BACHELOR THESIS

Testing Cognitive Bias Modification with the IVY Training App on Fatigue Self-Concept in Explicit and Implicit Vitality

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Abstract

Fatigue is a common problem in university students, as it is related to their high levels of stress due to high workload. Affected individuals experience enduring exhaustion which leads to a decrease in academic performance and general functionality. Increased levels of vitality, on the other side, are associated with better mental and physical well-being and more healthy behaviors. However, fear of fatigue and biased cognitions lead to avoidance behaviors of fatigue stimuli such as potentially tiring activities. These biases help maintain symptoms even after periods of study stress, which hinders increases in vitality. Those biases include perceiving the self as fatigued in general and increasingly attending and memorizing information that conforms with this fatigue self-concept. Cognitive Bias Modification (CBM) has already successfully changed biases in other conditions. The aim of this study was to test whether CBM with a newly developed app called IVY Training, is also able to change the fatigue self-concept and to increase vitality in students. The focus was hereby on testing its influence on implicit vitality (the unconscious self-concept) and on explicit vitality (the consciously expressible self-concept). **Method:** 56 university students completed the Subjective Vitality Scale (SVS) as explicit measure of vitality and a self-identity IAT as implicit measure of vitality both pre and post intervention. The intervention was a daily five-minute training with IVY for 14 consecutive days. **Results and Discussion:** The results showed that IVY had in general no positive influence on explicit vitality, but a small influence on the subgroups of fatigued individuals and individuals with a vitality bias at baseline level. Low correlations with adherence to app use supported the app's positive influence on these groups. The IVY Training app had a strong influence on implicit vitality, with increases towards (more) vitality bias for all groups, in particular for the fatigue bias and fatigued groups. The non-existing relationship of implicit vitality outcomes with adherence to app use, however, cast doubts on whether increases can be attributed to IVY. Feedback showed good levels of liking and understanding, low task difficulty, and no association between general liking and understanding with adherence to app use. Only task difficulty interfered with the number of times the app was used. Based on these findings it was concluded that, with reservations, the app could be beneficial for the target group with larger benefits for fatigued or fatigue biased students and stronger changes in implicit fatigue self-concept than in explicit fatigue self-concept.

Keywords: IVY Training app, CBM, fatigue self-concept, implicit and explicit vitality

Contents

1. **Introduction**

1.1 Fatigue in Students

As much as approximately half of all university students experience significantly high levels of stress presenting itself as symptoms of anxiety and/or depression (Regehr, Glancy, & Pitts, 2013; Cotton, Dollard, de Jonge, 2002). Reasons include high study workload and the pressure to obtain good grades (Law, 2007; Galbraith & Merrill, 2012). An associated problem is the high level of fatigue in university students (e.g. de Vries, van Hooff, Geurts, & Kompier, 2016; Smith, 2018; Law, 2007), which significantly increases after periods of academic stress (Dittner, Rimes, & Thorpe, 2011; Lee, Chien, & Chen, 2007; Chen, 1986). As compared to a fatigue prevalence rate of about 20% worldwide in the normal population (Young, 2004; Puetz, 2006), prevalence rates among university students are presumed to be higher due to their high levels of stress (Shankland et al., 2018; de Vries et al., 2016). In the Netherlands half of the students experience psychological problems with stress, fatigue and burnout being the most prevalent problems (LSVb, 2013). A similar result was found at a university in Taiwan (Lee, Chien, & Chen, 2007). Fatigue is thus a common problem in university students.

Fatigue in healthy individuals is a sensation to protect against physical and mental overload by inducing the desire to rest (Ryan et al., 2007). It is a subjective sensation which includes feeling tired, exhausted, weak, and lacking energy (Shen, Barbera, & Shapiro, 2006). It becomes a problem, however, when individuals keep feeling fatigued for at least one month, which is defined as prolonged fatigue, or even for more than six months, which is defined as persistent or chronic fatigue (Fukuda et al., 1994). This enduring fatigue impairs functionality in personal and occupational life to a degree similar to other chronic medical conditions (Büttmann et al., 2002; Kroenke et al., 1988; Chen, 1986). Furthermore, other physical and psychological disorders such as anxiety and depression, are often concomitant.

Once fatigue is enduring, the negative experiences, such as the persistent threat to functionality and well-being, can lead to fear of any fatigue stimuli that have shown to evoke fatigue in the past (Lenaert, Boddez, Vlaeyen, & van Heugten, 2018). This can lead to avoidance behaviors of any potentially tiring activities, resulting in less active and healthy lifestyles. Less activity, however, can lead to physical deconditioning which in turn leads to more fatigue. In other words, as a result of resting behaviors or avoidance of (physical) activity due to fear, fatigue can be learned in a way that it persists even when periods of stress are over (Lenaert et al., 2018).

In university students, this has two major consequences. Firstly, fatigue has a negative effect on cognitive performance which leads to lower learning outcomes and significantly decreased academic performance (Smith 2018; Palmer et al., 2013). Secondly, fatigue was found to be strongly associated with reduced wellbeing (Smith, 2018). It was also found that the more fatigued individuals felt, the lower they perceived their health (Flensner, Ek, Landtblom, & Söderhamn, 2008), which in turn leads to reduced wellbeing (Ryan & Frederik, 1997). Low perceived health, however, was found to be also associated with less healthy lifestyles (Riffle, Yoho, & Sams, 1989; Killeen, 1989). As discussed, these lifestyle changes, including resting and avoidance of (physical) activity, help maintain fatigue (Lenaert et al., 2018), a condition that harms both students' academic as well as personal lives.

Therefore, it seems evident that there is a strong need to counteract fatigue in students.

1.2 Vitality

One way of counteracting fatigue is to increase vitality. Vitality is the contrary feeling of fatigue and can be defined as positive and subjective feelings of being alive and energetic (Ryan & Frederick, 1997). It is composed of the three dimensions energy, motivation, and resilience (Strijk, Wendel-Vos, Hofstetter, & Hildebrandt, 2015). Hereby, energy refers to the feeling of being energetic; motivation refers to the active setting of goals which are pursued by investing a lot of effort; and resilience refers to the capability to handle and cope with daily problems and challenges.

More vital individuals experience usually higher levels of well-being, such as they feel more self-actualized and more self-determined, have more self-esteem, and have better mental and physical health (Ryan & Frederik, 1997). The reverse is also the case. Individuals who are less vital experience often higher levels of psychopathology such as anxiety, depression, or somatic complaints, as well as lower physical health.

Increases in vitality were found to also increase more healthy behaviors such as tobacco abstinence (Niemiec, Ryan, Patrick, Deci, & Williams, 2010), and to generally be linked with engaging in more (physical) activitiy (Ryan & Frederik, 1997). Therefore, the approach of reducing fatigue by promoting vitality is considered particularly suitable, since fatigue avoidance behaviors and less perceived health due to fatigue can lead to less healthy and active lifestyles, as discussed above (Lenaert et al., 2018; Riffle et al., 1989; Killeen, 1989).

1.3 Cognitive Biases and Self-concept

To find a successful way of increasing vitality, it is crucial to understand the processes and factors that underlie fatigue symptom maintenance, in more detail. Lenaert et al. (2018) distinguished four factors of how individuals learn to feel fatigued, in other words, what enforces fatigue maintenance. These factors were perceptual-cognitive biases, increased sensitivity to fatigue stimuli, the catastrophizing of feeling fatigued, and the over-generalization of incidences of fatigue to other situations. Looking at these factors, they seem to have one thing in common, that is their cognitive component, especially in respect to biased cognitions towards fatigue severity and frequency. This impression is supported by several studies which found that negative and irrational thinking patterns are linked to catastrophizing of symptoms and higher perceived severity of fatigue (e.g. Kangas & Montgomery, 2009; Thornsteinsson & Brown, 2009). More adaptive and rational thinking patterns, in contrast, were associated with less severe fatigue.

Research that addressed the contributing factor of cognitive biases in fatigue in more depth, found that fatigued individuals form beliefs, such as that fatigue symptoms are severe, detrimental and not controllable or curable (Moss-Morris & Petrie, 2003) which are largely biased (Hughes, Hirsch, Chalder, & Moss-Morris, 2016). Based on these biases, affected individuals form negative illness schemas which they draw upon when interpreting new information, leading to an interpretation bias (Hughes et al., 2016). Less frequently found, but still present in research findings, is an attentional bias towards illness related information as a strategy to avoid further impairment. These biases were indeed found to help maintain the experienced severity of fatigue (Hughes et al., 2016).

There are also indications that information is being processed in congruence with negative, fatigue-related self-views. Briones et al. (1996) found, for example, that enduring fatigue can influence whether an individual perceives him- or herself rather as vital or fatigued in general. The identification of the self with a chronic illness has already been defined as illness self-concept (Morea, Friend, & Bennett, 2008), and also in depression negative self-schemas have been identified (Davis & Unruh, 1981). It is therefore standing to reason that there are not only information processing biases about fatigue and its symptoms, but also about the self as a fatigued individual. These biases can be explained with the self-processing bias, that is the attention towards and increased memorization of cues in the environment that are related to the self (Cunningham & Turk, 2017). In this case fatigue cues would be more readily processed as they are congruent with fatigue self-concepts. These self-concepts can also lead to behaviors that are in accordance with the self-concept such as found in tobacco and alcohol use with individuals who had substance self-concepts (Lindgren, Neighbors, Gasser, Ramirez, & Cvencek, 2017). These individuals experience themselves as smokers or drinkers and consequently smoke or drink more readily, as it is in congruence with their self-concept. For fatigue, lifestyle changes such as avoidance behaviors have already been identified above (Lenaert et al., 2018; Riffle et al., 1989; Killeen, 1989). These might be maintained as they are congruent with the fatigue self-concept.

Concluding on the findings on fatigue, vitality, and cognitive biases, it is obvious that a change needs to be brought about in the cognitions of university students in order to increase vitality to decrease the common and detrimental problem of fatigue. More precisely, biases in fatigue self-concepts need to be changed in order to increase vitality and therewith to promote more healthy and active lifestyles that will counteract further fatigue maintenance. In the following paragraphs it will be explained how these self-concepts can be measured and changed.

1.4 Implicit and Explicit Measures

Self-concepts consist of what an individual is consciously thinking about the self, but they also involve an unconscious component (Asendorpf, Banse, & Mücke, 2002). Conscious self-concepts can be assessed using explicit measures, such as self-report questionnaires. But for the unconscious components of the self-concept, implicit measures are needed.

The unconscious and conscious self-concepts that can be assessed by implicit and explicit measures, relate to the dual process models. According to these dual process models, human cognition operates with two systems (Evans, 2003; Frankish, 2010; Strack & Deutsch, 2004). One is the implicit system, an impulsive system that can operate rapidly and is largely responsible for spontaneous behaviors. The other one is the explicit system of analytical and reflective thinking that requires more time and is largely responsible for controlled behaviors (Evans, 2003; Frankish, 2010; Strack & Deutsch, 2004). Cognitive biases were, especially in early research, attributed to the first system as it is rather based on impulses, and correct responses to the second system which is rather based on logic (Evans & Curtis-Holmes, 2005; Evans, 2003; Evans, 1998). More recent research, however, also found cognitive biases in the explicit system (Evans & Stanovich, 2013; Frankish, 2010). Logical interpretations where found to sometimes be based on incomplete information that was produced by the attentional bias of the first system and led to an interpretation bias in the second system.

In a study on implicit and explicit personality self-concept, Asendorpf et al. (2002) found that spontaneous behaviors could be predicted with results of implicit measures on self-concept, and controlled behaviors with explicit measures. In a different study on implicit and explicit substance self-concept, both implicit and explicit measures predicted substance use outcomes (Lindgren et al., 2017). Based on these findings, it becomes clear that the fatigue self-concept bias cannot exclusively be measured by an explicit method but also requires an implicit method, as both allow somewhat different inferences about resulting behaviors.

In both the studies of Asendorpf et al. (2002) and Lindgren et al. (2017) an Implicit Association Test (IAT) was used as the implicit measure. The IAT is a commonly used measure of implicit processes (Hofmann, Gawronski, Gschwendner, Le, & Schmitt, 2005) in which concepts are sorted into two categories for which categorization speed shows the strength of implicit association (Greenwald, McGhee, & Schwartz, 1998). In respect to self-concept it shows the degree to which participants identify themselves rather with fatigue or vitality concepts and is expressed in so called *D*-scores. Explicit measures like questionnaires can also assess self-concepts to some extend and have a low but significant relation with implicit measures (Hofmann et al., 2005). This shows that implicit and explicit self-concepts may be distinct but with some relation.

1.6 Cognitive Bias Modification

Self-concepts can be changed using the implicit method called Cognitive Bias Modification (CBM). CBM is a method that seeks to change cognitive biases by requesting participants to respond in ways contrary to their bias in often repetitive tasks, which leads to an implicit manifestation of these newly learned responses (Hertel & Mathews, 2011; Koster, Fox, & McLeod, 2009). Though literature has not yet assessed CBM’s effectiveness in changing fatigue self-concepts, it has already proved to successfully treat other psychological conditions that also included cognitive biases. For example, a literature review on CBM for social anxiety found promising treatment results for interventions which exposed participants to simulated social situations and trained them to interpret these as non-threatening rather than threatening - which is contrary to their interpretation bias (Mobini, Reynolds, & Mackintosh, 2012). Another study found that CBM could help to increase health behaviors and successfully decreases an approach bias in chocolate consumption, when training individuals to avoid pictorial chocolate stimuli (Schumacher, Kemps, & Tiggemann, 2016). Also, in alcohol addicts CBM interventions proved to successfully modify approach biases (Wiers, Eberl, Rinck, Becker, & Lindenmeyer, 2011) and attention biases (Schoenmakers et al., 2010).

Since these results show that CMB proved to be effective in other conditions that involve cognitive biases, it stands to reason that the same might be the case with self-concept biases in fatigue. Concerning its effectiveness not only on implicit biases but also on biases in the explicit system, research has not yet come to a definite conclusion. The results of a study by Hertel and Mathews (2011), however, suggests that participants are most of the time not consciously aware of the changes and only implicit measures are able to reveal them.

1.7 Aim of this Study

This study aims to test the influence of the CBM training app 'IVY' on vitality in university students. It aims to give first indications about the effectiveness of this newly developed CBM intervention, as well as to get participant feedback on the usability of the app. The Subjective Vitality Scale (SVS) as explicit measure, and an IAT as implicit measure are used both pre and post intervention. Although this app is still in its testing phase, it is assumed that it promotes the identification with vitality rather than fatigue concepts, which is expected to counteract the negative fatigue self-concept bias and increases vitality. Therewith more healthy and active lifestyles might be promoted which counteract further maintenance of fatigue symptoms and improve students' academic and personal lives.

1.8 Research Questions and Hypotheses

1. What is the influence of the IVY Training app on explicit vitality?
    - <u>Hypothesis 1a</u>: The mean difference between pre- and post-test SVS measures is significant. Mean values tend towards more vitality in post-test measures.
    - <u>Hypothesis 1b</u>: Increases in explicit vitality are positively related to adherence to app use.
2. What is the influence of the IVY Training app on implicit vitality?
    - <u>Hypothesis 2a</u>: The mean difference between pre- and post-test *D*-scores is significant. Mean values tend towards more vitality bias in post-test measures.
    - <u>Hypothesis 2b</u>: Increases in implicit vitality are positively related to adherence to app use.
3. What is the difference between the influence of the IVY Training app on implicit vitality and on explicit vitality?
    - <u>Hypothesis 3</u>: The influence of the IVY Training app is stronger on implicit vitality than on explicit vitality. The direction of influence is towards more vitality.

2. Method

2.1 Participants

The participants to this study consisted of 56 university students, who were selected using a purposive sampling method (Tongco, 2007). The inclusion criteria involved being a university student, being proficient in the English language, and possessing a smartphone. Out of these 56 university students who fulfilled the inclusion criteria, 67.9% were female, and 32.1% were male; They were between 18 and 31 years old, with a mean age of 21.45 ($\sigma = 2.29$). Most of the participants ($n = 40$) were recruited using the test subject pool system ‘Sona’ of the University of Twente. In this system university students receive credit points as a compensation for their participation, which they need for successful completion of their university degrees. Other participants from different universities, who were known to the researchers, were recruited based on their willingness to participate. The demographics can be found in Table 1.

Table 1

Demographics

		N	Percent
Gender	Male	18	32.1%
	Female	38	67.9%
Nationality	Dutch	6	10.7%
	German	48	85.7%
	Other	2	3.6%
University	University of Twente	40	71.4%
	Other Dutch University	2	3.6%
	German University	10	17.9%
	University other country	4	7.1%
Study Program	Psychology	38	67.9%
	Other	18	32.1%

2.2 Materials

All measurements were taken with the aid of the online survey tool ‘soSci Survey’. It included the various tests, was individually designed, and provided a link to the survey that was passed on to the participants. Accordingly, the tests were to be taken using a laptop or tablet. For the intervention, participants needed an Android smartphone or an iPhone. The data collected with the soSci Survey was statistically analyzed using the computer program IBM SPSS Statistics 24.

Subjective Vitality Scale. To measure explicit, subjective vitality the Subjective Vitality Scale (SVS) was used. This scale has been developed by Ryan & Frederick (1997) and encompasses seven items, such as ‘I feel alive and vital.’ or ‘I look forward to each new day.’. Participants are asked to rate these items on a 7-Point Likert scale with 1 being ‘not at all true’, 4 being ‘somewhat true’, and 7 being ‘very true’. Two versions are available of this scale, the individual difference level version and the state level version. The former asks participants to rate each statement as it relates to their general life, and the latter asks participants to rate each statement as it relates to this moment in time. For this study the individual difference level version was chosen as it relates more to a rather stable perception of the self, than the state level version which might depend too largely on moods and external circumstances. Since a study by Bostic, McGartland Rubio, and Hood (2000) found that removing the second item yielded more valid results, this study also uses the reduced 6-item version omitting item 2. Vitality scores (in the following often related to as explicit vitality) are computed by adding the scores on the 7-Point Likert Scale of each item and dividing it by the sum of items, that is by 6. This scale was shown to have high levels of internal consistency, as well as an adequate factor structure, and convergent validity (Rouse et al., 2015).

Checklist Individual Strength. This study was part of a larger study. In collaboration with Vogel (2019) the data to this study was collected. Therefore, the ‘Checklist Individual Strength’ questionnaire (CIS) was included as well, as it was relevant to the study by Vogel (2019), which focused on the influence of IVY on fatigue. The CIS is a 20 item self-report questionnaire to assess fatigue, which includes items like ‘thinking requires effort’, ‘I feel weak’, and ‘physically I feel I am in a good shape’, to be rated on a 7-Point Likert Scale ranging from ‘yes, that is true’ to ‘no, that is not true’ (Beurskens et al., 2000). The scale was validated by a study of Beurskens et al., (2000). For more details the study by Vogel (2019) can be consulted.

Self-identity IAT. To measure the participants’ implicit self-identification with vitality (implicit vitality), a self-identity IAT was used. It shows the degree to which participants identify themselves rather with fatigue or vitality concepts.

The IAT used seven blocks out of which block 4 and 7 were the actual test blocks and the other blocks were practice blocks to get accommodated with the task. Concepts that appeared in the middle of the screen had to be sorted into categories at the upper left and right side of the screen. Details can be found in Table 2 and an example of the task is presented in Figure 1.

Table 2

Specifics IAT Blocks

Blocks	Categories		Examples
	Left side	**Right side**	
1 = Practice block	self	others	Mine, their, she
2 = Practice block	fatigue	vitality	Exhausted, awake, weary
3 = Practice block	self fatigue	others vitality	Strong, he, their, tired
4 = Test block	self fatigue	others vitality	Strong, he, their, tired
5 = Practice block	others	self	Mine, their, she
6 = Practice block	others fatigue	self vitality	Sleepy, fit, me, attentive, he
7 = Test block	others fatigue	self vitality	Sleepy, fit, me, attentive, he

An IAT yields *D*-scores, which are the quotients of the averaged difference between the IAT (test) blocks (Greenwald, Nosek, Banaji, 2003). In the following these *D*-score outcomes are often related to as implicit vitality. These *D*-scores were directly computed by soSci Survey, involving total *D*-scores on all blocks including practice blocks, and *D*-scores for test blocks only. For this study the total *D*-score was chosen, as it includes more data. This was expected to yield more valid results, since using the test blocks only might involve learned responses from the practice blocks rather than the actual responses based on individual biases. However, there is no literature available yet, which supports or rejects this expectation. In case of this self-identity IAT, negative *D*-scores indicate a vitality bias, and positive *D*-score indicate a fatigue bias. The self-identity IAT was developed and validated within the scope of a study by Pieterse & Bode (2018), which yielded preliminary results.

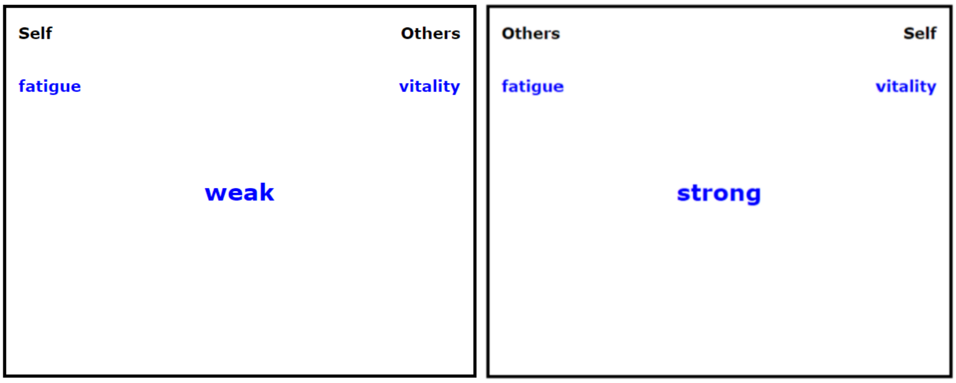

Figure 1. Self-Identity IAT Test Blocks

IVY Training app. For the intervention, the IVY Training app was used, which is an app freely available in the iTunes App Store and in the Android Play Store. It was developed by ‘Evolution36’ on behalf of the University of Twente. The IVY Training app uses the method of Cognitive Bias Modification (CBM) in form of a daily training. The goal of this CBM app is to strengthen the associations between the self and vitality concepts.

In case of the IVY Training app, participants were requested to swipe words, which appear in the middle of the screen, either up towards the category ‘Other/Self’, or down towards the category ‘Self/Vital’ (see Figure 2). This swiping gesture is supposed to simulate the movement of concepts away or towards the self. Examples for words that are to be swiped towards the self are ‘strong’, ‘vital’, ‘self’, or ‘attentive’, while words like ‘weary’, ‘other’, ‘weak’, ‘exhausted’, or ‘dull’ are to be swiped away from the self. This task had to be executed with considerable speed in order to largely respond with the implicit system which holds the (majority of) biases that are to be changed (Evans & Stanovich, 2013; Frankish, 2010). Right categorization led to a green light on the screen and the appearance of a new word, and wrong responses led to a red light on the screen and the swiping gesture had to be repeated until categorization was correct. This way, the identification of the self with words of vitality becomes implicitly manifested. This IVY training was available every day for the categorization of 100 words, which took about five minutes. The app also includes a daily reminder for participants to complete this daily training unit.

The IVY Training app is still in its testing phase which is why there is no literature available yet on its effectiveness. This study also seeks to test the app and to produce preliminary results on its effectiveness.

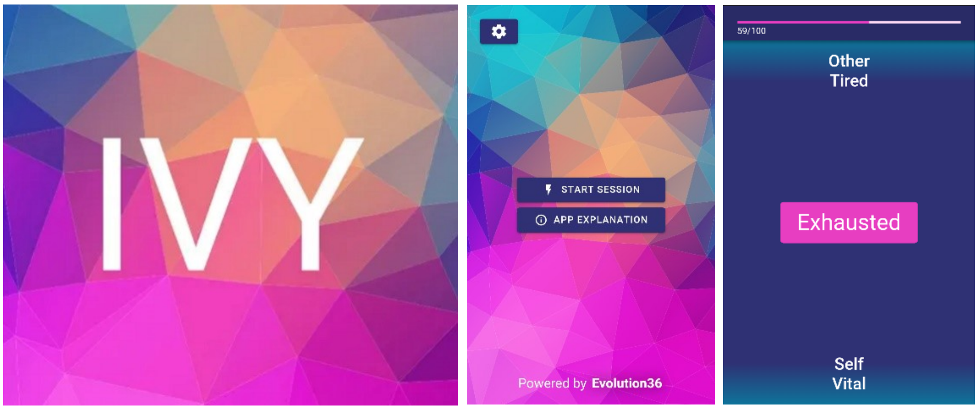

Figure 2. IVY Training app

Feedback. To gain insight into the usability of the IVY Training app, participants were asked for their feedback after completing the study. This can also help to understand the app's ability to influence vitality. Firstly, general liking was to be rated on a 5-Point Likert Scale with 1 being 'very good', 2 being 'good', 3 being 'barely acceptable', 4 being 'poor', and 5 being 'very poor'. Secondly, understanding of the app's instructions was to be rated on a 5-Point Likert Scale with 1 being 'always', 2 being 'very often', 3 being 'sometimes', 4 being 'rarely', and 5 being 'never'. Thirdly, on the same scale as understanding, task difficulty was to be rated. Fourthly, participants were asked the three open questions 'Which features would you most like to see added?', 'Which features of the app were least useful to you?', and 'Would you like to share any more thoughts about the app or any experiences with the app?'. In a fifth step, participants were asked to rate how often they used the app in the last two weeks on a 6-Point Likert Scale with 1 being 'every day', 2 being 'almost every day', 3 being ' most of the time', 4 being 'sometimes', 5 being 'almost never', and 6 being 'never.

2.3 Design and Procedure

This study employed a semi-experimental pretest-posttest design, with the influence of the IVY Training app being tested on the dependent variables implicit vitality and explicit vitality for all participants by comparing pre- and posttest measures. Figure 3 shows an illustration of the study design.

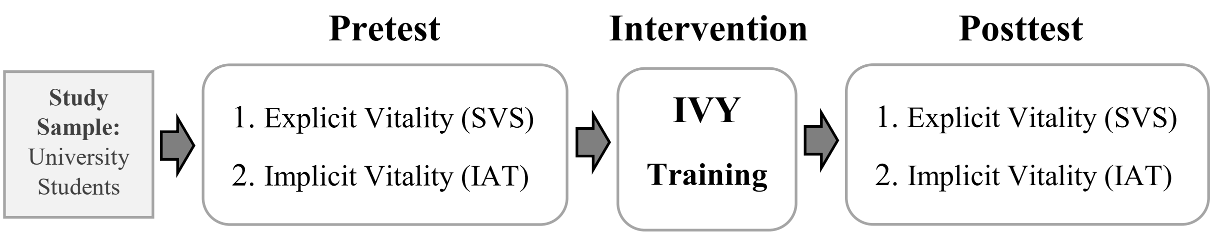

Figure 3. Study Design and Setup

After the study had been approved under the number 190341 by the Ethics Committee of the Behavioural, Management and Social sciences (BMS) of the University of Twente, students were able to either sign up to the study via the test subject pool system 'Sona' of the University of Twente, or were approached by the researchers. Subsequently, the participants received a link to the soSci pretest survey. After a short introduction to the study, students were presented with an informed consent form and were asked to either agree or disagree with their data use in the scope of this research, such as test results or their e-mail address to receive a reminder for the follow-up questionnaire. Students who agreed preceded to first filling in questions regarding their demographics. These questions were asking for age, whether they were currently a university student, language fluency, gender, nationality, their university, the study program they were currently enrolled in, their study year, their Personal Code by which the researchers were able to identify participants in both the survey and the app (consisting of the first letters of their first and last names and the last two digits of their year of birth), and their e-mail address (for sending a reminder to the posttest). Then, participants went on to fill in first the Checklist Individual Strength questionnaire (CIS) and then the Subjective Vitality Scale (SVS). Subsequently they received a short introduction to the self-identity IAT and immediately continued with the seven blocks of the IAT. After approximately 20-25 minutes, the students were done with the whole pretest survey and were asked to download the IVY Training app to complete the daily training units for 14 consecutive days.

One day before completion of the 14th day, the students received a reminder for the post measurement via e-mail, which included the link to the soSci posttest survey. The posttest survey was similarly structured as the pretest survey. Participants first received a brief introduction and then had to fill in their Personal Code again, to enable the researchers to link pre- and posttest cases. Subsequently, participants had to fill in the Checklist Individual Strength questionnaire (CIS) and then the Subjective Vitality Scale (SVS) again. After a short introduction, participants then immediately started with the seven blocks of the self-identity IAT. Next, after a short explanation, participants were asked to give feedback on the IVY Training app and their experiences. The first question asked for their general liking, the second for their understanding of the tasks, the third for task difficulty, and the fourth for how often they used the app. Subsequently, they had the opportunity to also give individual feedback and to share their experiences in three open questions. Finally, after completion, participants were thanked for their participation.

2.4 Data Analysis

The data obtained in this study was analyzed using the computer program IBM SPSS Statistics. In a first step, the data was analyzed for descriptive statistics to gain an overview of the data. Subsequently, the data file was split into groups of high and low vitality scores in explicit and implicit measures at baseline level. For implicit vitality, the data file was split into the groups 'vitality bias' (*D*-scores below 0 at baseline level), and 'fatigue bias' (*D*-scores above 0 at baseline level). For explicit vitality, the data file was split into the groups 'fatigued group' (cases below population average of the SVS averaged total scores at baseline level) and the 'vital group' (cases above population average of the SVS averaged total scores at baseline level). The descriptive statistics analysis was repeated for each of the four groups separately. Means and standard deviations were also computed for the feedback ratings 'general liking', 'understanding', 'task difficulty', and 'adherence' to app use.

In a second step, the mean difference between pre- and posttest SVS averaged total scores was computed, to test the influence of the IVY Training app on explicit vitality. A Shapiro Wilk test was run to test for normality and subsequently the Wilkoxon signed-rank test was executed to compute the mean difference and its significance. Effect sizes were calculated by subtracting the means and dividing the outcome by the pooled standard deviation, not only for this analysis of mean difference, but also for the following analyses. To find out whether adherence to app use can be related to post intervention increases in explicit vitality, the relationship between the difference scores of explicit vitality and adherence to app use was assessed using the Spearman's rank-order correlation.

In a third step, the mean difference between pre- and posttest *D*-scores was computed, to assess the influence of the IVY Training app on implicit vitality. A Shapiro Wilk test was run to test for normality and subsequently the paired-samples t-test was run to test for the mean differences. Subsequently, the relationship between adherence to app use and post intervention increases in implicit vitality was investigated, using the Spearman's rank-order correlation.

Both step two and three were also run for each of the vitality/fatigue bias groups and the vital/fatigued groups separately. These analyses were to provide insight into the influence of the intervention on explicit and implicit vitality with regards to individuals who were either showing fatigue or vitality at baseline level as expressed explicitly or as assessed with implicit measures.

In a fourth step, frequencies of participant ratings of their general liking, understanding of the app, task difficulty, and their adherence to app use were assessed, to gain an overview of the feedback data. Furthermore, their individual feedback was sorted into overarching subjects, to gain more insight into the usability of the app which holds implications for the evaluation of the app's influence on vitality. Subsequently, a cumulative odds ordinal logistic regression was performed to assess whether participants' ratings of general liking, understanding, and task difficulty of the app were associated with the variation in adherence to app use. This analysis was to provide insight into adherence in order to being able to draw further inferences about adherence's importance for intervention success.

3. Results

3.1 Descriptives

On average, participants had a score of 4.62 out of 7 ($\sigma = .99$) on the SVS averaged total score of the pre-test. A score slightly above medium vitality; On the posttest participants reached on average a score of 4.82 ($\sigma = 1.04$). Implicit vitality was measured with the self-identity IAT which yielded *D*-scores. On average, participants had a *D*-score of -.18 ($\sigma = .39$) on the pretest and a *D*-score of -.60 ($\sigma = .36$) on the posttest, showing an increase in vitality bias. When split into groups of vitality/fatigue bias (negative *D*-scores / positive *D*-scores) and vital/fatigued groups (above population SVS average / below population SVS average), means and standard deviations deviated from the values of the whole sample. Participants in the vital group showed a decrease in explicit vitality and an increase in implicit vitality. Participants in the fatigued group showed an increase in both explicit and implicit vitality. Vitality biased students showed an increase in both explicit and implicit vitality, and fatigue biased students showed a decrease in explicit vitality but an increase in implicit vitality (for details see Table 3). General liking of the app, understanding, perceived task difficulty, and adherence to app use were also measured to have a further indication of the app's influence on vitality. On average, participants rated the app with 3.88 out of 5 ($\sigma = .85$) a 'good' rating. Understanding was rated with a mean of 4.75 out of 5 ($\sigma = .61$), a score close to always understanding. Task difficulty was on average rated as 1.27 out of 5 ($\sigma = .52$), a rating between 'never' and 'rarely' difficult. The participants used the app on average a little more frequently than almost every day with a rating of 5.16 out of 6 ($\sigma = 1.25$) (see Table 3 & Figure 4).

Table 3

Descriptives

		Pretest		Posttest	
		Mean	**Standard deviation**	**Mean**	**Standard deviation**
Explicit vitality (SVS averaged total score)	Vitality bias (N = 38)	4.73	1.03	5.07	.99
	Fatigue bias (N = 18)	4.40	.88	4.29	.99
	Vital group (N = 29)	5.36	.64	5.10	1.02
	Fatigued group (N = 27)	3.83	.62	4.51	1.00
	Total (N = 56)	**4.62**	**.99**	**4.82**	**1.04**
Implicit vitality (D-scores)	Vitality bias (N = 38)	-.38	.28	-.67	.36
	Fatigue bias (N = 18)	.23	.21	-.45	.33
	Vital group (N = 29)	-.19	.38	-.58	.38
	Fatigued group (N = 27)	-.18	.39	-.63	.36
	Total (N = 56)	**-.18**	**.39**	**-.60**	**.36**
General liking app				3.88	.85
Understanding				4.75	.61
Perceived task difficulty				1.27	.52
Adherence				5.16	1.25

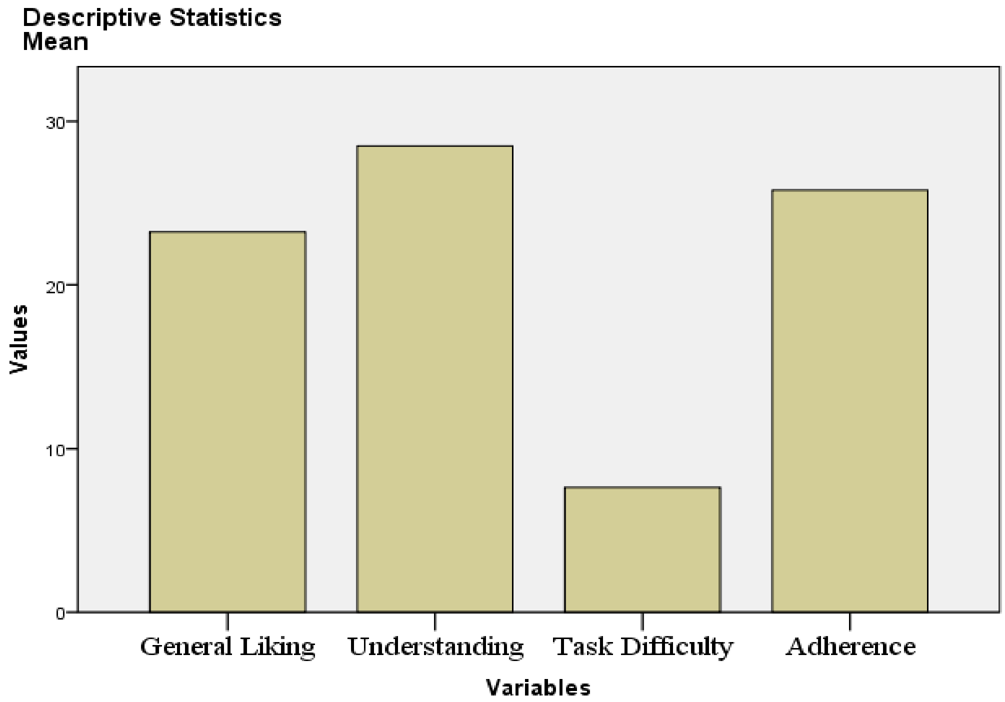

Figure 4. Ratings of the IVY training app and app use, with a maximum score of 30 representing 'very good'/'always'/'every day'

3.3 Research Question 1

To answer the first research question "*What is the influence of the IVY Training app on explicit vitality?*" the mean difference between pre- and posttest SVS averaged total scores was computed. It was hypothesized that the mean difference between both measurements is significant with mean values tending towards more vitality on posttest. Four outliers were detected that were more than 1.5 box-lengths from the edge of the box in a boxplot. Inspection of their values did not reveal them to be extreme and they were kept in the analysis. Since the difference scores of the SVS total scores between pre- and posttest were found not to be normally distributed, as assessed by Shapiro Wilk's test (p = .045), it was chosen to use the Wilkoxon signed-rank test as a non-parametric alternative. Out of the 56 participants, an increase in vitality was observed in 30 participants, whereas a decrease was observed in 17 participants. In 7 participants there were no improvements observed in vitality. The Wilkoxon signed-rank test determined that the improvements in explicit vitality from pre- to posttest were statistically not significant (Mdn = .1650), z = -1.689, p = .091. Therefore, hypothesis 1a was rejected for the whole sample.

Split for vitality and fatigue groups. When splitting the file into the two groups vitality bias and fatigue bias at baseline level, different outcomes were obtained, however.

The difference scores between pre- and posttest were found not to be normally distributed for the vitality bias group ($W(38) = .940$, $p = .041$), but normally distributed for the fatigue bias group ($W(18) = .956$, $p = .527$). Both the paired-samples t-test and the Wilkoxon signed-rank test as the nonparametric alternative, however, came to the same conclusion. The paired-samples t-test showed that the increase in vitality was statistically significant for the vitality bias group, $\mu = .34$, 95% CI [-.005, .679], $t(37) = 1.996$, $p = .05$ with a small effect size ($d_{Cohen} = .337$) (Cohen, 1992). For the fatigue bias group, the paired-samples t-test showed that the decrease in vitality was not significant, $\mu = -.11$, 95% CI [-.590, .370], $t(17) = -.484$, $p = .635$. The Wilkoxon signed-rank test also showed a significant increase in explicit vitality for the vitality bias group ($z = -2.138$, $p = .033$), and no significant difference for the fatigue bias group ($z = -.259$, $p = .795$). Therefore, hypothesis 1a was accepted for the vitality bias group but rejected for the fatigue bias group.

When splitting the file into the two groups of below and above population average scores on the SVS averaged total score at baseline level – in the following called fatigued and vital groups – the outcomes were again different. The Wilkoxon signed-rank test showed a significant increase in explicit vitality for the fatigued group ($z = -2.237$, $p = .025$) with a large effect size ($d_{Cohen} = .817$), but not for the vital group ($z = -.582$, $p = .561$). Therefore, hypothesis 1a was accepted for the fatigued group but rejected for the vital group.

Adherence's relationship with the intervention outcome. To find out whether there is a relationship between the low difference scores of explicit vitality and (non-) adherence to app use, a Spearman's rank-order correlation was run, first for the whole sample, then split into vitality and fatigue groups. It was hypothesized that increases in explicit vitality are positively related to app use. A preliminary analysis showed the relationship for the whole sample to be monotonic, as assessed by visual inspection of a scatterplot. The correlation between difference scores of explicit vitality (SVS) and adherence to app use was found to be statistically significant, $r_s(54) = .294$, $p < .05$. This is a low positive correlation (Mukaka, 2012), indicating that low scores in adherence to app use are related to low difference scores. Therefore, hypothesis 1b was accepted for the whole sample.

When split into vitality bias and fatigue bias groups, the correlation proved to be significant for the vitality bias group, $r_s(36) = .420$, $p = .009$, and not significant for the fatigue bias group, $r_s(16) = .043$, $p = .865$. Therefore, hypothesis 1b was accepted for the vitality bias group but rejected for the fatigue bias group.

When split into fatigued and vital groups, the correlation proved to be significant for the fatigued group, $r_s(25) = .521$, $p < .01$, and not significant for the vital group, $r_s(27) = .064$,

p = .743. Therefore, hypothesis 1b was accepted for the fatigued group but rejected for the vital group.

Relationship between vitality/fatigue bias and vital/fatigued groups. Due to these contrary results, a chi-square test for association was run, to assess whether there is a reverse relationship between the two grouping variables vitality/fatigue bias and fatigued/vital groups. The association between both groupings was not significant, $\chi^2(1) = .034$, $p = .854$. This indicates that although the reverse outcomes suggested a reverse relationship, both groupings were actually not related with each other.

3.4 Research Question 2

To answer the second research question "*What is the influence of the IVY Training app on implicit vitality?*", the mean difference between pre- and posttest *D*-scores was computed. It was hypothesized that the mean difference between both measurements is significant with mean values tending towards (more) vitality bias on posttest. Three outliers were detected that were more than 1.5 box-lengths from the edge of the box in a boxplot. Inspection of their values did not reveal them to be extreme and they were kept in the analysis. The difference scores between pre- and posttest measurements of implicit vitality – that is between D-scores – were normally distributed, as assessed by a Shipiro Wilk's test (p = .768). Therefore, the paired-samples t-test was selected as suitable. The analysis showed that the increase in vitality bias was statistically significant, μ = -.42, 95% CI [-.522, -.312], $t(55) = -7.969$, $p < .001$, which is a large effect size (d_{Cohen} = -1.111) (Cohen, 1992).

Split for vitality and fatigue groups. Again, the analysis was repeated for the vitality bias group and the fatigue bias group separately. The difference scores between pre- and posttest *D*-values were normally distributed for both the vitality bias group ($W(38) = .967$, p = .327), and the fatigue bias group ($W(18) = .971$, $p = .810$). The analysis with the paired-samples t-test showed that the increase in vitality bias was significant for both the vitality bias group, μ = -.30, 95% CI [-.411, -.182], $t(37) = -5.228$, $p < .001$, with a large effect size (d_{Cohen} = -.921), and the fatigue bias group, μ = -.67, 95% CI [-.849, -.492], $t(17) = -7.921$, p < .001, with a very large effect size (d_{Cohen} = -2.444), with a larger mean difference for the fatigue bias group (MD = .68) than for the vitality bias group (MD = .29).

When split into fatigued and vital groups, the difference scores were again normally distributed for the fatigued group ($W(27) = .188$, $p = .177$), as well as for the vital group ($W(29) = .128$, $p = .904$). The analysis with the paired-samples t-test showed that the increase in vitality bias was significant for both the fatigued group, μ = -.44, 95% CI [-.615, -.275], $t(26) = -5.385$, $p < .001$, with a large effect size (d_{Cohen} = -1.188), and the vital group, μ = -

.39, 95% CI [-.527, -.254], $t(28) = -5.872$, $p < .001$ with a large effect size ($d_{Cohen} = -1.034$), with a larger mean difference for the fatigued group (MD = .44) than for the vital group (MD = .39).

On the basis of the results of both the whole sample and the split groups, hypothesis 2a was accepted.

Adherence's relationship with the intervention outcome. To gain more evidence that the significant difference scores can be related to the intervention, it was tested whether there is a relationship between the difference scores of implicit vitality and adherence, first for the whole sample and then again split into vitality and fatigue groups. For that purpose, a Spearman's rank-order correlation was run. It was hypothesized that the relationship between adherence and the difference scores of implicit vitality is significant. A preliminary analysis showed the relationship in the whole sample to be monotonic, as assessed by visual inspection of a scatterplot. The correlation between difference scores of implicit vitality (*D*-scores) and adherence to app use was found to be negative and not statistically significant for the whole sample, $r_s(54) = -.046$, $p > .05$.

This outcome remained the same when running the analysis for vitality and fatigue bias separately, with no significant relation between difference scores and adherence in the vitality bias group, $r_s(36) = -.049$, $p = .769$, and in the fatigue bias group, $r_s(16) = -.081$, $p = .750$. The same holds for the splitting into fatigued and vital groups. There was no significant relation found between difference scores of implicit vitality and adherence to app use in the fatigued group, $r_s(25) = -.097$, $p = .632$, as well as in the vital group $r_s(27) = -.122$, $p = .527$.

On the basis of the results of both the whole sample and the split groups, hypothesis 2b was rejected.

3.6 Feedback

The participants were asked to rate the app with closed questions, as well as to give feedback on their experiences with open questions. This feedback gives information on usability and is also essential for interpreting the outcome of the intervention.

When rating their general liking of the IVY Training app, most participants (66.1%) rated it as good. Furthermore, out of the 56 participants, 82.1% reported to always understand the instructions and 76.8% never experienced difficulties with the tasks of the app. When asked to rate the amount of time spend with the IVY training (their adherence to the intervention program), 53.6% reported having used the app every day (see Table 4).

Table 4

Participants' Ratings of the IVY App

		N	Percent
General Feedback	1 Very poor	2	3.6%
	2 Poor	2	3.6%
	3 Barely acceptable	6	10.7%
	4 Good	37	66.1%
	5 Very good	9	16.1%
Understanding	2 rarely	1	1.8%
	3 sometimes	2	3.6%
	4 very often	7	12.5%
	5 always	46	82.1%
Task Difficulty – Too difficult?	1 Never	43	76.8%
	2 rarely	11	19.6%
	3 sometimes	2	3.6%
Adherence	1 Never	2	3.6%
	2 Almost never	1	1.8%
	3 Sometimes	3	5.4%
	4 Most of the time	4	7.1%
	5 Almost every day	16	28.6%
	6 Every day	30	53.6%

When the participants were asked to give feedback on the IVY Training app in three open questions, 7 distinctive subjects emerged (see Table 5). Other less distinctively related participant experiences were grouped into the categories complaints about 'malfunctions' of the app (not related to one of the 7 subjects), 'ideas for improvements', 'positive feedback', and 'other experiences' the participants wanted to share. Details about these less distinctively related experiences can be found in Appendix B Table 1.

The first out of the 7 distinctive subjects included the wish to have a progress overview which shows the minutes/hours/days completed with the app, as well as the results. The second subject involved the wish to be able to switch on and off the sounds of the app. The third subject was about the common complaint that when trying to move a word on the screen, the screen was moving instead. The fourth subject involved the wish for more functional and personalizable reminders for the daily sessions. The fifth subject included the complaint that the app and the app's tasks were boring, and the sixth subject involved the request for more words in the app. Finally, the seventh subject was about the request for more information and instruction in the app (see Table 5). More details can be found in Appendix B Table 1.

Table 5

Participants' Feedback Categorized into 7 Distinctive Subjects

	Subjects	Frequency of quotes	Example
1.	**Progress overview**	15	"Maybe it would be cool to be able to see your own progress"
2.	**Switch on/off sound**	10	"a button to turn off the volume"
3.	**Moving screen**	9	"sometimes you just moved the whole screen and not only the word itself, that was a little bit annoying"
4.	**Reminders**	5	"integrate an option where the participant can individually pick the time of the day most suitable for them to receive a reminder notification."
5.	**Boring**	5	"it got boring sometimes"
6.	**More words**	4	"add a larger variety of words"
7.	**Information**	3	"Seeing what psychological factors the App is trying to measure"

A cumulative odds ordinal logistic regression was performed to assess whether participants' ratings of general liking, understanding, and task difficulty of the app were associated with the variation in adherence to app use. The assumption of proportional odds was met, as assessed by a full likelihood ratio test comparing the fit of the proportional odds location model to a model with varying location parameters, $\chi^2(12) = 16.743$, $p = .160$. The final model statistically significantly predicted the dependent variable over and above the intercept-only model, $\chi^2(3) = 17.843$, $p < .001$. Both general liking and understanding were found not to significantly predict the variation in adherence to app use, $p > .05$. An increase in experienced task difficulty, however, was associated with a decrease in the odds of adhering to app use, with an odds ratio of .214 (95% CI, .889 to .052), Wald $\chi^2(1) = 4.504$, $p = .034$.

4. Discussion

This study aimed to test the influence of the 'IVY Training' app on vitality in university students, to give first indications about the effectiveness of this newly developed CBM intervention. By manifesting the identification with vitality rather than fatigue concepts, IVY intended to counteract the negative fatigue self-concept bias and to increase vitality. This was expected to promote more healthy and active lifestyles and to counteract fatigue maintenance. This study also aimed to generate insight into the usability of the app by means of participant feedback.

The results have shown that IVY had in the overall no positive influence on explicit vitality, but a strong influence on fatigued and a weak influence on vitality biased subgroups. Low correlations with adherence supported the app's influence on these groups. IVY showed a strong influence on implicit vitality, with increases towards (more) vitality bias for all groups, in particular for the fatigue bias and fatigued groups. The non-existing relation of these outcomes with adherence to app use, however, cast doubts on whether increases can be attributed to IVY. Feedback showed good levels of liking and understanding, and low task difficulty. In the following, these results will be discussed in more detail and separately for the three research questions.

4.1 Research Question 1

The first research question was "*What is the influence of the IVY Training app on explicit vitality?*". The pretest of explicit vitality showed that the students perceived themselves on average as slightly above medium vitality, meaning that about half of the students had low vitality values. This is in line with the findings that about half of university students are fatigued (low vitality) (Law, 2007; Lee et al., 2007). The analysis showed that the small increase from pre- to posttest was not significant, showing that IVY did not influence explicit fatigue. This is in line with the finding that the effect of CBM is likely not to be explicitly noticed (Hertel & Mathews, 2011).

Split for vitality and fatigue groups. Results differed when splitting the sample into the groups of below and above sample average in explicit vitality at baseline level (fatigued/vital groups). The increase in explicit vitality was significant for the fatigued group with a large effect size, but not for the vital group suggesting that fatigued students might still benefit from IVY. Interestingly, the opposite was found for the subgroups of implicit vitality and fatigue bias at baseline level. Students who implicitly associating themselves rather with vitality than fatigue had significant increases in explicit vitality, though with a small effect size. These increases in explicit vitality contradict the finding that changes due to CBM are not consciously perceived (Hertel & Mathews, 2011).

It becomes clear that firstly, the unconscious experience of vitality before the intervention, seemed to have an influence on consciously perceived vitality after the intervention. This indicates an effect of the implicit system on the explicit one, as also found by Evans and Stanovich (2013), and Frankish (2010). However, this effect did not appear for fatigue biased students. An explanation could be that they underwent a greater change towards vitality bias than formerly vitality biased students and that these greater changes do not (yet) reach consciousness. Alternatively, students unconsciously perceiving themselves as vital, might be generally more ready to experience increases in conscious vitality. Since literature has not yet addressed this topic, these explanations should be tested by future research.

Secondly, it becomes clear that vital/fatigued groups and vitality/fatigue bias groups are distinct. The analysis indeed showed no relation between them, showing that students who consciously felt vital, did not necessarily also unconsciously associate themselves with vitality and vice versa. This is in line with Hofmann et al. (2005) who found that the conscious and unconscious experiences do not always match. On the other hand, it could have been expected to find explicitly fatigued students to also hold implicit fatigue self-concepts, as they are largely responsible for maintenance of perceived fatigue (Lenaert et al., 2018; Hughes et al., 2016). However, this might be only found in a sample of fatigued students and not in the normal population.

Adherence's relationship with the intervention outcome. The results also showed a low positive correlation between improvements in explicit vitality and adherence to app use. This shows that the outcome somehow depended on frequency of app use, but also that to some extent it did not differ how often IVY was used. This is expectable, considering that IVY only influenced subgroups, not the whole sample. According to Hertel and Mathews (2011) the amount of time needed to modify a cognitive bias probably depends on the strength of biased cognitions. This suggests that cognitive biases might probably not have been so strong in this sample or varied, which might be why improvements were not so clearly connected to adherence. When splitting into the subgroups, the analysis showed that only the significant improvements in fatigued and vitality biased groups were associated with adherence, not the insignificant improvements. This gives further support for the influence of IVY on these subgroups and might indicate a moderating effect of adherence on intervention outcomes. However, this would have to be tested by future research including a control group in the design.

Answer to the research question. Based on these findings, the first research question "*What is the influence of the IVY Training app on explicit vitality?*" can be answered. It was hypothesized that mean differences between pre- and posttest SVS measures would be significant with mean values tending towards more vitality on the posttest. This seemed indeed to be true for students explicitly perceiving themselves as fatigued and holding implicit vitality biases at baseline level. However, it seemed not to be true for students explicitly perceiving themselves as vital and holding implicit fatigue biases at baseline level. It was also hypothesized that increases in vitality would be positively related to adherence. This was found to be true only for groups showing increases on the posttest. Therefore, it can be concluded that IVY seemed to have a significant influence on consciously fatigued and unconsciously vitality biased students.

4.2 Research Question 2

The second research question was "*What is the influence of the IVY Training app on implicit vitality?*". The pretest showed on average a slight vitality bias in students, which significantly increased towards the posttest. It indicates that IVY positively influenced implicit vitality. This is in line with findings of CBM effectiveness on other conditions, such as social anxiety (Mobini et al., 2012), unhealthy eating behaviors (Schumacher et al., 2016), or alcohol addiction (Wiers et al., 2011).

Split for vitality and fatigue groups. Results for the subgroups remained similar. Improvements were significant in each group, with effect sizes being large for vitality biased students but considerably larger for fatigue biased students. Since vitality biased students were double as many as fatigue biased students, this shows that the relatively small number of fatigue biased students experienced extreme improvements. It is not clear though, whether with a larger sample of fatigued students the same extreme improvements would be reached. Explicitly fatigued students also had slightly larger effect sizes than vital students. This suggests, that all groups clearly benefitted from IVY, but that implicitly and explicitly fatigued students benefited from it in particular. These are first indications for the particular effectiveness of the app on fatigued individuals.

Adherence's relationship with the intervention outcome. There was no significant association found between adherence and improvements in implicit vitality – neither for the whole sample, nor for any subgroup. This means that frequency of app use was unrelated to the intervention's outcome. One explanation is that IVY's influence on implicit vitality was powerful and a few sessions already brought about the change. The findings of Hertel & Mathews (2011) that the time needed to change a cognitive bias probably depends on bias severity, supports this assumption since fatigue self-concepts were not so severe in this normal population sample. Another explanation is that IVY was not responsible for the improvements in implicit vitality. Rather, a training effect might have occurred after a few sessions, since the tasks in the IAT and IVY Training were similar, and both used the same words. If students did not always honestly answer the question about their adherence, this would also explain the missing link between adherence and implicit vitality improvements. These explanations remain unanswered questions that need to be addressed by future research.

Answer to the research question. Based on these findings, the second research question "*What is the influence of the IVY Training app on implicit vitality?*" can be answered. It was hypothesized that mean differences between pre- and posttest *D*-scores would be significant with mean values tending towards less bias in post-test measures. This seems to be true for the whole sample and each subgroup, particularly for the fatigue bias and fatigued groups. However, some concerns remain whether these improvements can be attributed to IVY. Therefore, with reservations, it can be concluded that the IVY Training app seems to increase vitality bias in students, especially in fatigued and fatigue biased students.

4.3 Research Question 3

On the basis of the results on research questions 1 and 2, a conclusion can also be drawn on the third research question "*What is the difference between the influence of the IVY Training app on implicit and on explicit vitality?*". The non-existing relation with adherence for implicit vitality allows only an answer with reservations. It was hypothesized that the influence of the IVY Training app would be stronger on implicit than on explicit vitality with the direction of influence being towards more vitality. This seems to be true, since considerably larger effect sizes in implicit vitality show a stronger influence of IVY, and improvements in both implicit and explicit vitality tended towards more vitality. It shows that IVY seems to evoke changes more strongly in implicitly manifested biases than in explicitly manifested biases. Further, it shows that changes seem to be stronger for fatigue than for vitality groups, suggesting that the app's orientation towards changing negative biases may lead to stronger improvements in negatively biased students than positively biased ones. Therefore, it can be concluded that IVY had a stronger influence on implicit vitality than on explicit vitality, with fatigued and fatigue biased students benefiting most from it.

4.4 Feedback

Students' ratings and experiences with IVY give more input for interpreting its influence on vitality. Overall, students experienced IVY to be good. This shows that the points of criticism mentioned, such as malfunctions or missing functions or elements, were still acceptable to them and did not essentially downgrade their experience with IVY. Students reported to almost always have understood instructions and that they perceived task difficulty as low. Furthermore, students claimed having used IVY almost every day on average. This shows again, that the experience with IVY seemed to be good, as students were motivated to use it frequently. Liking and understanding were found not to be related to app use, but increased task difficulty lowered the probability of adherence. This shows that the criticisms of IVY did not influence frequency of app use, supporting the app's ability to influence vitality. Still, improvements of IVY should be considered, especially concerning simplifications of tasks and explanations.

4.5 Implications

Since the results of this study need to be apprehended with caution, the same holds for their implications. Firstly, the results hold implications for students' further health behaviors such as more (physical) activity. Since explicit self-concepts can be related to controlled health behaviors (Asendorpf et al., 2002), the increases in explicit vitality suggest increases in controlled health behaviors. This might include taking more often the decision to engage in active behaviors such as physical activities instead of engaging in resting and activity avoidance behaviors. Similarly, the strong increases in implicit vitality would lead to strongly improved spontaneous health behaviors (Asendorpf et al., 2002). This might include, for example, spontaneously rather taking the stairs than the elevator or without consideration saying yes when being asked to join an activity. This would be opposite to the common behaviors of resting and avoiding activity in the fatigued (Lenaert et al., 2018). As a result, this might mean that IVY may also help to counteract the maintenance of fatigue symptoms by increasing the occurrence of healthy and active behaviors.

Furthermore, that fatigued and fatigue biased students benefited most from IVY implies that it might be very and particularly suitable for the target group of fatigued university students.

The analysis of participants' feedback showed that liking of IVY, including students' criticism, did not interfere with adherence. This holds the implication that the app's design and features seemed to be appropriate as intervention for fatigue self-concepts.

4.6 Strengths and Limitations

Strengths of this study include the approach of using explicit and implicit subgroup differentiation to understanding the intervention's influence on implicit and explicit vitality.

The biggest limitation to this study is the missing control group, as effects cannot be attributed to the intervention with certainty, and moderating relations of adherence cannot be established. Further, both the self-identity IAT and IVY were not validated by research before, restraining the results' meaningfulness. Also, their task similarity and use of the same words might have led to a training effect rather than an intervention effect. Another limitation is that a delay between end of intervention and completion of the posttest occurred for some students, distorting immediate intervention effects. Finally, more meaningful results on IVY's influence on the target group might have been gained from a sample of fatigued students.

4.7 Recommendations

It is recommended for future research to replicate this study while including a control group. Further, the questions that came up with this study or remained unanswered should be answered with future research. This includes whether less grave improvements in implicit vitality can be experienced in explicit vitality as opposed to more grave improvements; whether individuals who hold vitality biases are more ready to experience increases in consciously perceived vitality; or whether IVY really has an influence on resulting health behaviors. Finally, it should be assessed why improvements in implicit vitality are not related to adherence, and how many training sessions with IVY are necessary to modify fatigue self-concepts of different severities. Gaining more insight on these remaining questions, will help to improve the beneficial influence of IVY for the target group and future health behaviors.

4.8 Conclusion

It can be concluded that IVY evoked changes in fatigue self-concept towards more vitality in both explicit and implicit vitality, though with clearly stronger improvements in implicitly manifested biases. Strikingly, increases in vitality were largest in fatigued and fatigue biased students, suggesting that the target group of fatigued individuals might benefit most from the intervention. Implications also include that IVY's achieved increases in vitality might lead to increases in healthy and active behaviors, which would counteract fatigue maintenance due to resting behaviors. However, since this study first tested the IVY app, findings are merely indications and include reservations due to doubts on the attributability of improvements to the app. Nonetheless, students' good attitude towards the app, despite points of criticism, supported the usability and appropriateness of the app for the target group.

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Appendix

Appendix A: Subjective Vitality Scale (SVS) by Ryan and Frederick (1997)

1. I feel alive and vital.
2. I don’t feel very energetic.
3. Sometimes I feel so alive I just want to burst.
4. I have energy and spirit.
5. I look forward to each new day.
6. I nearly always feel alert and awake.
7. I feel energized.

Appendix B: Table 1

Details Participants’ Feedback of the IVY App grouped into 7 Distinctive Subjects and 4 Categories of Less Distinctively Related Participant Experiences

Subjects	Participants‘ remarks
1. Progress Overview	see your progress/ days you already did
	see hours/minutes until I can start next session
	Seeing results
	Maybe it would be cool to be able to see your own progress
	i wanted to look at my progress, but it did not work
	Calender if I did the procedure yet
	A timer that show how long you needed on average to assign a word to a category
	A score that indicates how many mistakes you have made
	see imporvement over time
	the process graph on the top was only partly visible on my i phone x cause of the notch
	a progress overview of some sorts
	Overview how my results are
	I don't know if it is possible but for me it would have been helpful if the app could have remembered me more than once.

	Additionally, I'd like to see some sort of achievements overview
	It would be nice when you could only do one task a day. The reason for this is that I once did the task multiple times a day since I was not sure if i did so already and the app did not tell
2. Sounds	the sounds, I thought they were kind of annoying, so I turned my volume down
	the sound
	turn sound on/off
	sound
	Feature to turn off sound
	Sound
	a button to turn off the volume
	the audio signal for wrong and right were distracting and annoying
	turn off sound/switch on
	the sounds
3. Moving Screen	No moving screen
	Swiping mistakes cause of the overlay slipping when swiping
	delete the scroll ability in the app. This causes confusion once you put somting on the wrong side
	sometimes you just moved the whole screen and not only the word itself, that was a little bit annoying
	the backround was moving so it was sometimes quite difficult to put the words in th eright order instead of the backround
	when you get too high or too low on the screen, it should not move with your finger, only the word in the middle should move with the finger
	non-scrollable background while playing
	When trying to swipe the words, the background was sliding but not the word. So I had to lift my finger and do it again in order for the game to notice my decision.
	Yes. When i sometimes swiped up or down to put the word into the correct category, my whole screen moved. It was a little annoying
4. Reminder	integrate an option where the participant can individually pick the time of the day most suitable for them to receive a reminder notification.

	I do not know if it was an issue with my mobile phone or the app but sometimes I did not get the remnder to use the app
	Sometimes I was not reminded or ignored the reminder unconsciously, so without wanting to. Reminders should be more persistent, so I am less likely to forget to do the exercise
	I think it could be valuable if you could add the possibility to have multiple reminders and not just one.
	I'd like to have some kind of a daily reminder
5. Boring	the task was not too much fun which made is difficult to do it EVERY day
	more catching task
	it got boring sometimes
	Little boring
	The task remained the same it, therefore, would have been nice if the difficulty of task increases
	More words
6. More Words	add a larger variety of words
	More words
	more words
	more words (e.g. happy, ...)
7. Information	Seeing what psychological factors the App is trying to measure
	better instructions
	workout informations
Malfunctions	Additionally, I am using an Iphone 4 and the app was working really slow and not fluent but that might be because my phone is pretty old.
	I think the app is nice. But sometimes I could not start the procedure even if I did not completed it yet
	I wasn't always able to use the app, because it wouldn't let me. Either the button " Start session" wasn't pushable or the app wouldn't open.
	there was too much battery consumption, and the app itself moved most of the time instead of the word one wanted to drg to the side was very easy to handle
	In the beginning i had struggles starting the daly session therefore i deinstalled it and installed it again. After this the app worked quite well.

	green background when the answer was right, red when it was wrong
Ideas for Improvements	It should be possible to use the app horizontally on your mobile device because my screen was too large
	what if you would let the participants make a list with words they would like to identify with themselves, or give them the opportunity to make a choice out of a previously resembled list of words. that would be more personalized.
	'he' and 'she' words, since it is very confusing if you identify yourself with one of those or get easily hung up on the thought that it is discriminating and ignorant to only include those two
	I think the swipe gesture up and down was sometimes difficult to do quickly, especially for the upper words
	visual more appealing
	swipe left and right is more dynamic than up and down
Positive Feedback	Good that the app is simple, because it makes it easier to use. All the options directly lead you to where you have to go and there was no incongruence with what every option did
	None, all were usefull. Not many options, so that it keeps the app simple to use
	I think it was an interesting experience to work with the app
Other Experiences	or tapping to match words
	maybe a restriction to not do it when you just woke up
	everything except for the game itself and the explanation
	I think I used it mostly when I was tired because just got up in the morning, also I tried to do the exercise as fast as possible, listening to my instinct and that made me make more mistakes than if I would have done it more slowly.
	I did not feel much of a difference in my judgement about the words and association with my person from the beginning to the end of the two weeks
	Connecting good things with myself, but therefore also connecting bad things with others.