards these cues, as well. Retraining implicit self-concept biases among students thus, seems valuable in further approaches towards fatigue.

1.7 Cognitive Bias Modification

Implicit self-concept biases could be decreased by retraining learned behavior. By altering associations with fatigue, reactions based on the schema activation could be changed. Cognitive Bias Modification (CBM) has been developed to retrain several kinds of biases (Bowler et al., 2012). CBM aims at redirecting threat-related cognitive biases and modifying attentional biases by disengaging participants from threat-related information. Furthermore, it retrains approach, self-concept or interpretational biases by initiating participants to evaluate emotional ambiguous stimuli in a positive way. This method has been proven to be effective in reducing anxiety and depression (Bowler et al., 2012) as well as unhealthy behaviors such as alcohol consumption (Kakoschke, Kemps & Tiggemann, 2017).

However, among other studies, CBM's effectiveness has been questionable. A study by Liu, Li, Han and Liu (2017) detected minor therapeutic effects of CBM on cognitive biases and thus, recommended more reliable research on the effectiveness of CBM interventions. Another study by Koster and Berstein (2015) found similar results. The authors stated that the "clinical efficacy of CBM, to-date, has been disappointing" (Koster & Bernstein, 2015, p.1). However, they outline the potentials of CBM interventions, particularly, when it effectively modified cognitive biases. Thus, they suggested novel approaches among CBM interventions (Koster & Bernstein, 2015).

A novel approach among CBM interventions involves the application of CBM via smartphones (Yang, Cui, Li, Xiao, Zhang & Oei, 2017). Among their study, the researchers investigated the feasibility and effectiveness of three different types of training programs namely, CBM-A for attention biases, CBM-I for interpretation biases and finally, AIM for modifying attention and interpretation biases. Correspondingly, a sample of 76 undergraduate students suffering from high anxiety were randomly assigned to either of these three groups or the control group. First of all, the feasibility of the application of CBM-intervention via smartphones was supported. Second, the results revealed significant effects of CBM-I, modifying interpretational biases. However, attention biases (by CBM-A) as well as attention and interpretation biases (by AIM) were not sufficiently decreased. The authors explained the latter by limitations of the study, such as low engagement of participants. Further research with CBM interventions via smartphones was highly suggested (Yang et al., 2017).

A recent study tested a CBM intervention via a smartphone app called "Breindebaas" among alcohol addicts[1]. This app aimed at retraining unconscious associations supporting alcohol addiction. It was based on findings of Wiers, Rinck, Kordts, Houben & Strack (2010) who tested a novel training program among heavy drinkers. The training program involved participants to implicitly avoid or approach alcohol by pushing or pulling a joystick in response to a picture displaying alcoholic or non-alcoholic drinks. It successfully modified automatic action tendencies towards alcohol, outlining the significance of cognitive bias on behavior. Therefore, the Breindebaas app involved participants in exercises similar to the training program developed by Wiers et al. (2010). Preliminary results suggest successful modification of cognitive biases in particular, approach bias, via Breindebaas.

As implicit processes have been suggested to be retrainable by CBM applied via an application, a similar app could be proposed as a novel approach towards fatigue among students. By retraining implicit self-concept biases with the aid of similar exercises to the Breindebaas app, associations towards fatigue of affected students could be decreased.

[1] See: https://www.utwente.nl/en/news/!/2016/11/498964/swipe-away-your-drinking-problem (accessed 16-06-2019)

1.8 Research Question and Hypotheses

Based on the prevalence and significant impact of fatigue among students, further research among this field and approaches to lower threshold of participation was proposed. It was assumed that people suffering from fatigue hold self-concept biases, which could be retrained by CBM. Specifically, CBM interventions via smartphones were suggested as it has shown promising results in decreasing cognitive biases, such as interpretational biases and highly probable, approach biases as well. Thus, it seems valuable to investigate whether a CBM intervention via an eHealth app could decrease implicit self-concept biases und thereby, fatigue among students. Furthermore, due to the app's focus on retraining implicit processes it follows to take a closer look at changes of implicit fatigue while comparing it to possible indirect changes of explicit fatigue. Hence, the research question of this thesis was; *To what extent is implicit and explicit fatigue among university students reduced by CBM via a smartphone app?* The corresponding hypotheses were:

H_1: After 14 days of practice with an eHealth app based on CBM, participants report significantly lower scores on measures of implicit fatigue.

H_2: After 14 days of practice with an eHealth app based on CBM, participants report significantly lower scores on measures of explicit fatigue.

H_3: The influence of CBM via an eHealth app is stronger on implicit fatigue than on explicit fatigue.

H_4: Adherence of practicing with the app moderates the impact of the CBM intervention on implicit fatigue.

2. Methods

2.1 Design

The influence of an eHealth app, representing an implicit method to influence students' fatigue levels, was measured by the aid of an interventional online pre- and post-questionnaire survey design. Specifically, the study included a pre-test, followed by an eHealth app intervention and finally, a post-test (see Figure 1).

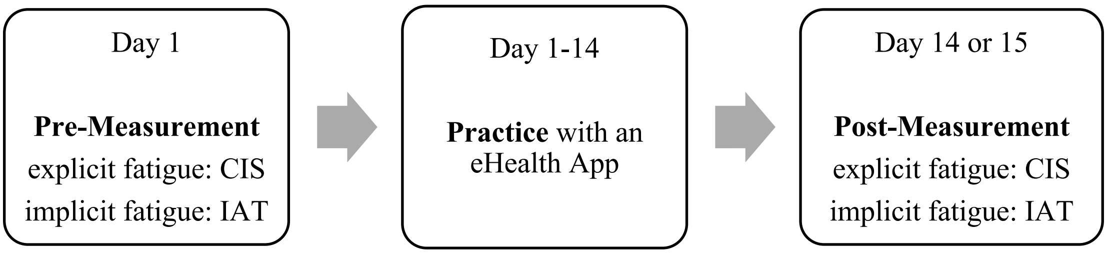

Figure 1. Schematic Overview of the Study Design

2.2 Participants

Participants were gathered based on a purposive sampling method (Tongco, 2007). Inclusion criteria were a minimum age of 18 years, enrollment in a study as well as proficiency in the English language. Participants were recruited via a university system called SONA, social media such as Facebook, and within the set of acquaintances of the researchers. The sample included 65 university students with 66,1% female and 33,9% male participants. The average age (M_{age}) was 21,4 years with a standard deviation (SD) of 2,33. Students came from 14 different universities, studying 15 different subjects of study. The majority studied at the University of Twente (71,6%), was enrolled for the studies of psychology (67,8%) and lastly, first-year students (58,9%). Additionally, information concerning nationality was gathered and divided in 85,7% German, 10,7% Dutch and 3,6% other nationalities.

2.3 Materials

The study involved pre- and post-tests which consisted of the Implicit Association test (IAT), the Checklist Individual Strength (CIS) and lastly, the Subjective Vitality Scale (SVS). The latter was included as this study was part of a larger, collaborating study, yet not further contemplated. While this was the first study in which IVY was used it also aimed at gaining further insight into the feasibility of the app as a possible CBM intervention. Thus, the post-measurement included an additional feedback section (see Appendix D). Among this part, participants were able to evaluate the usability of IVY and give suggestions for improvement. Furthermore, adherence of practicing with the app was enquired.

2.3.1 Implicit Association Test

The Implicit Association test was used to measure implicit fatigue. Referring to de Cuyper et al. (2017), it is the most widely used test to measure implicit self-concepts of personality. It offers outstanding psychometric properties, sufficient internal consistency as well as predictive validity and is flexible in its application (Bültmann, Kant, Kasl, Beurskens, van den Brandt, 2002; de Cuyper, et al., 2017). The IAT is a computerized test in which participants sort words to the correct category as quickly as possible. Words have to be assigned to four categories, particularly *self*, *others*, *vital* and *fatigue* as displayed in Figure 2 (Greenwald & Farnham, 2000). By the aid of response times, the strength of association between concepts can be accessed. A smaller response rate is believed to represent stronger associations in implicit memory (Greenwald & Farnham, 2000).

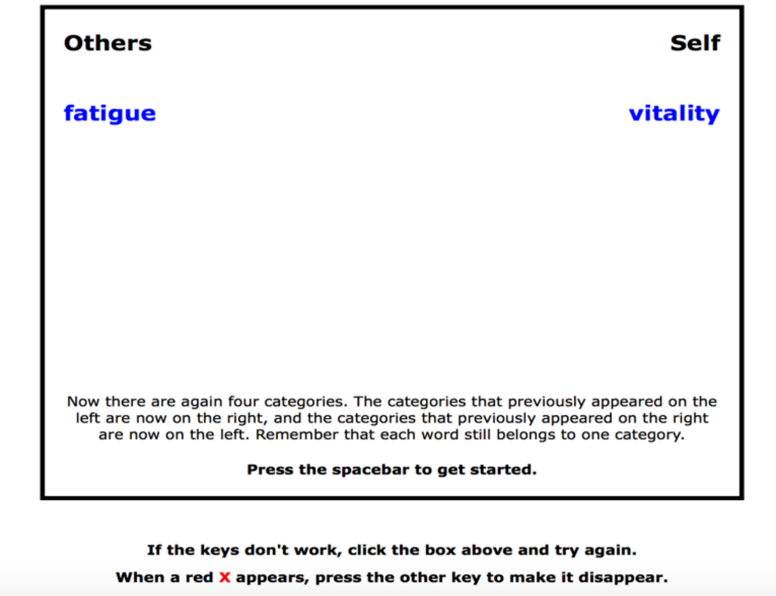

Figure 2. Screenshot of the Self-Concept IAT

The self-Concept IAT used in this study, consisted of seven blocks, including five practice blocks and two test blocks (Table 1, page 14). Within each block, two of the categories were placed on the top of the screen, one on the upper left corner and one on the upper right corner. The words that had to be sorted were categorized into four categories (Greenwald & Farnham, 2000). Correspondingly, two categories represented the target groups, in this case *self* and *others*. Example words for these categories were “mine” or “them”. The remaining two categories represent attributes, in this case *vital* and *fatigue* (Mendonca, Mata & Vohs, 2019). Example words were “fit” or “exhausted”. All words can be found in Appendix A. The example words for the categories appeared on the screen and had to be sorted into the corresponding category by the aid of pressing the keys “E” and “I” on the keyboard.

Table 1

Sequence of trail blocks in the fatigue/vitality IAT

Block	**No. of Trail**	**Function**	**Items assigned to the left-key response**	**Items assigned to the right-key response**
1	20	Practice	self	others
2	20	Practice	fatigue	vitality
3	20	Practice	self + fatigue	other + vitality
4	40	Test	self + fatigue	other + vitality
5	20	Practice	others	self
6	20	Practice	others + fatigue	self + vitality
7	40	Test	others + fatigue	self + vitality

2.3.2 Checklist Individual Strength

The Checklist Individual Strength (CIS) was applied to measure explicit fatigue. It was originally developed for hospital studies on chronic fatigue (Bültmann et al., 2000) and offers psychometric soundness with a Cronbach's alpha reliability coefficient of 0,90 (Bültmann, Kant, Kasl, Beurskens, van den Brandt, 2002). The scale consisted of twenty items which cover four different aspects of fatigue. Accordingly, eight items measured severity, five items measured concentration, four items measured motivation and the remaining three items measured physical activity. Participants were instructed to rate items based on how they felt the past two weeks on a 7-point rating scale ranging from 1 ("Yes, that is true") to 7 ("No, that is not true"). An example item was "I feel tired".

The scale was scored by summing up rating values which ranged from 20-140. Higher scores indicated higher levels of fatigue, concentration issues, lower motivation and/or lower levels of activity. The cut-off score of CIS total >76 was used, as it has been proven to be appropriate by a cohort study investigating on prolonged fatigue (Bültmann et al., 2000). Accordingly, participants scoring a total score above 76 were classified as fatigued.

2.3.3 IVY Training App

The IVY Training App, is an eHealth app available for iOS and Android, developed to retrain implicit self-concept biases[2]. The app aims at influencing self-concept biases by initiating the establishment of new connections. More specifically, by the aid of connecting positively formulated words, e.g. "vital" to oneself and negatively formulated words e.g. "slow" to others, as shown in Figure 3 (page 15), practitioners are supposed to feel more vital.

[2] See: https://apps.apple.com/gb/app/ivy-training/id1457680885#?platform=iphone (accessed 16-06-2019)

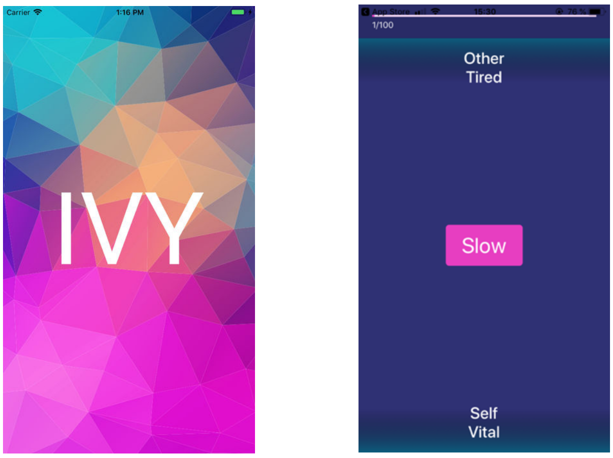

Figure 3: Screenshots of the IVY Training App

2.3.4 Feedback Section (Post-Measurement)

The post-measurement included a feedback section in which participants were able to rate and evaluate the IVY Training App (Appendix D). Concerning the rating of the app, three items were to be evaluated on a five-point Likert scale. An example question was "How would you rate working with the app in general?". Evaluating the app concerned three open questions, in which participants were able to share which features they liked or disliked as well as share recommendations. "Which features would you most like to see added?" was an example question. Lastly, within this section, participants were asked to indicate how often they used the app and thus, adhered to practice on a 6-point Likert scale ranging from 1 ("always") to 6 ("never").

2.4 Procedure

The study was approved by the BMS Ethics Committee (EC) of the University of Twente (190341). The researchers invited participants to voluntarily take part in the interventional study with the opportunity to receive SONA credits, that are credits within a university system. Additionally, participants from other universities were invited to take part in the study. After approving to take part in the study, participants received a link of the pre-measurement to conduct on their laptop. The pre-measurement consisted of an online questionnaire as well as the IAT, which were uploaded on an online platform called SoSci Survey.

The online questionnaire required each participant to sign an informed consent, which conformed to the specifications of the EC. Within the informed consent, participants could agree to provide their email-address for the purpose of receiving a reminder for the post-measurement. After filling in the questionnaires and conducting the IAT, participants were asked to download the IVY Training App and conduct a daily training for the upcoming two weeks. One training session lasted for around five minutes. After 13 days, each participant received a reminder via email including the link for the post-measurement. The study was online for 6 weeks until the desired number of a minimum of 50 results had been acquired.

2.5 Data Analyses

In order to assess the gathered data and evaluate on the research question, data analyses were conducted using IBM SPSS Statistics version 24. The first step concerned screening the data. Accordingly, the final data set was determined by checking for outliers or missing data values. From 65 cases, 9 participants' data had to be excluded due to missing values or missing English proficiency. Thus, a total number of 56 valid cases remained in the final data set.

Within the next step, the data was explored. Each scale of the pre- and post-test was assessed and screened independent from each other. In particular, IAT reaction times were expressed in D-scores according to Greenwald, Nosek and Banaji (2003) and were calculated by SoSci Survey. The D-scores were based on reaction times on the test blocks four and seven. While a negative D-score indicated a vitality bias, a positive score revealed a fatigue bias. Based on this, participants were sorted into two groups, being either vitality or fatigue biased at baseline measurement. Therewith, a more detailed overview of the sample was gathered as well as further analyses based on these sub-groups were conducted. Next, the values on the Likert-scale of the CIS of each participant were classified from one to seven. All positively formulated items were recoded. The last step evolved around conducting analyses with which the research question could be answered by testing corresponding hypotheses.

2.5.1 Hypotheses Testing

In order to evaluate the research question, four hypotheses were tested. H_1 and H_2 were explored by comparing each section of the pre-test to the corresponding section in the post-test.

The first hypothesis (*H_1: After 14 days of practice with an eHealth app based on CBM, participants report significantly lower scores on measures of implicit fatigue.)* was investigated by a paired sample t-test, using D-scores of the IAT. The analysis was conducted between the average D-score of the pre-measurement and the average D-score of the post-measurement. Furthermore, similar paired sample t-test analyses were conducted first, for D-scores of the vitality biased group and second, for D-scores of the fatigue biased group.

The second hypothesis (*H_2: After 14 days of practice with an eHealth app based on CBM, participants report significantly lower scores on measures of explicit fatigue.)* was tested by a paired sample t-test, comparing the scores of pre- and post-test of the CIS. The mean scores of each test were transformed into a new variable resulting in one mean score for the pre- and one for the post-test. Accordingly, the analysis was conducted between the two CIS measures from pre-measurement and the post-measurement.

The third hypothesis (H_3*: The influence of CBM via an eHealth app is stronger on implicit fatigue than on explicit fatigue.*) was tested by comparing effect sizes provided by previous analyses of H_1 *and* H_2.

Lastly, a moderating effect of adherence to practice with the app was evaluated by the fourth hypothesis (H_4*: Adherence of practicing with the app moderates the impact of the CBM intervention on implicit fatigue).* In order to gain a further insight into whether the variable *adherence* serves as a moderator, a bivariate correlation analysis was performed. As adherence scores were non-parametric, a Spearman's Rho correlation was conducted in order to investigate on the strength between *adherence* and *difference D-scores.* Therefore, adherence items were recoded in order to assert "always" practicing with the app the highest value, 6. Subsequently, a difference-score or rather, Z-score of the average D-scores of pre- and post-measurements was calculated and served as the second variable within the correlation analysis.

2.5.2 Feedback of the IVY App

Lastly, recommendations regarding the IVY app were screened. On that account, answers from the participants among the feedback section of the post-test were analyzed and categorized into response categories. Therewith, results could partly be accounted for and recommendations for the IVY app were formulated.

3. Results

3.1 Descriptives

First of all, an overview of the data was gathered. Subsequently, for each of the 56 participants a D-score and an average as well as total sum CIS score was calculated. The CIS scores were normally distributed while baseline D-scores and adherence scores were not normally distributed and non-parametric.

Firstly, pre-test D-scores were arched with an estimated kurtosis level at 1,74. Furthermore, the results of the pre-test D-scores reveal an average of -0,16 (SD=0,4), representing a vitality bias. Particularly, 38 participants (67,9%) of the sample were vitality biased compared to 18 participants (32,1%) with fatigue bias. Among the post-test, D-scores shifted to a normal distribution. The average score of the post-measurement (M=-0,59, SD=0,42) represented a vitality bias, as well. More specifically, the number of participants revealing a vitality bias increased up to 51 participants (91,1%) bias after the intervention.

Secondly, average scores of the CIS measures of the pre- as well as post-test were normally distributed. As displayed in *Figure 4*, scores of the CIS pre-measurement range from a minimum of 40 to a maximum of 106. The average score of 74,66 (SD=15,42) was just below the cut-off score at 76 and thus, slightly below being classified as fatigued. In total, 41,1% of the participants could be classified as fatigued. However, among the post-measurement average levels of fatigue lowered. Scores for CIS post-measures ranged from 36 to 113 with a mean of 65,27 (SD=17,6). The mean remained below the cut-off score with a total of 23,2% of the participants being classified as fatigued.

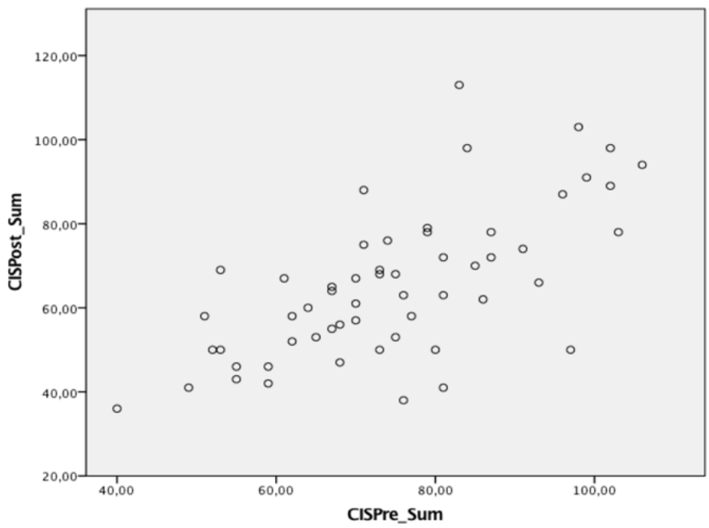

Figure 4. Distribution of CIS Pre-Measurement and Post-Measurement Scores

Finally, adherence scores were skewed (1,89) as well as arched (3,42) and thus, non-parametric. More specifically, 53,6% practiced with the app “always” and 28,6% “almost every day”. The remaining 17,8% practiced with the app “sometimes” or less.

3.2 Hypotheses Testing

All paired sample t-test analyses were conducted with a 95% confidence interval. The first hypothesis (*H_1*), investigating on a significant impact of the CBM intervention on implicit fatigue, was tested by the aid of a paired t-test analysis. Expectedly, a significant decline in D-scores was detected, t (55) = 6,404, p<.001. Thus, the hypothesis was accepted. Cohen’s D was estimated at 0,86 which represents a large effect size according to guidelines showed in Cohen (1992).

Subsequently, similar analyses were performed within sub-groups for vitality biased as well as fatigue biased participants. Within the vitality biased group, a significant difference of t (37) =3,663, p<0,001 was detected. The effect size was moderate with a Cohen’s D of 0,59. Within this sub-group, three participants showed a fatigue bias at post-measurement, while the rest remained vitality biased. Among the fatigue biased-group a significant difference between baseline measurement and post-test was detected, t (17) = 7,498, p<.001, with a large effect size (Cohen’s D = 1,77). Thereof, two participants remained fatigued and 16 revealed a vitality bias at post-measurement.

Next, the second hypothesis (*H_2*) regarding the impact of the intervention on explicit fatigue, was investigated by a paired t-test analysis, as well. A significant correlation was found between the intervention and explicit fatigue, t (55) = 5,137, p=.001 with a moderate effect size of 0,69. More specifically, significant changes from pre- to post-measurement were detected among the *Subjective Fatigue*, the *Concentration* as well as the *Physical Activity* but not among the *Motivation* dimension of the CIS (see Table 2). Therefore, the second hypothesis was accepted.

Table 2

CIS Scores of Each of the Four Dimensions

Scale Dimension	No. of Items	Mean Pre-Test	Mean Post-Test	t	p-value
Subjective Fatigue	8	31,04(SD=8,22)	26,46(SD=8,19)	4,47	<0.001
Concentration	5	21,02(SD=4,79)	18,07(SD=6,18)	4,72	<0.001
Motivation	4	12,45(SD=4,02)	11,57(SD=4,08)	1,73	.089
Physical Activity	3	10,16(SD=3,55)	9,16(SD=3,43)	2,27	.027

The third hypothesis (H_3), stated that the CBM intervention had significantly more impact on implicit fatigue than on explicit fatigue. Revealed by previous analyses, the intervention had a large effect size on implicit fatigue, compared to a moderate effect size on explicit fatigue. Thus, this hypothesis was accepted.

Among the last hypothesis (H_4) it was hypothesized that the effect of CBM on implicit fatigue is moderated by adherence to practice. In order to test the previous, a bivariate correlation was conducted. Accordingly, a Spearman's Rho analysis did not reveal a significant negative correlation, $r_s = -.099$, $p< .47$. Thereby, the fourth hypothesis was rejected.

3.3 Feedback

3.3.1 Quantitative Feedback

The first questions of the feedback section concerned the general experience, understanding of the instructions and finally, difficulty of the tasks. Table 3 displays the distribution of answers to each of these questions. In general, the app was rated as "good", "always" easy to understand and lastly, "never" too difficult.

Table 3

Distribution of Answers Concerning the Rating of the IVY App

Topic	**Likert scale**	**Median**	**Division of Answers in Percentages**
General Rating	1-5	2/ "good"	82,5% = "very good" or "good" 7% = "poor" or "very poor"
Understanding	1-5	1/ "always"	94,7% = "always" or "very often" 5,3% = "sometimes" or "rarely"
Difficulty of Tasks	1-5	5/ "never"	0% = "always" or "very often" 96,5% = "rarely" or "never"

3.3.2 Qualitative Feedback

The remaining items of the feedback section were sorted and analyzed by response categories, as shown in Table 4 (page 21). First of all, responses regarding additional features were mostly assigned the response category *progress,* followed by the category *difficulty.* Suggestions evolved around enabling to see one's progress or adding a greater variety of words. Further suggestions were summarized by the response categories *sound, adherence*, *moving screen* and *others,* with prevalence rates and example items displayed in Table 4.

Among the next sub-question, participants indicated that features assigned to *sound*, *progress* and *others* were least useful to them. Finally, regarding general comments to IVY, the response category *moving screen* was represented most, followed by *functionality, difficulty, design*, *adherence* and finally, *others* which included statements such as “boring”.

Table 4

Feedback Section: Prevalence of Response Categories

Sub-question	**Response Category**	**Prevalence**	**Example Item**
F104/ Features to be added	*progress*	8	“see your progress”
	difficulty	6	“more catching task”
	sound	5	“a button to turn of the volume”
	adherence	5	“calendar if I did the procedure yet”
	moving screen	3	“non-scrollable background while playing”
	others	6	“green background when the answer was right, red when it was wrong”
F105/ Features least useful	*sound*	2	“sound”
	progress	1	“workout information”
	others	1	“'he' and 'she' words, since it is (…) discriminating and ignorant to only include those two”
F109/ Comments	*moving screen*	6	“Swiping mistakes cause of the overlay slipping when swiping”
	functionality	3	“In the beginning I had struggles starting the daily session therefore I reinstalled it and installed it again. After this the app worked quite well.”
	difficulty	2	“was very easy to handle”
	design	2	“I think the swipe gesture up and down was sometimes difficult to do quickly, especially for the upper words”
	adherence	2	“sometimes you just moved the whole screen and not only the word itself, that was a little bit annoying”
	others	7	“Connecting good things with myself, but therefore also connecting bad things with others.”

4. Discussion

This study evaluated the research question “To what extent is implicit and explicit fatigue among university students reduced by CBM via a smartphone app?”. First, a significant impact of the intervention on implicit and explicit fatigue was detected, particularly on implicit fatigue and among the fatigue biased sub-group. Second, a correlation of adherence with the intervention and its effect on implicit fatigue was not disclosed.

4.1 Discussion of the Main Findings

When taking a closer look, it should first be noted that implicit and explicit fatigue scores converge. While almost half of the participants were classified as fatigued based on CIS measures, almost half of the participants revealed a fatigue bias based on IAT measures. This complements the findings of Hofmann, Gawronski, Gschwender, Le and Schmitt (2005), who detected a general correlation between the IAT and explicit self-report measurements of fatigue, such as the CIS.

Furthermore, prevalence of fatigue among this sample, support the statement of Oginska and Pokorski (2006) including that students are particularly suspect to cognitive problems and excessive drowsiness. Similar findings were reported by Dittner, Rimes & Thorpe (2011) in whose study almost half of the participants reported excessive fatigue by the end of the semester. Based on this study, Shim and his colleagues (2008) reasoned that academic and emotional stress negatively affected sleep and combined with high academic or pressure demands, it increased fatigue especially at the end of the semester.

In comparison, these findings converge with findings of the current study. Among this study, the majority of baseline measurements were taken at the end of the third module. Thus, fatigue rates might have been higher due to academic pressure, which in turn could have negatively affected the participants’ sleep quality. However, the influence of timing of the pre-test should be integrated with caution, as several participants studied at universities outside of the Netherlands. Thus, their schedules might have differed which in turn could have influenced the results differently.

4.1.1 Impact of the Intervention on Implicit and Explicit Fatigue

The results seem to indicate that the intervention was able to decrease implicit as well as explicit fatigue among both vitality and particularly, fatigue biased participants. Adding onto the previous, it could be implied that the intervention was most effective on an implicit level. Therefore, IVY seems to be able to retrain implicit processes similar to the computer-based training program by Wiers et al. (2010). This could be attributed to the fact that the app's practices are specifically designed to work on an implicit rather than on an explicit level. However, as fatigue decreased on an explicit level as well, it could be suggested that retraining implicit processes might indirectly decrease explicit fatigue.

In order to further evaluate the research question, a moderation effect of adherence to practice was explored. As adherence rates were high, it did not reveal as a difficulty among this study compared to findings of Yang et al. (2017). In their study, non-significant effects of CBM interventions via a smartphone on attentional bias were attributed to low engagement of participants. It should be remarked, that adherence scores were indicated by participants themselves. Thus, high adherence rates could be susceptible to bias such as memory bias or social desirability in order to avoid giving negative feedback.

Regardless, among this study adherence was not significantly correlated with difference D-scores, indicative for implicit fatigue. A negative correlation was detected, which would suggest that once adherence rises, implicit fatigue tends to decline. However, the strength of the relationship was not significant and could thus, be attributed to random error. Therewith, a moderation effect of adherence cannot be suggested, implying that participants who practiced frequently were not necessarily more vitality biased than participants who rarely practiced with IVY. This in turn could question IVY's effectiveness in general. If the frequency of practice did not influence the level of fatigue than the practice itself, namely IVY, might not have had an effect on fatigue at all.

Nonetheless among this study, a rejected influence of adherence could be attributed to non-parametric scores. Due to the fact that the greater part of participants adhered to practice always or almost every day, the sample barely included participants that adhered to practice never or rarely. Therefore, no sufficient distinction between participants that always adhered to practice and participants who barely adhered to practice can be drawn.

4.1.2 Feedback on the IVY Training App

Based on results of the quantitative feedback, it can be stated that the app was perceived as positive, easy to understand and lastly, refrained from tasks that were too difficult. Among the qualitative feedback, suggestions to add features in which participants are able to monitor their progress, add more difficult tasks and lastly, are able to turn off or change the sound are most outstanding. Additionally, functionalities of the app, e.g. swiping, were criticized frequently and demand improvement.

Issues concerning functionality, tedious tasks or a perturbing sound could be causes for lower adherence or dissatisfaction with the app. Among research by Garnett (2016), aspects promoting engagement with an app developed to reduce alcohol consumptions were outlined. Each one of these aspects, that were, ease of use, design, tailoring of design and information and lastly, unique smartphone features could be related to issues with IVY, e.g. impaired ease of use due to a moving screen. Contrary to what would be expected based on these findings, issues with IVY did not seem to affect adherence or satisfaction with the app greatly. Possible explanations could be that the issues mentioned, were not perceived as significantly disturbing. For instance, participants might have laid more importance on the ease of use than being disturbed by a moving screen. However, it should be remarked, that the sample included acquaintances of the researcher, which might have reinforced social desirability biases.

4.3 Conclusion

This study aimed at testing whether CBM applied via IVY could serve as an approach to the urgent issue of fatigue among students. It was suggested that addressing implicit self-concept biases via an app based on CBM could decrease fatigue while also lowering threshold of participation. In fact, among this study, after 14 days of practicing with IVY less fatigue and higher vitality biases were detected which seem to be attributable to the intervention.

First, particularly strong decreased implicit fatigue indicates that as intended, IVY seems to be able to decrease self-concept biases by retraining students' associations towards fatigue. Second, due to beneficial effects among the fatigue biased group, the intervention could possibly have similar effects on students suffering from chronic fatigue. Therefore, it could be proposed as a tool within treatment for chronic fatigue. Nonetheless, in order to confirm the previous, research with the app among chronic fatigue patients would be necessary. Furthermore, as vitality biases increased, the app could be of benefit for non-fatigued students as well. Thus, IVY could possibly serve as a prevention of fatigue as well as a tool within treatment for chronic fatigue.

Adding onto the previous, an app as means to offer CBM for students, could entail lower threshold for participation. CBM via smartphones offers high cost-effectiveness and high accessibility to a CBM intervention and therewith, treatment for mental issues such as fatigue. Furthermore, an app is less time consuming and avoids stigmatization, which were revealed to be major obstacles in students seeking help among the study of Uwatoko et al. (2018).

The IVY app used in this study has received reasonable feedback by the participants and combined with effective results, it could offer a possible mean for CBM via smartphones. However, the app is not without sizeable flaws which are highly suggested for further revision. Respectively, adjusting functionalities could further enhance adherence and satisfaction with the app, which in turn could lower threshold for participation.

4.4 Strengths

To start off, this study included a sample that was targeted and diverse. Due to the fact, that the study was rather explorative, a sample of students from various nationalities, universities and studies was included. Adding onto this, fatigued and non-fatigued participants were almost distributed by half at baseline measurement. Therefore, the sample can first, be evaluated as representative. Thereby, the study was able to provide implications of the results e.g. suggesting IVY as a possible prevention of fatigue. Second, this equal distribution enabled sub-group analyses with which the effect of IVY could be investigated on in more detail.

A further strength of the study concerns adherence of practice. Despite the fact, that the majority of the sample was able to receive a reward for participation (SONA credits), students not offered a reward engaged in and finished the intervention as well. Therefore, it could be inferred that the intervention or rather the IVY app, was appealing to students regardless of rewards. This in turn suggests applicability of IVY even beyond this study. Additionally, concise and feasible feedback concerning the app was gathered and thus, further revision and improvement was made possible.

By the aid of these strengths, the study was able to lay the groundwork for introducing a novel approach to combat an urgent issue. Thus, the study fulfilled its purpose in exploring a possible approach towards combating fatigue among students.

4.5 Limitations and Future Research

It should be noted that an explorative study entails several limits. First of all, findings cannot be generalized as the study did not include a control group. Therefore, it cannot be assured that the findings, particularly the decrease in implicit and explicit fatigue, are indeed solely attributable to the intervention. Decreased fatigue bias could be attributed to other factors, e.g. daily mood fluctuations. Furthermore, a rejected correlation between adherence and implicit fatigue possibly questioned IVY's effectiveness or might be based on unevenly distributed adherence scores. By adding a control group, more conclusive insights into possible moderating effects of adherence could be gained and therewith, lowered fatigue scores could be attributed to practice with IVY.

Next, several unexpected complications arose during data collection. As the Android version of IVY was not working initially, complaints arose from participants during the study as well as within the feedback section. What is more, several participants started the pre-measurement on their phone which did not allow them to conduct the IAT correctly. They had to terminate the pre-test until they were able to conduct the test on their laptop. Thereby, few participants resigned from the study. A suggestion to conduct the test via laptop among the invitation could have prevented drop-out rates. In order to rule out similar complications, a pilot test is recommended in future studies.

Lastly, the posttest was not conducted on the 14th day by the majority of participants. As the greater part conducted the posttest in a timely manner, with one or two days of delay, sizeable distortion within the average results are not suspected. However, two participants conducted the post-measurement up until eight and 12 days after their intended date. This could have resulted in deviated scores. Yet, similar to the majority of the sample, these participants revealed a change from an initial fatigue bias to a vitality bias. Based on merely two participants with a delay of post-measurement no inferences can be drawn. In addition, it is unknown whether these participants continued practicing with the app or not during their delay. Regardless, these findings draw attention to possible long-term effects of the intervention and are thus, prompted for further examination.

4.6 Final Conclusion

Overall, while this research outlined the urgent issue of fatigue among students, it was able to take first steps towards approaching this issue by proposing CBM interventions via smartphones. Findings of this study suggest that specifically fatigue biases could be decreased on an implicit level by retraining self-concept biases. Additionally, the study was able to test the IVY Training App in particular, and prompt features for revision to lower threshold of participation in a CBM intervention. However, in order to fully accept IVY as a tool to offer CBM via smartphones findings need to be generalized by the aid of a control group. Thereby, first, lowered fatigue could be attributed to the app and second, a moderating effect of adherence could further be explored. Altogether, this study was able to provide promising groundwork concerning a novel approach to decrease fatigue among students by retraining implicit self-concept biases via a smartphone app.

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Appendices

A. **IAT** (categories with corresponding words to be sorted)

Category A: *Self*	**Category B: *Others***	**Category C: *Fatigue***	**Category D: *Vitality***
I	others	exhausted	vital
me	he	weary	energetic
mine	other	tired	fit
my	she	lifeless	lively
self	their	weak	strong
		slow	fast
		sleepy	awake
		dull	attentive

B. Informed Consent

UNIVERSITY OF TWENTE.

I declare that I have been informed in a clear manner about the nature, method, purpose and burden of the research. I know that the data and results of the research will only be disclosed anonymously and confidentially to third parties. I agree to provide my e-mail address in order to be able to receive a reminder for the follow-up questionnaire. My questions have been answered satisfactorily. I voluntarily agree to participate in this study. I thereby reserve the right to terminate my participation in this study at any time without giving reasons.

- ◯ Yes, I agree and want to procede with the study
- ◯ No, I do not agree with this and will disengage from the study

Marie Wächtler and Marietta Vogel, Universiteit Twente, NL – 2019

C. Checklist Individual Strength (CIS)

1. I feel tired	S
2. I feel very active	M
3. Thinking requires effort	C
4. Physically I feel exhausted	S
5. I feel like doing all kinds of nice things	M
6. I feel fit	S
7. I think I do a lot within a day	A
8. When I am doing something, I can concentrate quite well	C
9. I feel weak	S
10. I don't do much during the day	A
11. I can concentrate well	C
12. I feel rested	S
13. I have trouble concentrating	C
14. Physically I am in a bad condition	S
15. I am full of plans	M
16. I am tired very quickly	S
17. I have a low output	A
18. I feel no desire to do anything	M
19. My thoughts easily wander	C
20. Physically I feel I am in a good shape	S

S = Subjective Fatigue Dimension
C = Concentration Dimension
A = Physical Activity Dimension
M = Motivation Dimension

D. Feedback Section

1. How would you rate working with the app in general?
   very good, good, barely acceptable, poor, very poor

2. Did you understand the instructions of the app easily?
   always, very often, sometimes, rarely, never

3. Were the tasks of the app too difficult?
   always, very often, sometimes, rarely, never

4. Which features would you most like to see added?
   open fields

5. Which features of the app were least useful to you?
   open fields

6. Would you like to share any more thoughts about the app or any experiences with the app?
   open fields

7. In the last two weeks, how often did you use the app?
   every day, almost every day, most of the time, sometimes, almost never, never