Pilot Study of a Mobile Cognitive Bias Modification: The Personalised IVY App

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Abstract

Fatigue is a regularly experienced symptom in the general population, with a substantial impact on sufferers' daily life and serious effects on society as a whole. Vitality, on the other hand, leads to many benefits on an individual and societal level. Cognitive bias is thought to play a role in maintaining fatigue symptoms, in the form of a self-as-fatigued identity bias. Cognitive bias modification (CBM) has been developed as a means to adjust cognitive biases. One of such interventions is the eHealth Implicit VitalitY (IVY) app, which requires users to repeatedly pair fatigue-related words with a 'fatigued and other' category, and vitality-related words with a 'vital and me' category. The current pilot study continues the research on the IVY app and adds an element of personalisation to the IVY app. Participants used the personalised IVY app twice a day for three consecutive days and completed an online survey both before and after app use, which included measures for cognitive bias, fatigue, and vitality.

This study aims to evaluate this app's effectiveness on cognitive bias modification, investigates the effect of app use on levels of fatigue and vitality, and analyses possible moderator variables. The acquired data were analysed in a linear mixed model, which included moderation analyses to identify possible moderator variables. Overall, the personalised IVY app was effective in modifying cognitive bias towards a vitality bias but did not cause significant changes in the levels of self-reported fatigue and vitality. Of all investigated moderator variables, only the number of completed training sessions was found to be significant, with the app being effective for participants who completed all sessions and not for those who completed less than six sessions.

As a pilot study, this research already provided valuable insights. Its main contribution is the indication of the effectiveness of the personalised IVY app, which is not moderated by any variables other than number of completed sessions. The initial findings of effectivity provide important starting points for future research in personalised CBM interventions and moderation analyses, by including a large range of investigated moderator variables. To the extent of our knowledge, this study is also the first to analyse a possible moderating effect of personalisation in CBM interventions.

Introduction

Fatigue

General fatigue is a common occurrence, with 20.4% of adults globally experiencing this symptom (Yoon et al., 2023). It has been defined by Aaronson et al. (1999) as "the awareness of a decreased capacity for physical and/or mental activity due to an imbalance in the availability, utilisation, and/or restoration of resources needed to perform activity". This general fatigue can arise from everyday activities like concentrating on a task, performing an unpleasant activity, or even doing something enjoyable (Craig, 1992). Fatigue is also known as exhaustion or weariness (Sharpe, 2006), and is frequently described by respondents as "feeling tired all the time" or "feeling weak" (Lewis & Wessely, 1992). However, patients view fatigue as being different from normal tiredness, and as being uncontrollable, overwhelming, and, frequently, untreatable (Hewlett et al., 2005; Repping-Wuts et al., 2008).

Such fatigue symptoms have a negative effect on behavioural, psychological, cognitive, physiological, psychosocial, emotional, and occupational functioning, affecting quality of life and activities of daily living to varying degrees (Aaronson et al., 1999; Curt, 2000; Fisk et al., 1994; Fredriksson-Larsson et al., 2013; Kouijzer et al., 2018; Oliva Ramirez et al., 2021; Techera et al., 2016). Fatigue also has an economic impact on a societal level, in terms of lost productivity and healthcare costs. These figures range from $9.10 to $10.09 billion annually, and $136.4 billion in total, as measured in various countries (Reynolds et al., 2004; Ricci et al., 2007; Zhao et al., 2023). Additionally, fatigue impacts society by negatively affecting household productivity, reducing labour force productivity, lowering employment rates, and capacity to work (Curt, 2000; Oliva Ramirez et al., 2021; Reynolds et al., 2004). In fact, Horrey et al. (2011) highlight that fatigue contributes majorly to workplace and transport-related mortality and morbidity on a global level.

Fatigue symptoms that can be linked to a single cause, like a temporary illness, mental or bodily labour, inadequate recovery, or emotional distress, is also described as acute fatigue. It occurs in a healthy population and is considered to be a normal regulatory response, with a rapid onset and short duration. A distinction is usually made between this kind of fatigue and chronic fatigue, which can be a common symptom in health conditions (e.g. chronic pain, fibromyalgia, kidney disease, cancer, multiple sclerosis, chronic obstructive pulmonary disease (COPD), myocardial infarction, rheumatoid arthritis, sleep disorders, and depression (Connolly et al., 2013; Curt et al., 2000; Fava et al., 2014; Fredriksson-Larsson et al., 2013; Geerts et al., 2023; Katz, 2017; Kouijzer et al., 2018; Oliva Ramirez et al., 2021; Smolensky et al., 2011; Vincent et al., 2013)). Conversely, fatigue in people with chronic fatigue syndrome (CFS) cannot be explained by such somatic conditions (Afari & Buchwald, 2003). Chronic fatigue cannot be alleviated by normal restorative techniques and is characterised by a more insidious onset, persisting over time, and being perceived as unusual, excessive, or abnormal (Aaronson et al., 1999; Techera et al., 2016).

Related to the concept of fatigue is vitality, which has been defined as “a positive feeling of aliveness and energy” (Ryan & Frederick, 1997), and is related to high physical and mental energy, vigour, and self-perceived or subjective energy (Campbell et al., 2018; Fritz et al., 2017; Weiher et al., 2022; Wood et al., 1990). In contrast to the negative effects associated with fatigue, vitality has been linked with improved physical and mental health and well-being (Lavrusheva, 2020), giving people a feeling of confidence and agency, and acting as an activating source to pursue personal goals. Additionally, vitality may reduce the risk of various diseases, and increase sleep quality and energy levels (Rozanski, 2023). Psychologically, vitality enhances mood and subjective happiness, increases creativity, can improve self-regulation and self-control, and leads to decreased anxiety (Lavrusheva, 2020; Rozanski, 2023).

In relation to these benefits, vitality also enhances work performance, leading to longer employability and providing a supportive mechanism for career success. Additionally, vitality has been linked with a decreased probability of work absenteeism (Lavrusheva, 2020; Van Steenbergen et al., 2016). Accordingly, Van Steenbergen et al. (2016) found that one point higher in vitality score was associated with a decrease of €1706 per person in total employer costs, and €1887 per person in total society costs.

Cognitive Bias

Several underlying mechanisms of fatigue have previously been identified. Among these are autonomic nervous and immune system activity, various genetic and biological mechanisms, nerve conduction, neuroendocrine activity, prolonged stress, and depression (Barsevick et al., 2010; Bol et al., 2009; Greim et al., 2007; Tanaka et al., 2011, 2013). An addition to this list of factors implicated in fatigue is cognitive bias (Geerts et al., 2023; Wolbers et al., 2021), which has been defined as “the selective processing of relevant cues over other cues in the environment” (MacLeod & Mathews, 2012). To illustrate, patients with CFS show enhanced selective attention toward health-threat information and are more likely to interpret ambiguous information somatically, giving these cues priority in cognitive processing (Hou et al., 2008, 2014; Hughes et al., 2016). Such cognitive biases may reinforce unhelpful illness beliefs and behaviours, and subsequently play a role in maintaining fatigue symptoms (Hughes et al., 2016).

According to the schema enmeshment model of pain by Pincus and Morley (2001), this biased attention, memory and processing are caused by the gradual enmeshment of three psychological schemas symbolising the symptom, the illness, and the self (Disner et al., 2011). Such schemas are defined as “cognitive frameworks enabling us to process stimuli, assign them meaning, and determine how to interpret our experiences” (Watanabe et al., 2019). This gradual enmeshment happens though frequent simultaneous activations, where activation of one schema automatically spreads to the other schemas. In a similar way, people might develop a schema of the self as a fatigued person (self-as-fatigued identity bias) when they automatically activate associations between fatigue symptoms and the self over a prolonged period (Grumm et al., 2008; Wolbers et al., 2021).

This fatigue bias can also be considered within the framework of the dual process model, which states that both automatic and controlled processing determine subsequent human behaviour, thoughts, and feelings. The automated and unconscious processing is fast, implicit, and effortless. Controlled processing, on the other hand, considers long-term goals and personal standards, which requires conscious reflection and consequently takes a longer time to complete (Strack & Deutsch, 2004). Within the framework of this model, cognitive biases are unconscious, leading to the automatic processing of specific cues in the environment over others (Wiers et al., 2013; Wolbers et al., 2021). More specifically, Ouimet et al. (2009) and Pincus and Morley (2001) found that self-schemas such as the ones involved in fatigue are also strongly embedded within the implicit system.

Cognitive Bias Modification

Such automated unconscious processes involved in cognitive biases are the focus of cognitive bias modification (CBM). CBM has been shown to be effective at inducing change on targeted biases through the retraining of learned thought patterns, with effect sizes that lie between 0.49 and 0.70 (Cristea et al., 2015, 2016; Hallion & Ruscio, 2011; Jones & Sharpe, 2017; Krebs et al., 2018; Martinelli et al., 2022; Wolbers et al., 2021). Stemming from the theoretical foundation of the dual process model, CBM targets automatic and unconscious processing with the purpose of retraining thought patterns. Similar to the activated associations that can lead to a self-as-fatigued identity bias, CBM can aim to modify such fatigue bias through simple repetitive association tasks. Additionally, studies have demonstrated that a change in bias can subsequently lead to a change in behaviour, with higher levels of bias modification resulting in greater symptom alleviation. (Jones & Sharpe, 2017; Kakoschke et al., 2017).

One such CBM was developed by Wolbers et al. (2021) for breast cancer patients, with the aim of modifying fatigue bias and subsequently reducing fatigue symptoms. This IVY (Implicit VitalityY) App attempted to do so by training participants to pair fatigue-related words with the ‘other’-category by swiping them away from themselves, and to relate vitality-related words to the ‘self’-category by swiping them towards themselves. Wolbers et al. (2021) concluded that in general, patients were open to using the IVY app for bias modification, and especially liked the simplicity of the training.

This IVY app was based on the combination of two paradigms: the Implicit Association Test (IAT) and the Approach-Avoidance Task (AAT). The IAT can be used to measure implicit biases, by assessing the strength of associations between two target concepts and two attribute categories (Geerts et al., 2023; Greenwald et al., 1998; Teige-Mocigemba et al., 2010). Similarly, the retraining of thought patterns in CBM can be achieved with simple repetitive association tasks, aiming to change the valence of a stimulus by pairing it with another stimulus (De Houwer, 2007). In the IVY app, this is done through the pairing of the ‘fatigue’ and ‘other’, and the ‘vitality’ and ‘self’ categories. The AAT is a variant of CBM, during which participants are asked to pull some stimuli towards them and push others away from them. It aims to modify biases by pairing target stimuli with a feature that requires them to be pushed or pulled, to promote avoidance or approach tendencies, respectively (Heuer et al., 2007; Kakoschke et al., 2017). The AAT is applied in the IVY app through the swiping motions.

Personalisation

The IVY app contains standard stimulus words, which are the same for all users. In a similar study by Geerts et al. (2023), participants expressed a desire for more personalisation in their training. Such a step towards personalisation has been taken in previous studies, which concluded that participants found their interventions to be feasible and acceptable, and appreciated the options for personalisation (Manning et al., 2021; Seesink et al., 2022). Additionally, the effectiveness of personalised interventions has already been established in a variety of (mental) healthcare contexts, as well as when implemented in CBM interventions (Colkesen et al., 2011; Kopetz et al., 2017; Marsden et al., 2019; Ng & Weisz, 2016; Soto-Ruiz et al., 2022; Yousuf et al., 2019). Moreover, as indicated by findings by Bolt et al. (2024), Jones and Sharpe (2017) and Riper et al. (2018), the addition of personalisation to the IVY app might also increase the adherence and effectiveness of the app. As such, an intriguing next step for the IVY app would be to allow users to personalise these stimuli.

Possible Moderators

Even though preliminary evidence seems to point towards (personalised) cognitive bias modification trainings being effective, the answers are less directive concerning possible moderators on this relationship between the training and bias modification (Boffo et al., 2019). To contribute to this research, an extra step can be taken in studies on the IVY app to include potential moderator variables.

A first possible influence on the effectiveness of the app is demographic variables, as there are initial findings that personal and demographic variables might moderate the efficacy of CBM interventions. First, age has been strongly linked to ‘fluid’ intelligence, or the ability to learn novel skills. As such, this demographic variable might be a predictor of the capacity to benefit from the IVY app. Accordingly, Liu et al. (2017), Martinelli et al. (2022), Mogoaşe et al. (2014), and Price et al. (2016) indeed identified age as a moderator variable for CBM interventions. A second potential moderator is gender, which is in line with findings from Liu et al. (2017) and Menne-Lothmann et al. (2014). Third, previous research identified symptomatology as a possible moderator variable, with CBM showing bigger effects for samples higher in symptomatology (Beard et al., 2012; Menne-Lothmann et al., 2014). Fourth, research has demonstrated prominent cultural differences in cognition and cognitive bias (Moser et al., 2022). As such, it would be interesting to investigate nationality as a possible moderator for the IVY app.

A fifth potential moderator is training adherence, as researchers have underlined the importance of investigating the number of completed training sessions as a moderator variable when evaluating the effectiveness of CBM interventions similar to the IVY app (Boffo et al., 2019; Eberl et al., 2014; Martinelli et al., 2022). Sixth, Carey et al. (2008) posited that previous exposure to technology possibly influences the effectiveness of online interventions due to increased commitment and engagement. This is further underlined by Geerts et al. (2023), who suggested that digital skill might influence the effectiveness of cognitive bias modification. As a seventh potential moderator on the efficacy of the IVY app, Vanbecelaere et al. (2023) highlighted the importance of research into hardware and software features.

A final opportunity here is to combine the extra steps of personalisation and potential moderators for the IVY app. To the extent of this researcher’s knowledge, no previous studies have investigated a possible moderating role of personalisation itself in personalised CBM interventions. However, seeing as natural language often contain ambiguous words that complicate word categorisation (Degani & Tokowicz, 2010; Eddington & Tokowicz, 2015), the possibility arises that the added element of personalisation in the IVY app might lead to ambiguous stimuli being chosen. Additionally, Marsaux et al. (2015) indicate that higher degrees of personalisation can lead to larger intervention effects, a result that might also relate to the IVY app.

This Study

The current study is a concept study that continues the research by Wolbers et al. (2021), by adding aspects of personalisation to the IVY app, with the aim of investigating whether the personalised IVY app is effective in modifying towards a vitality bias. As such, the first research question of this study is as follows: “Does the personalised IVY app significantly modify cognitive bias towards a vitality bias?”. This is supplemented by the second research question: “Does the personalised IVY app cause a significant change in levels of self-reported vitality and fatigue?”.

Additionally, this study will focus on the possible moderation effect of various demographic variables, symptomatology, number of completed training sessions, digital literacy, phone operating system, and personalisation. Therefore, the third research question of this study is: “Are there any moderator variables that significantly influence the effectiveness of the personalised IVY app?”.

Methods

Study Design

The current study employed a mainly quantitative research design, with one analysis incorporating both quantitative and interview data. The quantitative part was a single-group experimental design that consisted of three days of app usage in a row between pre- and post-measurement surveys. In the qualitative part, semi-structured interviews were conducted on a subgroup of the research sample to gain a deeper understanding of participants’ perceptions on the personalisation process.

Materials

Online Survey and Implicit Association Task

The first part of participation in the study was an online survey via the soSci platform. Participants completed similar surveys for both the pre- and post-measurement. The pre-test survey included the participant information and informed consent (see Appendices A and B), as well as demographics. Participants were asked to specify whether they are proficient in the English language, and whether they had any pre-existing conditions associated with fatigue symptoms (i.e., CFS, chronic pain, fibromyalgia, kidney disease, cancer, multiple sclerosis, COPD, myocardial infarction, rheumatoid arthritis, sleep disorders, and depression), with the aim to investigate the possible impact on the strength of implicit beliefs underlying fatigue. At the end of the post-test survey, participants were asked how many training sessions they completed in the IVY app, and on what smartphone model and operating system they used the app.

Self-Reported Fatigue. To determine the participants' level of fatigue, the Checklist Individual Strength (CIS) (Beurskens et al., 2000) was included in both the pre- and post-test survey. This questionnaire consists of 20 items that assess feelings of fatigue during the past week on a 7-point Likert scale. The CIS was validated among the working population and has shown to be a good predictor of chronic fatigue. The questionnaire showed excellent reliability for this study's population, with a Cronbach's α of 0.93 for both the pre- and post-test.

Self-Reported Vitality. To measure levels of vitality, the VITA-16 (Strijk et al., 2015) was included in both the pre- and post-test survey. The VITA-16 is a 16-item questionnaire assessing vitality level among adults during the past month. Answer options can be indicated on a 7-point Likert scale. The questionnaire showed good to excellent reliability for this study sample, with a Cronbach's α of 0.89 for the pre-test and 0.93 for the post-test.

Digital literacy. As a measure of participants' digital literacy levels, the pre-test survey included the MDPQ-16, which is a shortened version of the MDPQ (Roque & Boot, 2016). This test was originally developed for the older population but has also been found to be a reliable and valid measure of mobile device proficiency for younger adults. The MDPQ-16 shows acceptable reliability for this study sample, with a Cronbach's α of 0.78.

Fatigue or Vitality Bias. To determine participants' fatigue or vitality bias, the Implicit Association Test (Greenwald et al., 1998) was included in both the pre- and post-survey. Participants were asked to press a designated key on their keyboard, according to the category of the stimulus word in the middle of the screen. The IAT consisted of seven blocks in total (see Table 1), which were made up of different combinations of 'self/other' and 'fatigue/vitality' pairings. The average response latency per block as well as the number of wrong and valid assignments of words was measured and automatically converted into D-scores, following the regulations set out by Greenwald et al. (2003). These D-scores constitute an index value for the strength of the association measured by the IAT. The split-half reliability of the IAT for the current study sample was adjusted using the Spearman-Brown prophecy formula (Brown, 1910; Spearman, 1910) and was found to be acceptable, constituting 0.75 in the pre-test and 0.73 in the post-test.

Table 1

Blocks in the IAT

Block	Left	Right	Function	Trials
1	Self	Others	Exercise	20
2	Vitality	Fatigue	Exercise	20
3	Self + vitality	Others + fatigue	Exercise	20
4	Self + vitality	Others + fatigue	Test	40
5	Others	Self	Exercise	20
6	Others + vitality	Self + fatigue	Exercise	20
7	Others + vitality	Self + fatigue	Test	40

Personalisation. In a final section of the survey, participants were asked to rank previously validated fatigue- and vitality-related stimulus words (Geerts et al., 2023) (see Table 2) on a scale of 1 to 10, based on the word's representativeness of the participant's personal perception of fatigue or vitality. In addition, participants were asked to provide three personalised stimulus words they associate with fatigue and three personalised stimulus words they associate with vitality. These stimulus words had to be a single word, should not be found on the existing list of stimuli, needed to be clear and explicit, and needed to be personally relevant for the participant. A full list of all idiosyncratic words and the frequency with which they were chosen can be found in Appendix A.

Table 2

Existing list of stimulus words.

Vitality	Fatigue
Energetic	Exhausted
Fit	Spiritless
Lively	Weak
Awake	Slow
Active	Dull
Strong	Sleepy
Vital	Fatigued
Fast	Lifeless
Powerful	Powerless
Attentive	Tired

CBM Application IVY

The eHealth Application IVY is part of the Twente Intervention and Interaction Machine (TIIM), which has been developed by the BMS Lab of the University of Twente. The personalised IVY app contained the personal stimuli that were entered by participants in the pre-test survey and were converted by the researchers into personalised frequencies with the help of the calculation table in Appendix B. A training session in the IVY app contained 120 words and was composed of both standard and personalised words. Each session included repeated associations between fatigue-related words and a 'fatigue and other' category, and between vitality-related words and a 'vital and me' category. These repeated associations are made with the aim of modifying cognitive bias towards a vitality bias.

Follow-Up Interviews

The first 20 participants who completed both the pre- and post-test also participated in short semi-structured interviews about the process of personalisation and their experience with the IVY app and training in general (see Appendix C for the participant information and informed consent). These interviews were held online or in-person. The full interview scheme can be found in Appendix D, but this research did not utilise the full interview information. Instead, only information about whether participants perceived their own personally chosen stimulus words as ambiguous was used.

Procedure

Participants who accessed the survey were informed about the procedure and all steps included in the study. After participants were provided with participant information and the option for informed consent, the survey could be started. Participants started with answering questions about demographics, English proficiency, technology use and pre-existing medical conditions. Afterwards, participants filled in the CIS and VITA-16, and subsequently took part in the IAT. They subsequently ranked stimulus words and entered their personal words. At the end of the survey, participants created a personal code for identification purposes, and entered their email address. The pre-test survey took approximately 20 minutes.

Upon completion of the pre-test survey, participants were automatically sent an email with further instructions regarding the downloading and registration of the IVY intervention in the TIIM app. After completion of the registration, the researchers would create the personalised IVY interventions for each participant, which would become available in the TIIM app within 24 hours. Participants received a notification when their personalised training sessions were available, so that they could start with their IVY intervention.

Within a training session, participants were instructed to swipe the stimulus word appearing in the middle of the screen either towards the 'vital and me' category (towards oneself, at the bottom of the screen) or towards the 'fatigued and other' category (away from oneself, at the top of the screen). The category would turn green if the stimulus word was swiped to the right category, and red if it was swiped to the wrong category (see Figure 1).

This immediate feedback was supplemented with the sound of a bell for a correct swipe, or an unpleasant sound for an incorrect swipe. Overall, participants were expected to engage in a total of six training sessions over the course of three days, with one session becoming available at 8am and one at 4pm. Each training session lasted approximately 5 minutes, leading to a total of around 30 minutes for the training session in the IVY app.

Four days after completion of the pre-test, participants were sent an invitation email to participate in the post-test. This survey again consisted of the CIS, VITA-16 and IAT, as well as questions about participants' phone system and the number of completed training sessions. The post-test survey took approximately 15 minutes. A full overview of the procedure can be viewed in Figure 2.

Figure 1

Phone Screen of the IVY Intervention During Training.

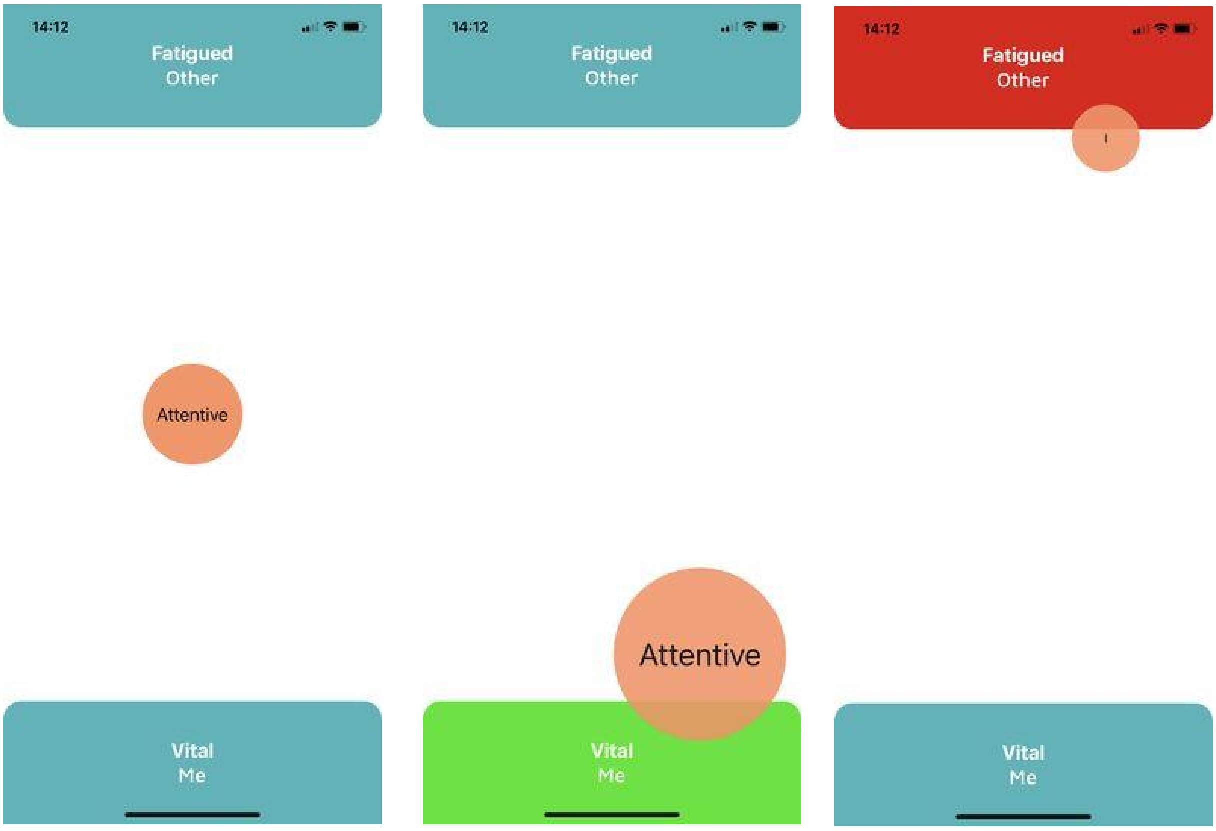
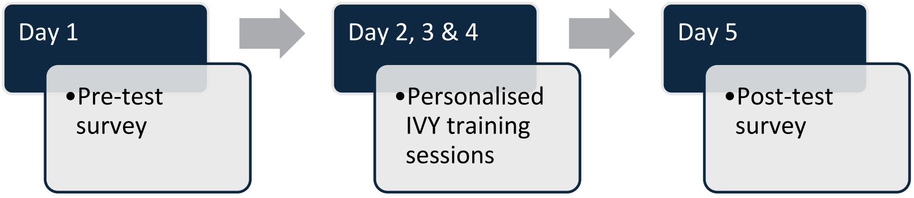


Figure 2

Timeline of the procedure for participants.



Participants

The sample of this study included 42 participants who fulfilled the requirements for participation in the study. The inclusion criteria incorporated a minimum age of 18 years, access to a smartphone and a laptop, and proficiency in English. There were no exclusion criteria. As this research is a concept study of the personalisation of the IVY app, both people with and without fatigue symptoms could take part in the study. Participants were recruited using the convenience sampling method. Students from the BMS faculty of the University of Twente could sign up through a university system and were awarded with one SONA point (of which they need a minimum of ten before their graduation) upon completion of participation. Additionally, friends and peer students were recruited by the researcher.

The final sample of the study consisted of 42 participants, of which 73.81% (*N* = 31) was female and 26.19% (*N* = 11) was male. The mean age of the sample was 22.95 years (*SD* = 2.05). The interview sample was 70% (*N* = 14) female and 30% (*N* = 6) male, with a mean age of 22.55 (*SD* = 1.93). Prior to the start of the study, each participant was provided with a participant information sheet and a consent form (see Appendix E), including information on the approval of the study by the ethics committee of the University of Twente (file number 240294).

The full overview of demographics of the study sample can be found in Table 3. In this table, several variables contain grouped values. For 'nationality' and 'university', survey answers with a low response frequency (between 1 and 3) were combined into an 'other' category. The 'study field' variable contains values that were grouped by the researcher from participants' answers about their study programme. Further, seeing as only four participants did not complete all training sessions in the IVY app, these participants were put in one group instead of mentioning their individual number of completed sessions. Participants were grouped in a similar way for the 'fatigue condition' variable, seeing as only one participant currently had such a condition, four participants had had one less than 12 months ago, and two more than 12 months ago.

Table 3

Demographic variables of the final sample.

Demographic variable			*N*	Percent
Nationality				
	Dutch		23	54.76%
	German		17	40.48%
	Other		2	4.76%
Occupation				
	Working		5	11.90%
	Studying		37	88.10%
		University bachelor	22	52.38%
		University master	11	26.19%
		University of applied sciences	4	9.52%
University				
	University of Twente		22	52.38%
	Other		15	35.71%
Study field				
	Social Sciences		17	40.48%
	Medical Sciences		8	19.05%
	Engineering Sciences		6	14.29%
	Computer Science		4	9.52%
	Other		2	4.76%
Fatigue condition				
	Never		35	83.33%
	Currently/previously		7	16.67%
Phone system				
	Android		20	47.62%
	iOS		21	50.00%
	MIUI		1	2.38%
Completed all training sessions				
	Yes		38	90.48%
	No		4	9.52%

Data analysis

To evaluate the effect of the personalised IVY app on fatigue or vitality bias, the automatically generated D-values as IAT scores at the pre- and post-test were compared in a linear mixed model. Here, a more negative D-value indicates a vitality bias, whereas a more positive D-value demonstrates a fatigue bias. Before the application of the linear mixed model, the parametric assumptions were tested (i.e., the homogeneity assumption and the assumption of normality of residuals). To test the assumption of normality, the Shapiro-Wilk test was used (Shapiro & Wilk, 1965). If the p-value from the Shapiro-Wilk test was smaller than 0.05, the distribution was significantly different from a normal distribution, and thus the assumption of normality was violated. If both these assumptions were found to be acceptable, the linear mixed model could be applied. However, if these were not found to be acceptable, the Wilcoxon's signed ranks test for 2 measures was used. Additionally, the data were checked for outliers. Following the guidelines by Osborne and Overbay (2004), outliers were excluded from the relevant analyses if they were more than three standard deviations away from the mean.

The linear mixed model contained a fixed effect for app use, which was a dummy variable with value 0 for the pre-test and value 1 for the post-test. It also included a random effect for 'participant', and the dependent variable was the IAT score. The model required the R package 'lmerTest', was fit by maximum likelihood, and the t-tests used Satterthwaite's method. To conclude that the IVY app has a significant effect towards a vitality bias, the effect of app use needs to be statistically significant ($p \leq 0.05$), and this change in IAT score needs to be in a negative direction. In case of a significant effect, the effect size was calculated using Hedges' *g* (Hedges, 1981).

To investigate whether there was a significant difference in levels of fatigue and vitality before and after using the personalised IVY app, the differences in CIS- and VITA-16-scores were compared between pre- and post-test. In case the parametric assumptions for a linear mixed model were acceptable, this comparison was done in similar linear mixed models as for the IAT scores, with separate models for the CIS and VITA-16 scores. In this case, however, the dependent variables were the CIS and VITA-16 scores. If one of the parametric assumptions was violated, the Wilcoxon's signed ranks test was used.

Possible moderator variables were investigated through moderation analyses, to see whether any of those variables influence the training effect of the IVY app on fatigue or vitality bias. To this end, a fixed moderation effect for the moderator variable was included in the earlier mentioned linear mixed model for the IAT scores. Here, a variable significantly moderated the relationship between app use and IAT score if the p-value was 0.05 or lower. For each possible moderator variable, a separate moderation analysis was performed. In case of a significant moderation effect, post-hoc analyses for that moderator variable were performed to further investigate this effect.

The moderator variables investigated were the variables mentioned in Table 3, as well as age and gender. University, occupation, study field, and study level were not previously identified from literature but were included as moderator variables, as it was expected that most participants would be students due to the application of the convenience sampling method. Additionally, participants' digital literacy was included, as measured by the MDPQ-16. Further, symptomatology was included through measurement of participants' base levels of vitality and fatigue (pre-test VITA-16 and CIS scores), as well as the survey question regarding fatigue conditions.

As a measure of the degree of personalisation, words with a frequency of '1' in the tables in Appendix A were marked as idiosyncratic words (e.g. 'baking' or 'commuting'). Subsequently, the number of idiosyncratic words was counted per participant, with most participants having chosen two idiosyncratic words ($N = 12$), followed by four ($N = 8$), one ($N = 7$), five and zero (both $N = 5$), three ($N = 4$), and six ($N = 1$). Word ambiguity is a variable from the follow-up interviews and describes whether interview participants perceived at least one of their own chosen stimulus words as ambiguous. For example, one such participant chose the word 'energy' as a personal fatigue-related word, but was confused during later app usage about which category they had put the word in.

In case of numerical moderator variables or dummy variables with 2 levels, the possible moderator variables were included in the linear mixed model in the previously described manner. If the variable was a dummy variable with 3 or more levels, an additional ANOVA analysis was performed on the linear mixed model with the moderation analysis. This was done in order to check for the effect of the variable as a whole, instead of the separate effects of the values or groups within this possible moderator variable.

Results

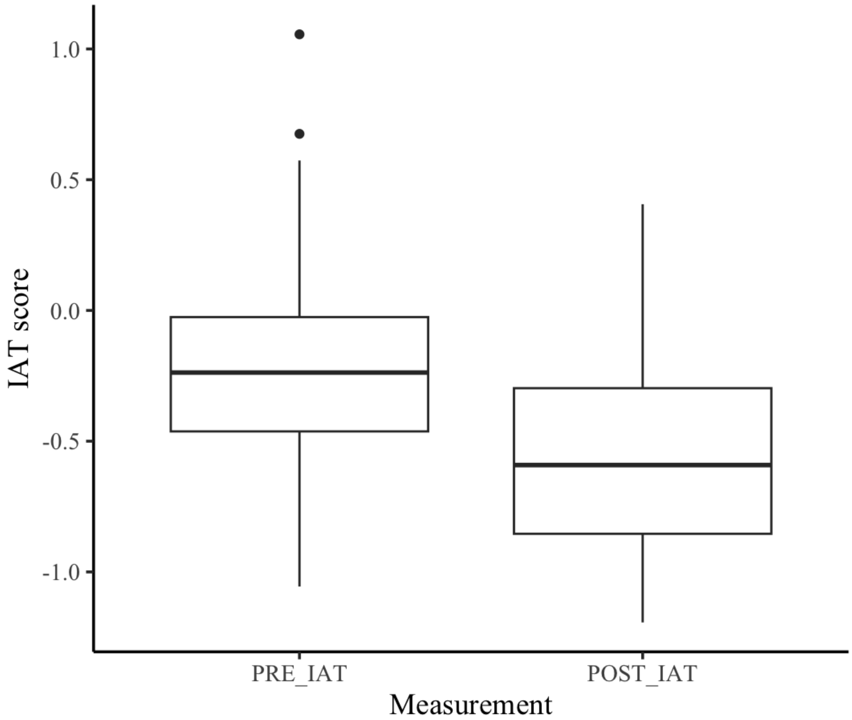
Data collection took place between 17 April and 3 May 2024. During this period, 59 participants completed the first survey, of which 44 participants (74.58%) also completed the second survey after at least 1 training session in the personalised IVY app. One of these 44 participants had to be excluded from the data analysis, because they received a standard, instead of a personalised, version of the IVY app. Another had to be removed from the dataset as they did not meet the inclusion criterium of English proficiency.

Effectiveness of the Personalised IVY App

The average score on the IAT was higher for the pre-test ($M = -0.23$, $SD = 0.42$) than the post-test ($M = -0.56$, $SD = 0.37$), indicating an average bias more towards vitality in the post-test. The distribution for these scores can be viewed in Figure 3. One of the outliers visible in this figure was more than three standard deviations away from the mean and was thus excluded from analyses with the IAT scores. The parametric assumptions for a linear mixed model were checked and were found to be acceptable (see Appendix F, Panels A and B). The pre- and post-IAT scores were analysed in a linear mixed model with a random effect for participant, which showed that the personalised IVY app was effective in modifying towards a vitality bias ($b = -0.29$, $SE = 0.07$, $t(41) = -4.31$, $p < 0.001$), and that this effect was moderate ($g = 0.76$, 95% CI [0.36, 1.16]).

Figure 3

Boxplots for the distribution of IAT scores on the pre- and post-test.



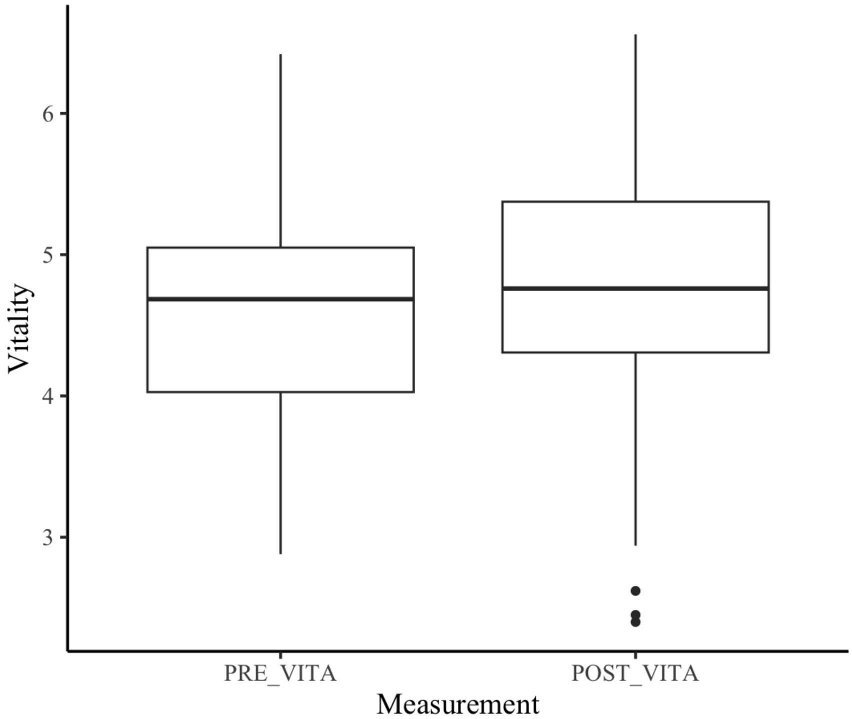
Note. Positive scores (> 0) on the IAT indicate a bias towards fatigue, whereas negative scores (< 0) on the IAT indicate a bias towards vitality.

Effect of the Personalised IVY App on Levels of Self-Reported Vitality and Fatigue

There was no change in the average score on the VITA-16 for the pre-test (M = 4.62, SD = 0.86) and post-test (M = 4.66, SD = 1.04), indicating a similar average level of vitality at both measurement points. The distribution of these scores can be viewed in Figure 4. No outliers were found to be more than three standard deviations away from the mean. Both the normality assumption (p = 0.01) and the homogeneity assumption were not found to be acceptable (see Appendix F, Panels C and D), so the non-parametric Wilcoxon's signed ranks test was performed instead. This test did not show a significant difference between the level of vitality before and after use of the IVY app ($T^+ = 530.5$, $T^- = 372.5$, p = 0.32).

Figure 4

Boxplots for the distribution of vitality (VITA-16) scores on the pre- and post-test.

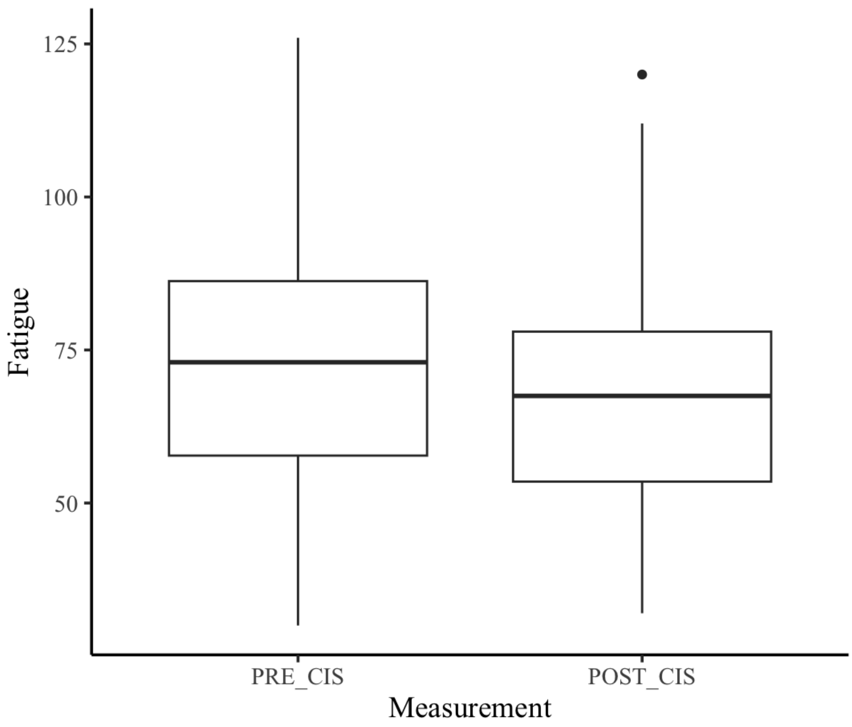


Note. Higher scores on the VITA-16 indicate higher levels of vitality, whereas lower scores on the VITA-16 indicate lower levels of vitality.

For the CIS, the average score was higher on the pre-test (M = 71.48, SD = 21.62) than on the post-test (M = 69.40, SD = 20.53), indicating a higher average level of fatigue at time of the pre-test. The distribution of these scores can be viewed in Figure 5. No outliers were found to be more than three standard deviations away from the mean. The parametric assumptions for a linear mixed model were found to be acceptable (see Appendix F, Panels E and F). The pre- and post-CIS scores were analysed in a linear mixed model with a random effect for participant, which showed that use of the personalised IVY app did not lead to a significant change in level of fatigue (b = -2.07, SE = 2.80, $t(42)$ = -0.74, p = 0.46).

Figure 5

Boxplots for the distribution of fatigue (CIS) scores on the pre- and post-test.



Note. Higher scores on the CIS indicate a higher level of fatigue, whereas lower scores on the CIS indicate a lower level of fatigue.

Moderation Analyses

Many possible moderator variables were previously identified. These moderation analyses were included in the previously specified linear mixed model for the IAT scores. The parametric assumptions were checked for the models of each of the moderator variables and were all found to be acceptable (see Appendix F, Panels G to AJ). Of these variables, only 'full sessions' was found to significantly moderate the relationship between the pre- and post-scores on the IAT. An overview of the moderation effects of the numerical and dichotomous categorical variables can be found in Table 6. The results of the ANOVA analyses for dummy variables with more than two levels can be found in Table 7. The digital literacy scores were highly skewed, with 21 participants (50.00%) obtaining the full score (see Figure 6). As such, this variable was dichotomised into participants who obtained the full score and participants who did not. That second group of participants completed an average of 3.75 sessions.

The variable 'Ambiguous words' is obtained from the interview sample, in which only 20 out of 42 participants took part. As such, a new linear mixed model analysis first had to be performed to analyse the effect of app use on post-IAT score in this interview sample. In this sample, the average score on the IAT was higher for the pre-test (M = -0.09, SD = 0.46) than the post-test (M = -0.58, SD = 0.39), indicating an average bias more towards vitality in the post-test. The distribution of these scores can be viewed in Figure 7. None of the outliers visible in this figure were more than three standard deviations away from the mean. The parametric assumptions for a linear mixed model were checked and were found to be acceptable (see Appendix F, Panels AK and AL). The pre- and post-IAT scores were analysed in a linear mixed model with a random effect for interview participant, which showed that the personalised IVY app was effective in the interview sample in modifying towards a vitality bias ($b = -0.49$, $SE = 0.13$, $t(20) = -3.79$, $p = 0.001$), and that this effect was large ($g = 1.10$, 95% CI [0.34, 1.87]).

Figure 6

Histogram for the distribution of digital literacy (MDPQ-16) scores.

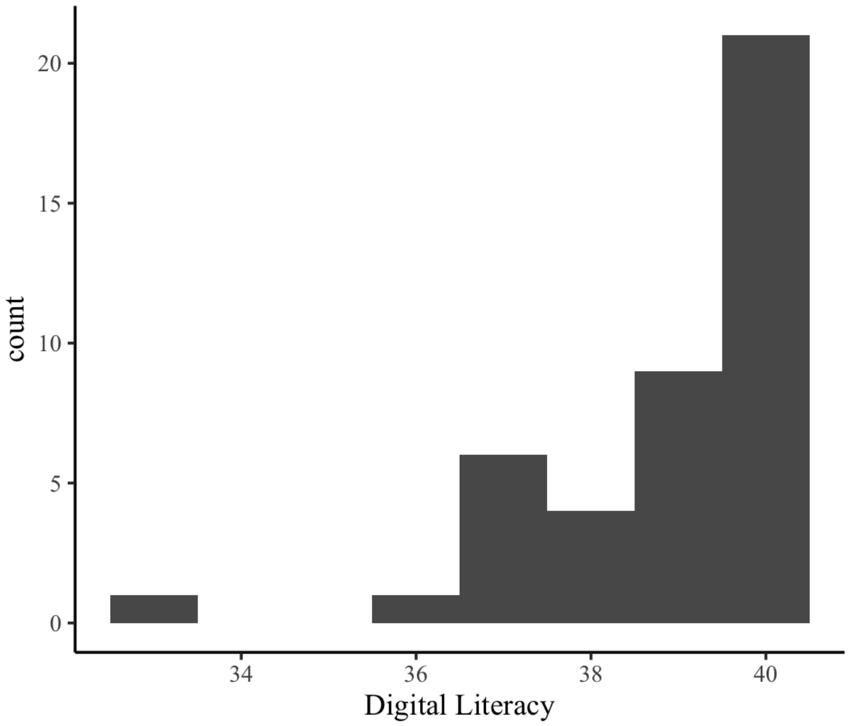
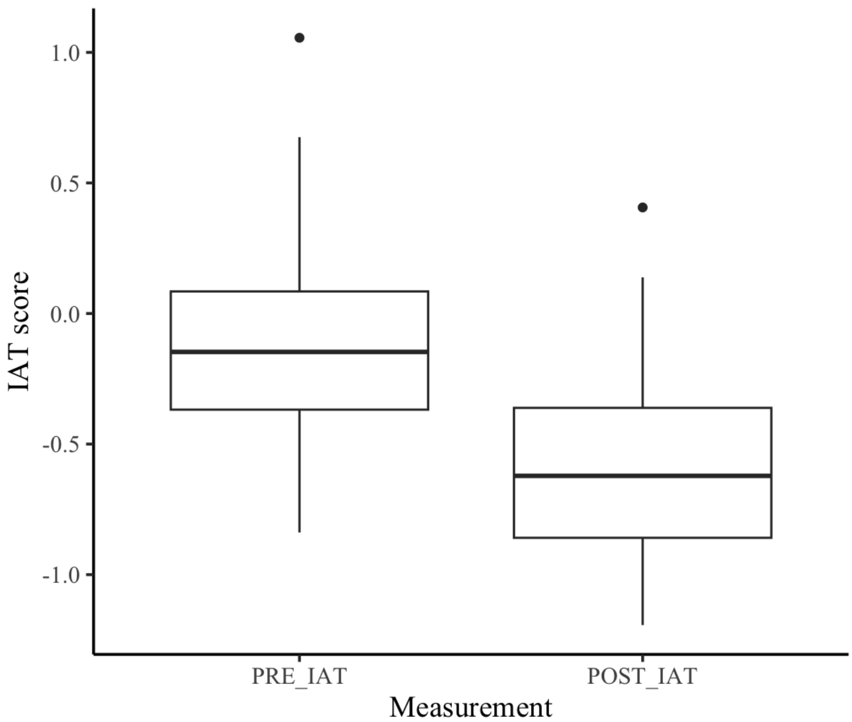


Figure 7

Boxplots for the distribution of IAT scores on the pre- and post-test in the interview sample.



Note. Positive scores (> 0) on the IAT indicate a bias towards fatigue, whereas negative scores (< 0) on the IAT indicate a bias towards vitality.

Table 6

Moderation effects of numerical and dichotomous categorical moderator variables.

Variable	*b*	*SE*	*DF*	*t*	*p*
Age	-0.00	0.03	41	-0.06	0.95
Gender	-0.00	0.16	41	0.02	0.98
University	-0.18	0.15	36	-1.18	0.25
Occupation	0.22	0.20	41	1.08	0.29
Fatigue condition	0.09	0.18	41	0.48	0.64
Full sessions *	-0.50	0.21	41	-2.35	0.02
Digital literacy	-0.14	0.13	41	-1.07	0.29
Idiosyncratic words	0.04	0.04	41	1.01	0.32
Fatigue level	-0.01	0.00	41	-1.77	0.08
Vitality level	0.00	0.00	41	0.96	0.34
Ambiguous words	0.24	0.25	20	0.92	0.37

Note. 'Age' describes the age of participants. 'Gender' is a dummy variable with value 1 for male and 0 for female. 'University' is a dummy variable with value 1 for the University of Twente and 0 for other universities. 'Fatigue condition' is a dummy variable with value 1 for participants who currently have or previously had a condition associated with fatigue, and value 0 for participants who do not. 'Full sessions' is a dummy variable with value 1 for participants who completed all training sessions in the IVY app, and value 0 for those who did not. 'Digital literacy' is a dummy variable, with value 1 for participants who got the maximum score on the MDPQ-16 and 0 for those who did not. 'Idiosyncratic words' describes the number of idiosyncratic personal stimulus words chosen by participants. 'Fatigue level' describes participants' scores on the pre-test CIS questionnaire. 'Vitality level' describes participants' scores on the pre-test VITA-16 questionnaire. 'Ambiguous words' is a

dummy variable, with value 1 for participants in the interview sample who perceived at least one of their stimulus words as ambiguous, and value 0 for those who did not.
* $p < 0.05$.

Table 7

Outcomes of ANOVA analysis on categorical moderator variables with more than two levels.

Variable	*NumDF*	*DenDF*	*F*	*MSE*	*p*
Nationality	2	41	1.20	0.11	0.31
Study field	4	36	1.93	0.16	0.13
Study level	2	36	1.08	0.10	0.35
Phone system	2	41	0.04	0.00	0.96

Note. ‘Nationality’ describes participants’ nationalities, with values ‘Dutch’, ‘German’, and ‘Other’. ‘Study field’ describes the study field of studying participants and contains the values ‘Social Sciences’, ‘Medical Sciences’, ‘Engineering Sciences’, ‘Computer Science’, and ‘Other’. ‘Study level’ describes the study level of studying participants and contains the values ‘University Bachelor’, ‘University Master’, and ‘University of Applied Sciences’. ‘Phone system’ describes the system on which participants used the IVY app and contains the values ‘Android’, ‘iOS’, and ‘MIUI’.

Post-Hoc Analysis Moderation Effect

From the moderation analyses, the variable ‘full sessions’ was found to significantly moderate the relationship between post-IAT score and app use. Further analyses indicate that for participants who completed all training sessions, the personalised IVY app is effective in modifying towards a vitality bias. However, for participants who did not complete all sessions, this is no longer the case (see Table and Figure 8).

Table 8

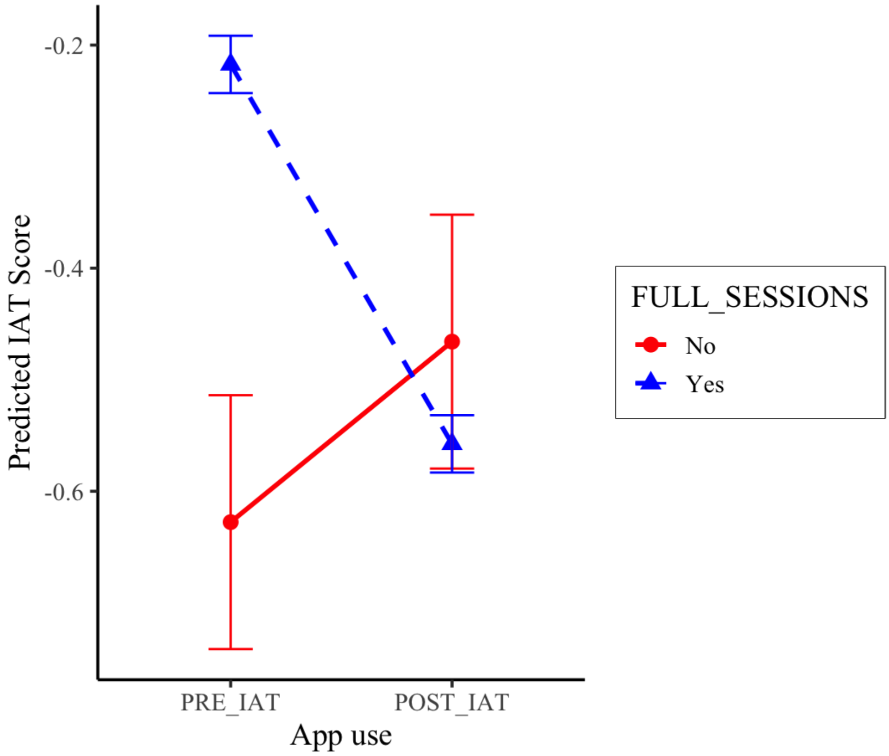
Effectiveness of the personalised IVY app for the moderator variable ‘full sessions’.

	b	*SE*	*t*(43)	*p*
Did not complete all sessions (No)				
Pre-IAT – post-IAT	-0.16	0.21	-0.77	0.44
Completed all sessions (Yes)				
Pre-IAT – post-IAT ***	0.34	0.07	4.97	<0.001

Note. *b* describes the difference between the predicted means of pre- and post-IAT scores (pre minus post), based on the predictions of the line ar mixed model including the moderator variable ‘full sessions’.
*** $p < 0.001$

Figure 8

Visualisation of the effectiveness of the personalised IVY app for participants who did and did not complete all training sessions.



Note. Positive scores (> 0) on the IAT indicate a bias towards fatigue, whereas negative scores (< 0) on the IAT indicate a bias towards vitality.

Discussion

The current study explored the addition of personalisation to the previously developed IVY app, with the main aim of investigating the effectiveness of this personalised app on cognitive bias modification. This research further aimed to analyse the effect of the personalised IVY app on self-reported levels of vitality and fatigue, as well as the potential influence of moderator variables.

Effectiveness of the Personalised IVY App

The results of this study indicated that the personalised IVY app was effective in modifying cognitive bias towards a vitality bias, with a moderate effect size. The effectiveness of the app was expected in view of a multitude of studies investigating the efficacy of CBM (Jones & Sharpe, 2017; Kakoschke et al., 2017; Menne-Lothmann et al., 2014; Wolbers et al., 2021). However, most studies reported effect sizes between 0.49 and 0.70 (Cristea et al., 2015, 2016; Hallion & Ruscio, 2011; Jones & Sharpe, 2017; Krebs et al., 2018; Martinelli et al., 2022; Wolbers et al., 2021). As such, a strength of this study is its effect size, which is higher than is usually reported by similar CBM interventions and was found after only three days of app usage.

On the other hand, the present study's effect size had a wide confidence interval, which indicates that this number might not be very representative to the population. Attia (2005) suggests that this might be due to a small sample size, though there are no further indications of such a limitation. Additionally, this study did not include a control condition. This is a limitation of the study, as the inclusion of such a group would offer the opportunity to compare the effectiveness of the personalised IVY app with a control condition, providing better support for conclusions about such effectiveness. A further limitation is the lack of a follow-up measure of fatigue and vitality bias, as it is currently unknown how sustainable to found effects on cognitive bias are. As such, future research with the personalised IVY app would preferably include a control condition, a follow-up measurement, and if possible, a bigger sample size.

Effect of the Personalised IVY App on Levels of Self-Reported Fatigue and Vitality

Secondly, the results of this study indicated that the personalised IVY app did not cause a significant change in levels of fatigue and vitality. This result is surprising, looking at findings from similar studies. For instance, Jones and Sharpe (2017) performed a meta-analysis on CBM intervention studies and found that CBM consistently alleviated anxiety symptoms, and a smaller and less robust effect on depressive symptoms. A similar study was conducted by Kakoschke et al. (2017), who found positive effects of approach bias modification on harmful consumption behaviours.

However, seeing as these studies do not investigate fatigue or vitality, the result found in the current study might instead reflect new insights for these constructs. In addition, Jones and Sharpe (2017) identified cognitive bias as a mechanism for behaviour and symptom change. This suggests that symptom change may only take place after modification in bias and might therefore take longer than bias modification. Seeing as the post-test was conducted immediately after completion of the training, it is possible that this timing was too early to allow for the change in cognitive bias to influence levels of fatigue and vitality. A limitation of the study here is the absence of a later follow-up survey in which self-reported levels of fatigue and vitality are measured. The inclusion of such a measurement would thus be recommended for future research.

Moderator Variables

The third aim of this study was to investigate possible moderation effects of a multitude of variables. Out of all potential moderators, only one was found to significantly influence the effectiveness of the personalised IVY app.

Digital Literacy

The insignificant moderation effect of digital literacy might be explained by the low variability in this study's sample, which can subsequently be identified as a limitation. The studies by Carey et al. (2008) and Geerts et al. (2023), that previously highlighted the importance of digital literacy, contained more variability within the sample, with Carey et al. (2008) including both technology users and nontechnology users. Geerts et al. (2023) did not measure digital literacy but did contain a bigger range in age of participants. Seeing as younger people are generally more digitally skilled (Schirmer et al., 2022), this likely also translates to a bigger range in digital literacy. The current research, on the other hand, was conducted on a sample of relatively young people with high digital literacy scores. As such, future research would be advised to include a bigger range of participant age or digital literacy in their sample, to provide more clarification on the unexpected findings.

Fatigue and Vitality

Related to the issue of digital literacy is the unexpected insignificant moderators of fatigue conditions and levels of fatigue and vitality. These insignificant results were also unexpected, as Beard et al. (2012) and Menne-Lothmann et al. (2014) identified symptomatology as a potential moderator. However, only a small proportion of the study sample was composed of participants who previously had a condition related to fatigue, with just one participant who had such a condition at the time of the study.

In contrast, the sample in the study by Beard et al. (2012) was composed of 2,135 participants, who could subsequently be divided into high and low symptomatology groups for the moderation analysis. This healthiness of the majority of this study's sample might have subsequently influenced levels of self-reported fatigue and vitality, leading to a potential bias in these scores. These sample composition issues thus form a limitation of the study. A larger sample variability on these variables in future research might provide more insight into their possible moderating roles. Further studies can also look closer into the moderating effect of fatigue level, as that effect was found to be nearly significant.

Demographics

The conducted analyses indicated that age, gender, nationality, study field, study level, university, phone system, being a student or working were all insignificant moderators of the relationship between app use cognitive bias at post-measurement. These results were unexpected, as Liu et al. (2017), Martinelli et al. (2022), Mogoaşe et al. (2014), and Price et al. (2016) mentioned age as a moderator variable for CBM interventions, Liu et al. (2017) and Menne-Lothmann et al. (2014) identified gender, Moser et al. (2022) mentioned nationality, and Vanbecelaere et al. (2023) underlined the importance of hard- and software. However, in the meta-analysis done by Jones and Sharpe (2017), only one out of five studies identified age as having a significant moderating role, and they also found mixed results concerning gender as a moderator variable. Additionally, the study by Moser et al. (2022) was the only study that could be found to investigate the moderating role of nationality, and this study's main aim was the analysis of culture on cognitive bias, in the context of environmental change. Their results might therefore not extend to the current study.

The study-related variables were included as the sampling method of the present study was expected to yield a high number of participants who were students. To the extent of this researcher's knowledge, no other studies have previously investigated the potential moderation of these variables in CBM. This study thus provides some first insights into this role. A further strength here is the heterogeneity of the sample for the study field variable. On the other hand, the unexpected results might relate to limitations of the current study, as it included small variability in age, nationality, university, study level, occupation, and phone system. As such, future research would ideally include a larger variability for those moderator variables, to better investigate their roles.

Personalisation

The present study did not find either measures of personalisation to significantly influence the efficacy of the IVY app. However, the operationalisation of this variable might be a limitation of the study, as the number of idiosyncratic words and word ambiguity might not completely reflect the degree of personalisation. Also, the convenience sampling method likely led to an overrepresentation of certain groups, which possibly made some words idiosyncratic (e.g. 'volleyball'), where they would not have been in a different sample composition.

So, future research continuing the personalisation of the IVY app should aim to include better measures of personalisation or even have different experimental groups with varying degrees of personalisation. An interesting step that could allow for an even bigger degree of personalisation was taken by Manning et al. (2021), who allowed participants to choose personal stimuli in the form of photos from their phone library. Such a direction could also be taken by future research with the personalised IVY app. Further studies should also aim to include more valid measures of personalisation, and ideally include an experimental group with the standard version of the app, to provide more clarification into the role and potential added value of personalisation.

Number of Training Sessions

Out of the tested moderator variables, only the number of completed sessions was found to significantly moderate the relationship between app usage and cognitive bias at post-measurement, with the app being effective in modifying towards a vitality bias for participants who completed all training sessions. However, this effect was no longer present for participants who did not finish all sessions, which further supports the indicated effectivity of the personalised IVY app in bias modification. This result was expected, seeing as Beard et al. (2012) and Boffo et al. (2019) found similar effects. It is further supported by findings from Boffo et al. (2019) and Eberl et al. (2014), who highlight the importance of at least five training sessions for CBM interventions. In the present study, participants who did not do all training trials completed an average of 3.75 sessions. However, Geerts et al. (2023) also underline the need for further research into the optimal required number of sessions.

General Limitations and Strengths

The previous sections have already mentioned specific strengths and limitations related to certain results. A main limitation is the low variability of the sample for some variables, which possibly influences the generalisability of the present study. A further example of such a limitation is the general healthiness of the sample. As such, it would be interesting for future research to investigate the effectiveness of the personalised IVY app in specific subgroups (such as older populations, or fatigued participants). On the other hand, a strength of this study is that it included a large range of potential moderator variables, compared to previous studies investigating moderation effects for CBM interventions. This provides a good basis to build upon for future studies with the personalised IVY app or CBM interventions in general.

Contributions

Despite its limitations, this study also brings some notable insights. First, this research included a big range of moderator variables, Additionally, to the extent of this researcher's knowledge, this study is the first to analyse a possible moderating effect of personalisation in personalised CBM interventions. Most importantly, however, the current study demonstrated the effectiveness of the personalised IVY app in modifying cognitive bias towards a vitality bias. Also, only the number of completed training sessions was found to significantly moderate this efficacy, further underlining this efficacy. The rest of the possible moderator variables were all found to be insignificant, meaning that the personalised IVY app is effective, no matter the user's age, gender, nationality, and so on. That insight provides a promising outlook for the future of personalised CBM interventions.

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Appendix A

Personal Stimulus Words

Table A1

Idiosyncratic personal stimulus words for vitality, and their frequencies.

Personal stimulus word	Frequency
Sport	12
Friends	8
Volleyball	6
Running	5
Walk/walking	4
Hiking	4
Sun/sunshine	4
Music	4
Outdoors/outside	3
Nature	3
Holiday	3
Social/socialising	3
Healthy	3
Travelling	3
Singing	3
Vacation	2
Competition	2
Happy	2
Biking/cycling	2
Inspired/inspiration	2
Laughing	2
Horse riding	1
Creating	1
Creativity	1
Cooking	1
Baking	1
Lotta	1
Pottery painting	1
Pony’s	1
Yoga	1
Boyfriend	1
Violin	1
Dogs	1
Football	1

Personal stimulus word	Frequency
Goal reaching	1
Purpose	1
Free time	1
Drinking wine	1
Skiing	1
Mountain biking	1
Family	1
Resilient	1
Prosperous	1
Snowboarding	1
Skating	1
Helping	1
Swimming	1
Camping	1
Motivated	1
Engaged	1
Functioning	1
Going out	1
Drawing	1
Gym	1
Satisfied	1
Blossom	1
Picnic	1
Talking	1
Handball	1
Competence	1
Calm	1
Peaceful	1
Activities	1
Sleep	1
Thriving	1
Dynamic	1
Robust	1

Table A2

Idiosyncratic personal stimulus words for fatigue, and their frequencies.

Personal stimulus word	Frequency
Study/studying	8
Lonely/loneliness	5
Bored/boredom	5

Personal stimulus word	Frequency
Stress/stressed	5
Argument/arguing	4
Phone	4

Personal stimulus word	Frequency
Sleep/sleeplessness	4
Hunger/hungry	3
Lectures	3
Drained	3
Unmotivated	2
Sick	2
Crowds	2
Injury	2
Worry/worrying	2
Bed	2
Obligations	2
Rain	2
Work/working	2
Procrastination	2
Foggy	2
Motiveless	1
Alone	1
Talking	1
Long talking	1
Disease	1
Discussion	1
Fighting	1
Conflicts	1
Conference	1
Exam preparation	1
Shopping	1
Loudness	1
Setbacks	1
Overthinking	1
Overworking	1
Partying	1
Responsibility	1
Family	1
Dark	1
Hangover	1
Uncomfortable	1
Life	1
Getting up	1

Personal stimulus word	Frequency
Drama	1
Expectations	1
Alcohol	1
Deprived	1
Low	1
Gone	1
Quiet	1
Empty	1
Unmoving	1
Travelling	1
Coding	1
Moving house	1
Socialising	1
Commuting	1
Sad	1
Lazy	1
Headaches	1
Aimless	1
Tracksuit	1
Friction	1
Hopelessness	1
Negativity	1
Repetitiveness	1
Self-reproach	1
Winter	1
Unhealthy	1
Anxiety	1
Fear	1
Energy	1
Depressed	1
Sluggish	1
Lethargic	1
Driving	1
Videos	1
Dejected	1
Doing nothing	1
Couch	1

Appendix B

Calculation Table Personalised Stimuli

Vitality	Frequency	Fatigue	Frequency
Personal stimulus 1	4	Personal stimulus 1	4
Personal stimulus 2	4	Personal stimulus 2	4
Personal stimulus 3	4	Personal stimulus 3	4
Preference 1	4	Preference 1	4
Preference 2	4	Preference 2	4
Preference 3	3	Preference 3	3
Preference 4	3	Preference 4	3
Preference 5	3	Preference 5	3
Preference 6	3	Preference 6	3
Preference 7	2	Preference 7	2
Preference 8	2	Preference 8	2
Preference 9	2	Preference 9	2
Preference 10	2	Preference 10	2
Total	40	Total	40

Appendix C

Participant Information and Informed Consent for the Interview

Dear Participant,

in the past days you used the eHealth Application IVY to retrain your brain. You were asked to repeatedly pair fatigue-related stimuli with “other” and vitality-related stimuli with “self”. You were asked to personalise the application according to your individual preferences in two ways, by ranking existing stimuli according to how much the words appealed to you, but also by choosing three words freely. The first aim of our study is to find out whether the personalised version of the IVY Application is effective.

The second aim of the research is to examine the feasibility and the acceptance of the IVY App. This is also the reason why we meet for the online interview today. I would like to find out more about the process of personalising and assess the practicality and limitations of the personalised version of the application. I would like to know how easy or difficult it was for you to find personal stimuli words and how satisfied you were with the training.

The study, including this interview, was approved by the Ethics Committee of the Faculty of Behavioural, Management, and Social Science at the University of Twente. The interview is going to take place online via Zoom or Microsoft Teams and will last approximately 15 minutes. The interview will be held in English. By giving consent, you agree that this research is completely voluntary and that you understand that you can drop out at any point. In case you would like to withdraw from the interview, please let me know that you would like to quit participating. Withdrawing from the study will not have any negative consequences for you and all the data gathered thus far will be destroyed. There are no major risks associated with participating in the interview.

The obtained data will consist of a recording of the Zoom or Microsoft Teams session (audio and video). The recording is going to be transcribed (i.e., put into written form) and deleted afterwards. These transcripts will be the data source to be analysed. Prior to the analysis of the data, all personal data will be anonymised and will be used for research purposes only. The data will be stored in a secure way. Your answers will be treated confidentially. They will not be shared with other parties than the researchers and the according supervisors. The data will be stored securely after the final report is submitted.

This interview is either conducted by Insa Holtkamp or Mette Meijer, BSc Psychology students at the University of Twente. Should you have any questions, remarks, or concerns about your participation in the interview or the study, please do not hesitate to contact us via one of the following e-mail addresses:

m.meijer-3@student.utwente.nl

i.k.holtkamp@student.utwente.nl

Thank you for your participation!

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

______________________	______________________	______________________
Name Participant	Signature	Date

Appendix D

Full Interview Scheme

Research Question: To what extent do participants perceive a personalized version of the IVY application as feasible and acceptable?

Before I start the interview:

- ✓ Write down the ranking and personal stimuli words of the participant
- ✓ Double check whether information sheet and consent form have been filled in
- ✓ Ask which language (i.e., German or English)
- ✓ Ask for verbal consent

List of **probes** to be used to gain more in-depth answers:

- Interesting, can you tell me more about…
- Can you give me an example of that?
- So, I hear you say…
- Is that a good summary?
- Are there any more things to tell?

Recorded interview:

1. Some open starting questions

→ What are your thoughts about the IVY intervention, now that you have experienced it?

→ How satisfied were you with the experience? Why?

- try to find out a bit more about pros and cons; use probes

For later analysis, these are going to be focus points (among others):

- what did the interviewee come up with first?
- did they mention the possibility to personalise spontaneously on their own initiative

2. The Process of Personalising

I saw that you chose stimuli words x, y, z for fatigue and x, y, z for vitality.

→ How did you come up with these individual words?

(Possible "support" questions: Did you rely on the ideas given? Did you have something in mind immediately)

→ What makes word x a relevant word to you?

In the survey you filled out before the IVY training, you were asked to rate fatigue- and vitality-related words according to your preference.

→ How did you rank them? Did you notice that the words you rated higher appeared more often in the training?

→ Did the words in the training feel familiar to you?

→ Which way of personalising did you prefer? Ranking the existing words according to your preference or choosing your own stimuli words? Why?

→ Did the fact that you trained with a personalised version influence your motivation?

→ Imagine the application to be compiled of words from the standard list or maybe you remember the IAT from the surveys. Do you consider the possibility to personalise as valuable when comparing both options?

2. Feasibility → practicality, resources, constraints, and potential challenges

→ How easy or difficult was it for you to find personalised stimuli words for the IVY application? What made it so easy or difficult?

→ Are there any aspects of the personalised IVY application that you felt could be improved or enhanced to better meet your needs?

→ Do you think that the personalised IVY application that you used can be applied to a larger group of people the way it is now? Why or why not?

→ If not, what would IVY need to be feasible for widespread use?

3. Acceptance → satisfaction, willingness to continue using the application, likelihood to recommend it to others

→ Did you complete all sessions? If not, why?

→ What do you think of the number of training sessions? The frequency of training sessions? The duration of training sessions?

→ Did the TIIM app/IVY intervention work smoothly on your phone? (Which phone/operating system (Android, IOS, Windows phone) do you possess?)

→ What are your expectations about the effects?

→ Do you approve the personalised version of the IVY application? Why or why not? If not, what would IVY need for you to be able to approve the application?

Appendix E

Participant Information Sheet and Informed Consent

We are focusing on participants who are at least 18 years old and possess good English proficiency. Participants are required to have access to a laptop as well as a smartphone.

Participation is completely voluntary, and you can withdraw from the study at any time. Withdrawing from the study does not have any consequences. Collected data will not be used for any purposes besides this research.

There are no major risks associated with this study.

If technical difficulties may occur throughout the study, please contact one of the researchers.

Prior to the analysis of the data, all personal data will be anonymised and will be used for research purposes only. The data will be stored in a secure location. Your answers will be treated confidentially. They will not be shared with other parties than the researchers and the according supervisors. The final dataset is stored securely after the final report is submitted. All other data is deleted.

The research is conducted by Mette Meijer and Insa Holtkamp (BSc Psychology students at the University of Twente).

The study is approved by the Ethics Committee of the Faculty of Behavioural, Management, and Social Science at the University of Twente.

Thank you for your participation! Should you have any questions, remarks or concerns about this study, please do not hesitate to contact one of the researchers responsible for the study: m.meijer-3@student.utwente.nl or i.k.holtkamp@student.utwente.nl

Informed consent

- I confirm that I have read and understood the participant information relevant for this study.
- I understand that in order to take part in this study, I should be at least 18 years old and have sufficient English proficiency. I have access to a laptop and a smartphone.

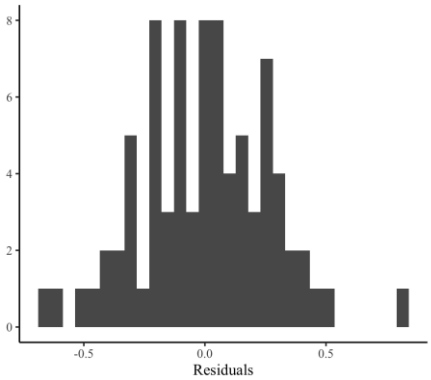
- I understand that personal data about me will be collected for the purposes of the research study, and that these will be processed in accordance with data protection regulations.
- I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected.
- I understand that my data is anonymous and will be stored on secure university servers. I understand that it will only be used by the researchers for research purposes.

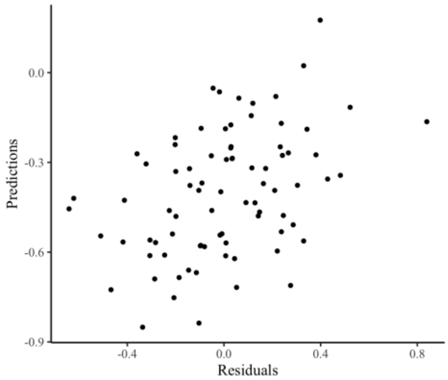
I agree to take part in this study.

Appendix F

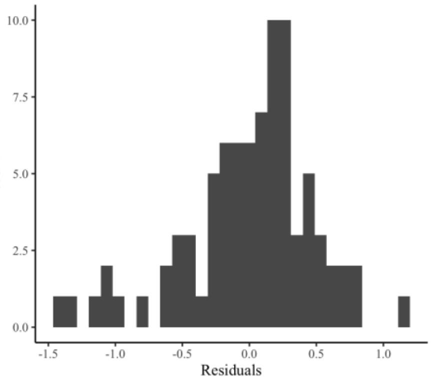
Parametric Assumptions of the Linear Mixed Models

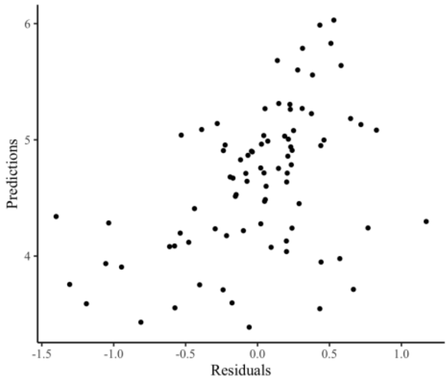
IAT scores (A) Normality assumption (B) Homogeneity assumption



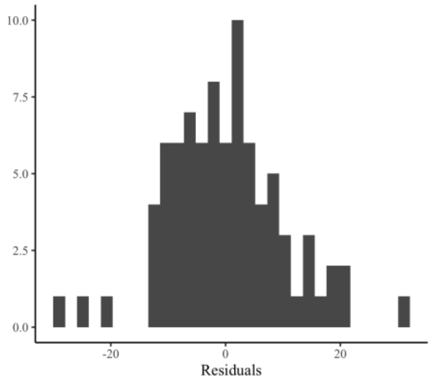


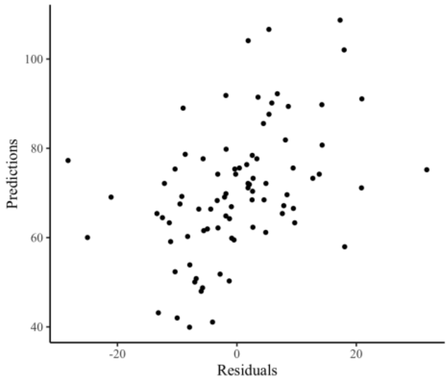
VITA-16 scores (C) Normality assumption (D) Homogeneity assumption



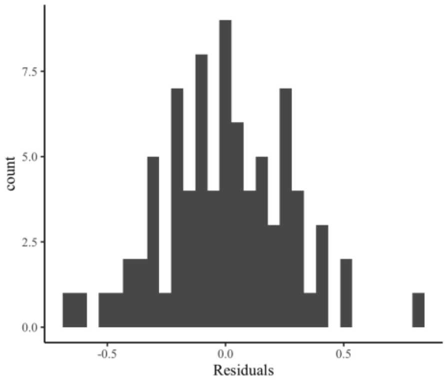


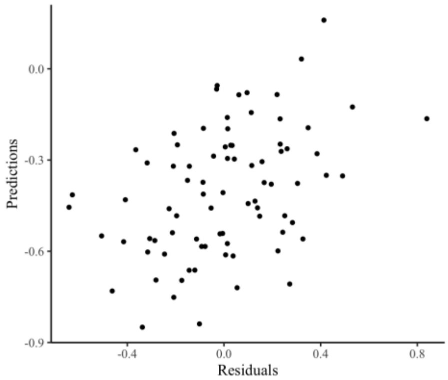
CIS scores (E) Normality assumption (F) Homogeneity assumption



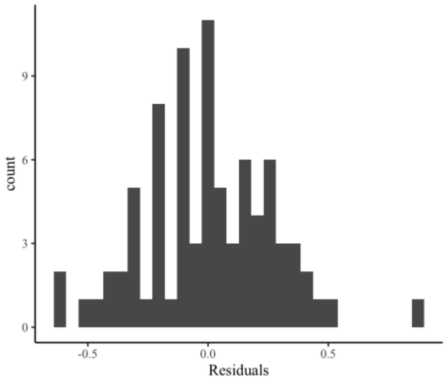


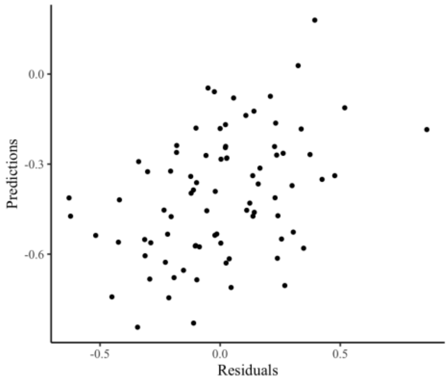
Moderator age (G) Normality assumption (H) Homogeneity assumption



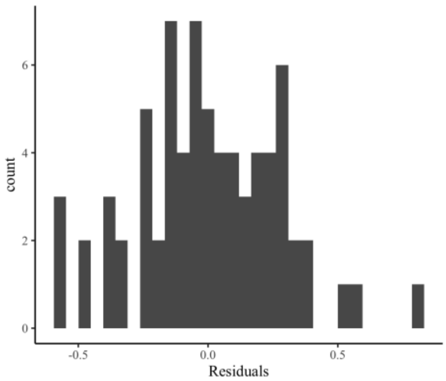


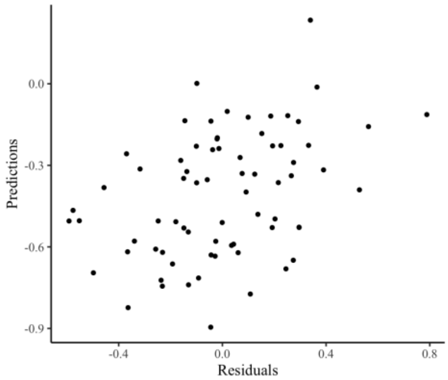
Moderator gender | (I) Normality assumption | (J) Homogeneity assumption



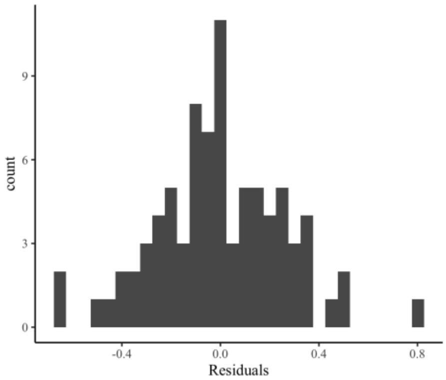


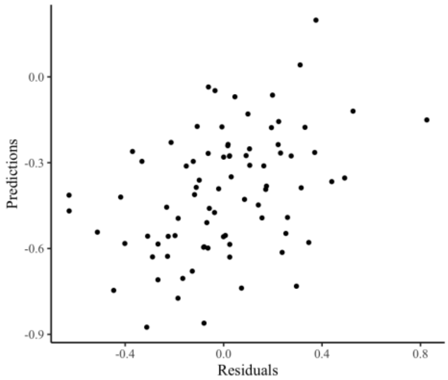
Moderator university | (K) Normality assumption | (L) Homogeneity assumption



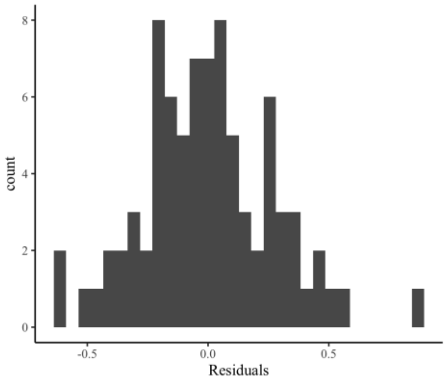


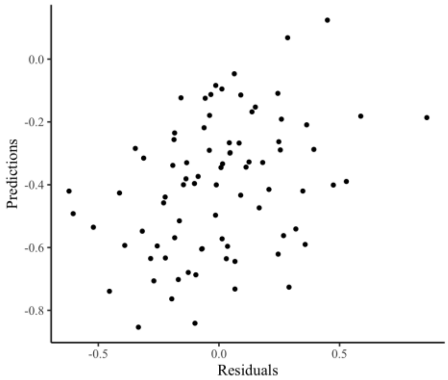
Moderator occupation | (M) Normality assumption | (N) Homogeneity assumption



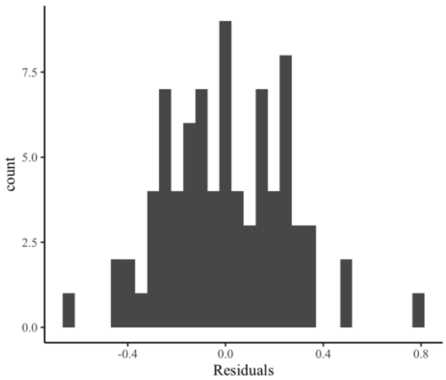


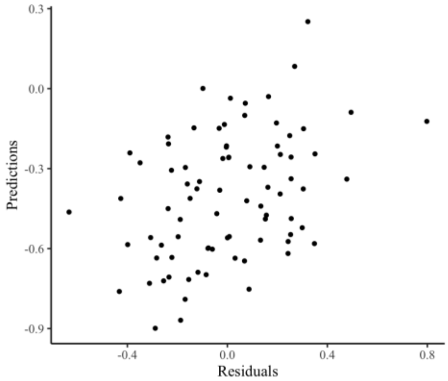
Moderator fatigue condition — (O) Normality assumption — (P) Homogeneity assumption



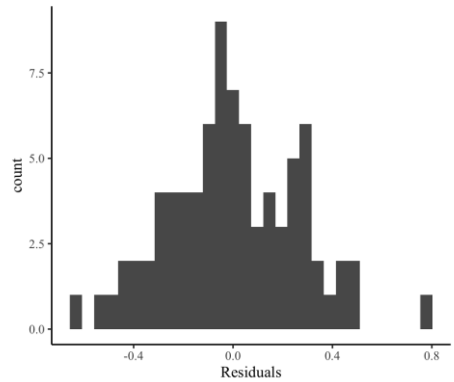


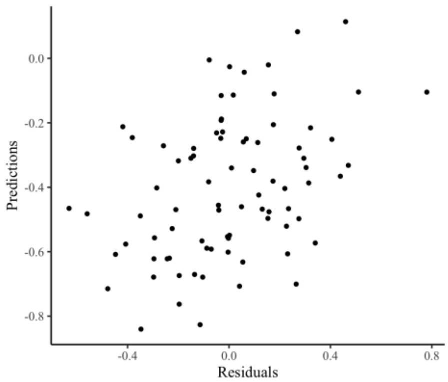
Moderator full sessions — (Q) Normality assumption — (R) Homogeneity assumption



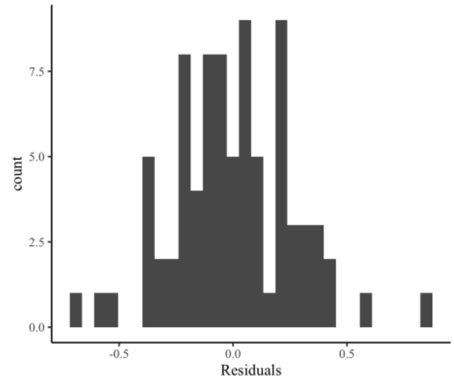


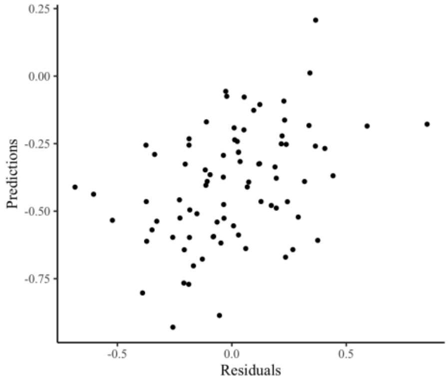
Moderator digital literacy — (S) Normality assumption — (T) Homogeneity assumption



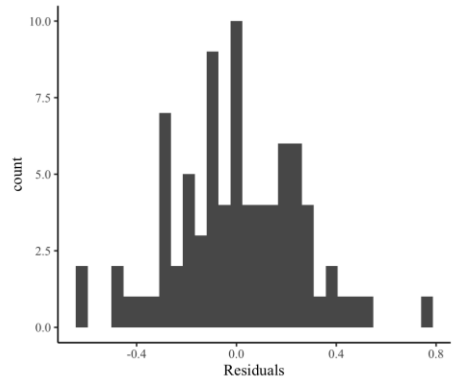


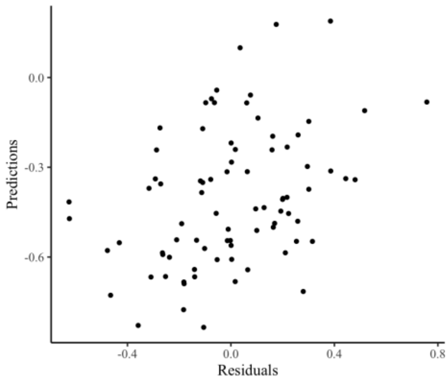
Moderator idiosyncratic words | (U) Normality assumption | (V) Homogeneity assumption



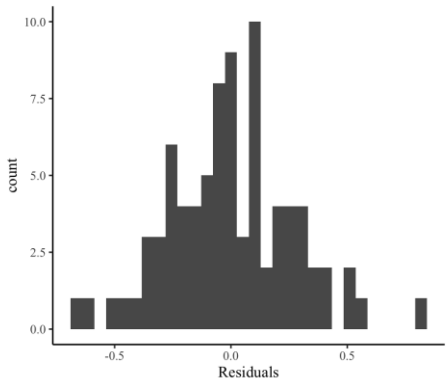


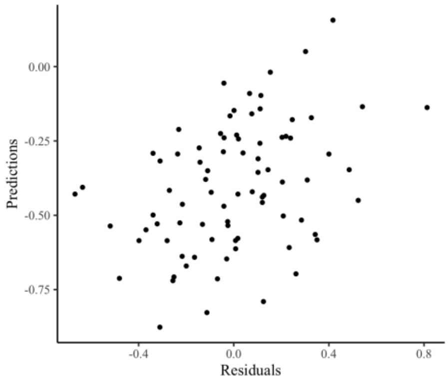
Moderator fatigue level | (W) Normality assumption | (X) Homogeneity assumption





Moderator vitality level | (Y) Normality assumption | (Z) Homogeneity assumption

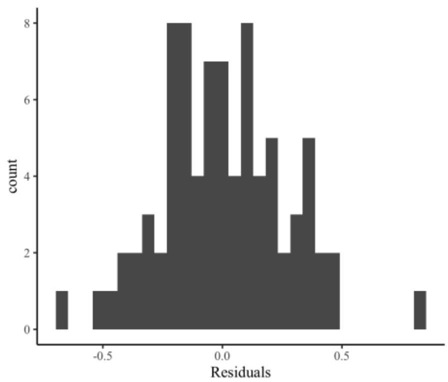


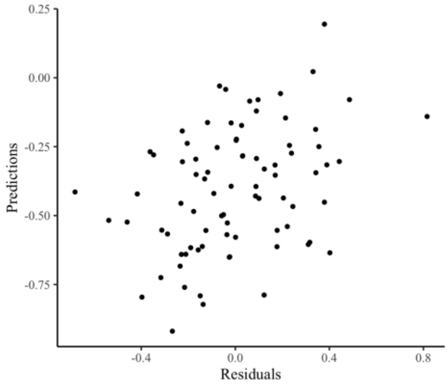


Moderator nationality

(AA) Normality assumption

(AB) Homogeneity assumption

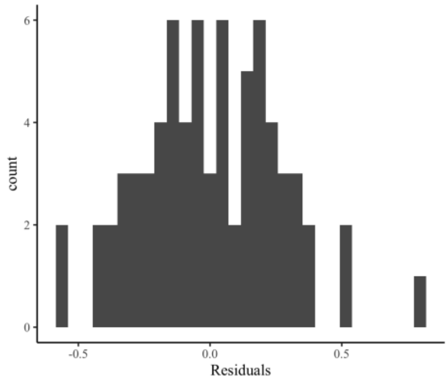


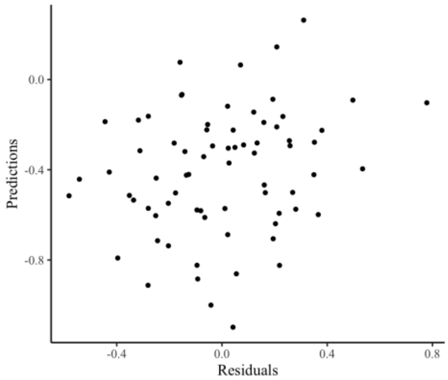


Moderator study field

(AC) Normality assumption

(AD) Homogeneity assumption

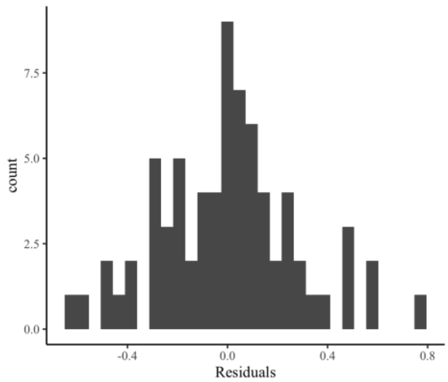


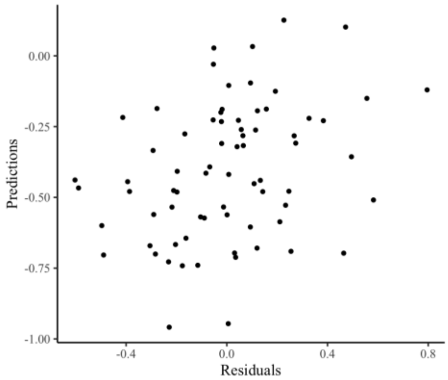


Moderator study level

(AE) Normality assumption

(AF) Homogeneity assumption

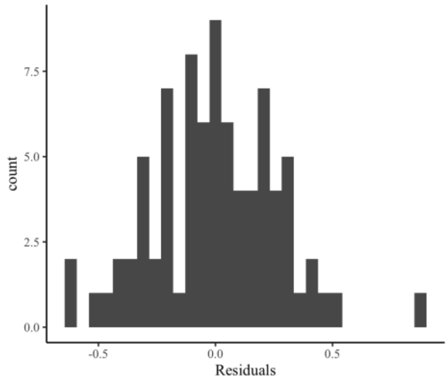


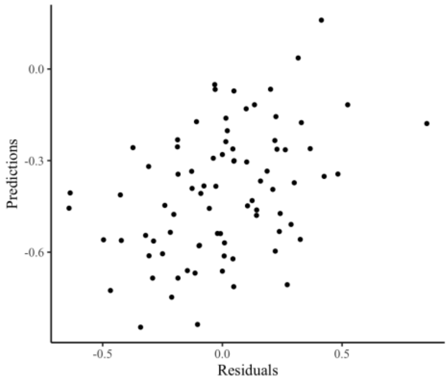


Moderator phone system

(AG) Normality assumption

(AH) Homogeneity assumption

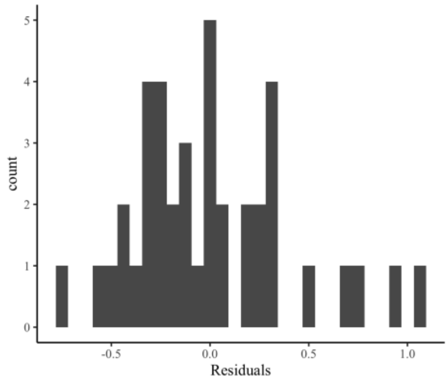


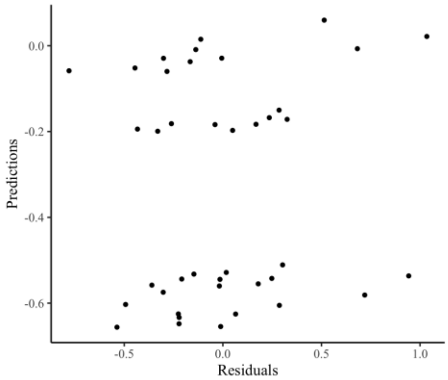


Moderator ambiguous words

(AI) Normality assumption

(AJ) Homogeneity assumption

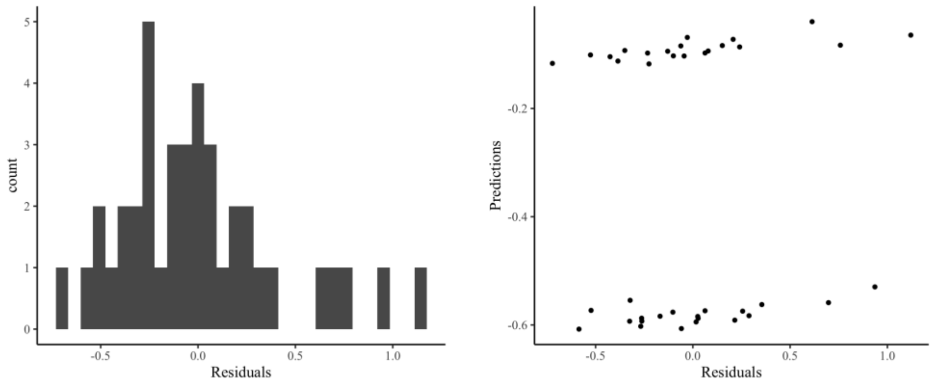




IAT scores interview sample

(AK) Normality assumption

(AL) Homogeneity assumption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Residuals
Predictions
Residuals