The Role of Interpretation Bias in Fatigue: Health Locus of Control and Modifying Fatigue Bias

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Abstract

This paper examines the potential utility of Interpretation Bias Modification (CBM-I) as a tool for reducing fatigue bias and feelings of fatigue. This new form of treatment has shown promise for treating other ailments, but has also been shown that the effectiveness is impacted by many other factors. Health locus of control is a measure of how much control an individual believes they have over their own health. Previous literature has shown that patients that have more internal health locus of control (IHLC) tend to see better improvement over time as well see more improvement from health interventions. Thus, the three subscales of the multidimensional health locus of control scale (MHLC) were used in a moderator analysis to see if they had any interaction with the CBM-I training.

In order to investigate the utility of CBM-I training and the interaction of the MHLC subscales an e-health intervention app was created using the TIIM application from the University of Twente. This intervention consisted of a pre and post-training questionnaire and 3 days of CBM-I training using items created by the researchers. The pre and post test questionnaires collected participant data including measures of fatigue using the Chandler Fatigue Scale, as well as fatigue bias from an interpretation bias task created by the researchers based on the work by Hughes et al. (2016). The intro questionnaire also measured health locus of control using the MHLC scale form A. The e-health intervention was distributed online via a website link and SONA.

Analysis of the collected data showed that the training did not have a measurable effect on bias, but did correlate with a reduction in fatigue. Additionally, no measurable interaction was found with the MHLC subscales. This suggests the possibility that CBM-I training was effective in reducing felt fatigue, but not in reducing bias. Further research is necessary as to how the training was able to reduce fatigue without reducing bias, as well as any other potential interactions with locus of health control or other personality traits.

Keywords: Cognitive bias, interpretation bias, cognitive bias modification, e-health, locus of health control, bias

1. Introduction

Fatigue is a feeling of extreme tiredness to the point of being overwhelming, and it usually occurs alongside other symptoms such as depression or muscle soreness. Causes of fatigue can vary from reactions to illnesses or medications, a result from exercise, lifestyle habits, and sleep disturbances and disorders. Fatigue can be debilitating in severe cases, making performing an individual's daily tasks difficult. Myalgic Encephalomyelitis, also known as Chronic Fatigue Syndrome (CFS), is a severe chronic illness affecting 17 to 24 million globally. The symptoms of CFS can vary on a case-by-case basis, with the main defining symptom being "cognitive and physical impairment worsened by exertion" (Arron et al., 2024, para. 3). Due to the complexity of the effects of CFS, there is no clear explanation for the onset of CFS, and it is still debated whether the illness is psychological or neurological (Lim & Son, 2020).

Recently, there has been an interest in researching the potential connections between cognitive biases and CFS.Studies have indicated that the attention of CFS patients is biased towards fatigue or illness-related stimuli (attention bias), as well as a tendency to interpret ambiguous information as being fatigue or illness-related (Hughes et al., 2016). These cognitive biases observed in CFS patients have been linked to multiple negative health behaviors, such as fear-avoidance, catastrophizing, and all-or-nothing behaviors. In order to address these biases, a form of psychological intervention was constructed called cognitive bias modification (CBM). This intervention attempts to alter the biases of a patient in hopes of reducing symptom severity (MacLeod & Mathews, 2012).

Another branch of research has focused on the different connections between health locus of control (HLC) and CFS. HLC is a personality trait that describes how much direct control a person believes they have over their health (Wallston et al., 1976). Research has shown a distinct pattern of HLC in CFS patients. Furthermore, it has also been demonstrated that HLC affects the outcomes of CFS treatments (van de Putte et al., 2005). Other studies suggest that HLC is related to a patient's perception of their symptoms (Ragg, 2003). Lastly, HLC has also been linked to numerous detrimental health behaviours (Mozafari et al., 2024).

While connections have been made between cognitive biases and CFS, there is very little research using CBM-style interventions as a form of treatment for fatigue or CFS. Thus, this paper attempts to test the effectiveness of using a CBM-based intervention to alter fatigue-biased cognitive processes with the hopes of also reducing feelings of fatigue. Furthermore, as HLC has

been linked to similar negative health behaviours as cognitive biases, this study will also investigate whether or not HLC interacts with the outcome of the CBM intervention.

1.1 Cognitive Bias

Cognitive biases are a set of subconscious mechanisms that influence how people process information and have been linked to the development and perpetuation of some psychopathologies and chronic conditions, such as Multiple Sclerosis, Chronic Fatigue Syndrome, anxiety disorders, and substance abuse (Gorini and Pravettoni, 2011; Lucchiari and Pravettoni, 2013; Martinelli et al., 2022; Marieke de Gier et al., 2024). Research has focused on 2 main biases: attentional bias and interpretation bias . Attentional bias is a bias in what information or stimuli someone focuses on. For example, someone with a fear of dogs may have biased attention towards dogs. Conversely, IB is the tendency to interpret ambiguous information as confirming a held belief or bias. For example, someone with social anxiety could be more likely to interpret ambiguous social interactions negatively (MacLeod, 2012; Jones & Sharpe, 2017).

In a report by Hughes et al. (2016), the idea is that CFS sufferers exhibit more cognitive biases in their attention and interpretation of information. More specifically, Hughes wanted to test whether CFS patients' attention would be biased toward illness-related information during visual probing tasks (VPT). Additionally, Hughes modified an existing IB task to determine if CFS patients tended to interpret ambiguous information as negative/somatic. The results of the experiment concluded that the proposed hypothesis is supported; CFS patients showed a bias for symptom-related information in their attention and a negative bias in their interpretation. As there is evidence that CFS patients are biased in their cognition, Hughes suggests that CBM could prove effective in CFS treatment.

Investigation into the usability of CBM as a clinical resource for reducing fatigue has shown support from patients and healthcare providers. The simplicity of CBM training allows flexibility in how it can be administered. Research into the potential of using a smartphone app to administer anti-fatigue CBM training to breast cancer patients showed positive reception by both patients and healthcare personnel. Due to the nature of fatigue limiting motivation and energy to perform tasks, along with many patients' frustration in their inability to do anything during cancer treatment, CBM training is an attractive option for health care professionals to

recommend to patients (Wolbers et al., 2021). If CBM can be proven to be effective in reducing or preventing fatigue, it could be a useful tool for future healthcare.

1.2 Cognitive Bias Modification

CBM interventions are designed to alter or reverse a negative bias in one's interpretation of attention processes. CBM is a relatively new form of treatment, its efficacy is still under review. However, recent findings support its effectiveness in the proper setting. Martinelli et al. (2022) extensively reviewed the efficacy of CBM, with findings that multiple factors need to be taken into consideration when implementing CBM training. Many variables moderated the effect of CBM, including whether or not it is administered in a clinical setting, whether modification is positive or negative, or what symptom sub-type is targeted. It was also noted that the direct effect of CBM on the reduction of symptoms is inconsistent across the literature, with some arguing that the evidence of a direct effect of the training being overstated (MacLeod and Grafton, 2016).

1.2.1 Interpretation Bias Modification

One common form of cognitive bias modification seen is interpretation bias modification (CBM-I) First designed by Grey & Mathews (2000) Interpretation bias training (CBM-I or IBM) involves the completion of an ambiguous story, sentence, or word by the participant in a way where they are forced or coerced into using either benign meanings to train benign interpretation, or negative meanings to train negative interpretation (MacLeod, 2012). In most cases, CBM-I training is split up into sessions with each session having a certain number of tasks patients need to complete. So far, the literature does not show an advantage for a specific number of sessions nor an amount of tasks in a session. Original findings by Mathews & Mackintosh (2000) showed that one session was effective in reducing anxiety levels in participants, maintaining the effects of the CBM-I training 24 hours after the session (Yiend et al. 2005, as cited in MacLeod, 2012). Other research by Beard and Amir (2008) has shown that for social anxiety, administering CBM-I over 8 sessions after it was shown that single sessions of CBM-I did not elicit a change in social anxiety (Salemink et al., 2009). As CBM-I is a relatively new technique it is not unusual to see conflicting research in regards to the recommended procedure.

1.2.3 CBM and Fatigue

Very little research has been done experimenting with the utility and effectiveness of CBM training regarding managing general fatigue or treating CFS. One paper by Geerts et al.

(2022) discusses the usability of CBM for managing fatigue in patients suffering from Chronic Kidney Disease (CKD). The results of this study showed positive reception by patients undergoing training and by healthcare professionals administering the training; there was no suggestion that the training reduced fatigue. However, other research conducted by Lehmann (2021) showed that CBM was effective in reducing attentional and self-identity bias regarding fatigue in kidney patients, contradicting what Geerts et al. found via reports of patients' feelings on the training's ability to change cognitive processes. Both the training methods used attempted to target attentional bias and self-identity bias. Further research has tested the utility of CBM training to reduce fatigue felt by university students utilizing an app to administer training. The finding showed that the app was able to reduce both levels of implicit and explicit fatigue reported by students using CBM to modify biases in students' self-concept over a 14-day training period, with sessions estimated to take 5 minutes (Vogel, 2019).

1.3 Locus of Control

Originally formulated by Rotter in the 1950s, locus of control is a description of how a person attributes an event or reward. Commonly divided into 2 distinct types: external control and internal control. People who believe that their actions are responsible for the things that happen around them exhibit internal control, while people who perceive the events of their lives as the product of fate, destiny, or any outside construct exhibit external control (Kaiser, 2024; Mozafari et al., 2024). Research has predominantly shown that higher levels of external control correlate with lower levels of psychological well-being (Kaynak et al., 2022; Enwere & Afunugo, 2024).

1.3.1 Health Locus of Control

The concept of locus of control was adapted for use in health care by Wallston et al. (1976) as a tool for research in hopes to predict health behaviours. This led to the development of the health locus of control (HLC) scale, and later the multidimensional health locus of control (MHLC) scale. Both of these scales measure the extent a person believes internal or external factors control their health outcomes. Meaning someone with internal health control believes that their actions have the most impact on their health, while someone with external control believes that outside forces have more influence over their health. In order to provide more depth and flexibility, the MHLC was developed as a replacement for the HLC scale. This scale measured 3 distinct health beliefs: internal health control (IHLC), chance external health control (CHLC),

and powerful-others external health control (PHLC). External health control was split into 2 distinct subgroups to provide more insight on where a person attributes the control of their health. CHLC is the dimension that measures the extent someone believes their health is determined by random factors such as luck or fate. PHLC measures the extent a person believes that their health is controlled by people of authority, such as medical professionals, government officials, or other trusted authority figures (Wallston et al., 1976).

1.3.2 Locus of Health Control and Health Interventions

HLC and its measures were mainly developed for use in healthcare. Specifically, it's used to predict and/or explain certain health related behaviours and outcomes as well as make comparisons between the different HLC attributions (Kassianos et al., 2016). Connections between HLC and health interventions have been reported in research. The main findings suggest that patients that exhibit higher IHLC tend to engage in more preventative health behaviors and respond positively to health interventions. This generally leads patients with high IHLC to be healthier and respond to treatment better. While it was observed that patients that scored higher levels of EHLC tended to have worse health outcomes, there was also evidence that patients with high PHLC scores responded positively to interventions in some situations. Primarily, this was seen when a patient believed that the healthcare professionals had control over their health. Patients with higher CHLC have shown to display more negative health behaviours, and were less likely to engage in health care treatment altogether (Mozafari et al., 2024).

Thus generally speaking, the current research suggests that individuals with higher levels of IHLC have healthier behaviours on average. On the other hand, individuals that have higher EHLC negatively affect overall health behaviour for the most part with some situations where high levels of PHLC does lead to better adherence to interventions and improve the effectiveness of treatment.

1.3.2 Locus of Health Control and CFS

Due to the unexplained and seemingly multivariate nature of CFS, there has been some research into potential connections between CFS and HLC. Studies such as the analysis conducted by van de Putte et al. (2005) show a much higher level of EHLC in CFS patients and even in the parents of the patients. Additionally, they associated higher levels of IHLCl with a 61% reduction in risk for CFS. Additionally, the analysis conducted by Ragg (2003) showed that more IHLC was correlated with many positive changes in CFS patients. Conversely, external

attribution of control correlated with less overall improvement over the same periods. This could suggest an enhancing effect between a patient's attribution of their health and the effectiveness of treatment. However, the specifications of the participants' treatment during this study were not collected or reported, thus leaving room for speculation regarding these findings.

In conclusion, the research suggests that higher IHLC is associated with both a reduced risk for CFS as well as better outcomes for CFS patients. On the other hand, higher EHLC were shown to be associated with a reduction in improvement.

1.3.4 Locus of Health Control and CBM-I

The research on connections between HLC and CBM training is scarce. The only somewhat relevant literature found was an experimental study conducted by Würtz et al. (2021). In this study, the researchers wanted to test whether trauma symptoms can be reduced using CBM to modify biased appraisals. The researchers also investigated whether or not locus of control has a moderating effect on the training effect of their CBM intervention. From the results of the experiment, the researchers concluded that there was no evidence that locus of control moderated the training effect of their CBM app. However, the researchers did note that the locus of control measure used had low reliability. Thus, while this study does provide some evidence to suggest a lack of interaction between CBM and locus of control, the researchers did acknowledge the need for additional research to verify this.

The study conducted by Würtz et al. (2021) gives some indication on how HLC might interact with CBM-I, it does not provide any direct research on the interaction. This is because the study by Würtz et al. (2021) used a different CBM technique that targeted biased appraisals, and not interpretations. Furthermore, the scale used by the researchers measured general locus of control instead of health locus of control. Thus, the connection between CBM-I and health locus of control has yet to be investigated.

1.3.5 Research Goals

CBM-I is a relatively new form of psychological intervention that has been shown to be effective in treating a number of psychological disorders. There has been interest in researching its potential for treating CFS symptoms. Other forms of cognitive bias modification (eg. attentional and self-identity) have had mixed results in reducing fatigue. As of writing, no literature was identified utilizing CBM to modify fatigue-biased interpretations. Concerning the gap in current CBM research, this paper will attempt to answer the following research questions:

RQ 1: How effective is interpretation bias modification at reducing fatigue biased interpretations?

RQ 2:How effective is interpretation bias modification at reducing self-reported fatigue levels?

Similar to interpretation bias, health locus of control has been observed to correlate with negative health behaviours. Specifically, negative health behaviours have been identified in individuals with higher levels of external health control (EHLC). Furthermore, health locus of control has been shown to affect the effectiveness of health interventions. Some research even suggests that CFS patients with high levels of EHLC see less improvement in symptoms than those with higher IHLC. With the amount of evidence to suggest that health locus of control is an important factor for predicting health improvements, very little research has gone into investigating potential interactions between health locus of control and CBM-I training. This paper will investigate this connection. Prior research indicates that interventions tend to be more effective for those with higher levels of IHLC as they tend to be more proactive with treatment. With no evidence suggesting CBM-I is an exception, it is expected that the effect of training will be stronger for people with higher IHLC scores and weaker for people with higher CHLC or PHLC scores. Additionally, as those with higher CHLC believe their health is controlled by forces such as fate or chance, it is expected that those with higher CHLC scores will experience a weaker effect from CBM-I training. Lastly, as those with higher PHLC attributes their health outcomes in the hands of other people, it is expected that those with higher PHLC scores would not benefit as well from a self-motivated intervention like CBM-I.

RQ 3: Is there evidence to suggest that the three MHLC subscales (IHLC, CHLC, and PHLC) interact with the training effect of interpretation bias modification training?

2. Methods

2.1 Participants

Criteria for participation included individuals who had sufficient knowledge of the English language and were aged 18 or older. Access to a smartphone or tablet was also required for participation. Before the start of data collection, the study received ethical approval from the BMS Ethics Committee of the University of Twente (approval code 250688).

2.2 Design and Procedure

2.2.1 Distribution

For this pilot study, data was collected through an app-based system designed by the Behavioral, Management, and Social-Science (BMS) Lab of the University of Twente. Participants were gathered via the SONA system, Discord Servers, a website, and direct recruitment by the researchers.

2.2.2 Procedure

Following the installation of the Tiim application, participants were able to start with the study.Before participants could access the pilot study, they first needed to complete the informed consent module. In this module, participants were instructed to read the informed consent form . They were informed about the details of the anonymization, use, and storage of their data, as well as their right to withdraw from the study at any point. If the participant did not give consent, they would immediately be brought to the end of the study with no data of theirs being saved. If they agreed to the terms of the informed consent form they were allowed to continue with the pilot study. If informed consent was not granted, the other modules could not be accessed and they were informed they could safely uninstall the TIIM application.

After consent is given, the pre-training questionnaire is given, and the data is stored. This pre-training questionnaire included demographic data collection followed by measures of fatigue, interpretation bias, and other psychological constructs. This section took 20 to 30 minutes. Once completed, participants are thanked and informed of the training procedure.

The following day, the training procedure begins. The participants are asked to complete 30 training tasks for that day of training. This training procedure takes about 5 to 10 minutes in total, with no data being collected from the training tasks. The participant is asked to complete training tasks for 3 days with notifications from the application reminding them to complete the tasks each day. After completing the training task on the last day, the participants are asked to complete the post-training questionnaire in the TIIM application. This final questionnaire contains the fatigue measure and another internal bias measure.

2.3 Materials

2.3.1 Tiim App

The Tiim application is an E-health intervention development tool created by the BMS Lab at the University of Twente. The tool allows researchers to streamline the creation of

E-health intervention applications for treatment or research purposes. The Timm app has been thoroughly researched in both its usability and effectiveness. This research has demonstrated that the Timm app was very easy to understand via its "codeless approach" to intervention creation as well as its flexibility using a "module system" for creating tailored interventions. Furthermore, the application was used in over 350 studies with multiple unique use cases, vetting the application's usage in a research setting (van't Klooster et al., 2024).

The main features this research required were the ability to distribute the study via smartphone, the ability to collect participant data, and the ability to time the release of specific questionnaires. The Tiim application meets all of these requirements while also being very simple to use. Thus, the Tiim application was used to create this pilot study.

2.3.2 Fatigue Measure

In order to assess baseline as well as post-training fatigue levels, participants were required to fill out the Chalder Fatigue Scale (CFQ-11), a self-report questionnaire which measures both mental and physical fatigue. The scale consists of 11 items on a four-point Likert scale and measures the severity and its impact of fatigue of the past two weeks. A higher score indicates greater fatigue severity.

2.3.4 Interpretation Bias Measure

Interpretation bias was assessed at baseline as well as post-training with self-developed Interpretation Bias Tasks based on the task created by Hughes et al. (2016). Participants were first presented with ambiguous situations related to fatigue and/or everyday situations. The situation was given a unique title in order for the participant to better recall each scenario in the next section. An example scenario can be seen in Figure 1 with the follow up question seen in Figure 2.

Figure 1

Example of Interpretation Bias Task Item: Ambiguous Scenario With Interaction

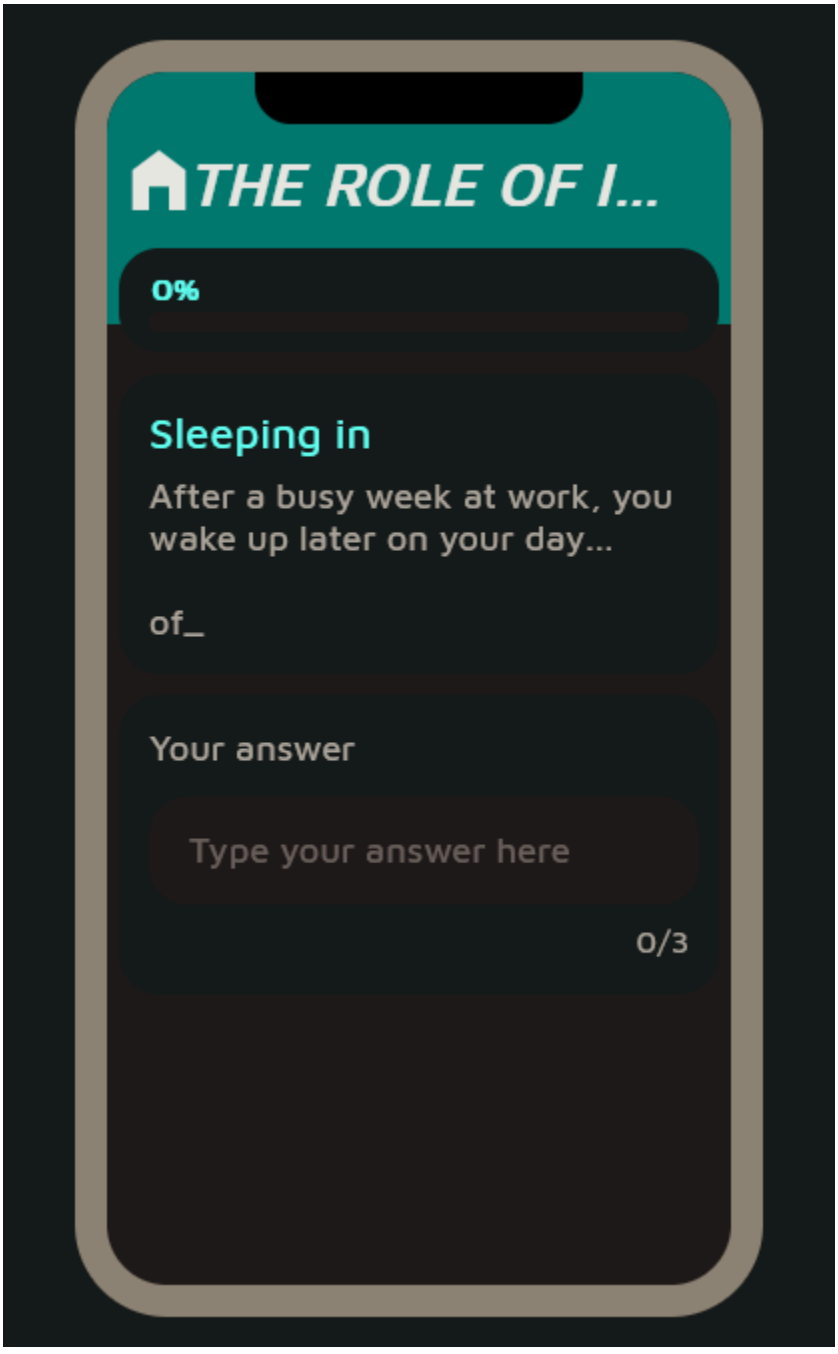
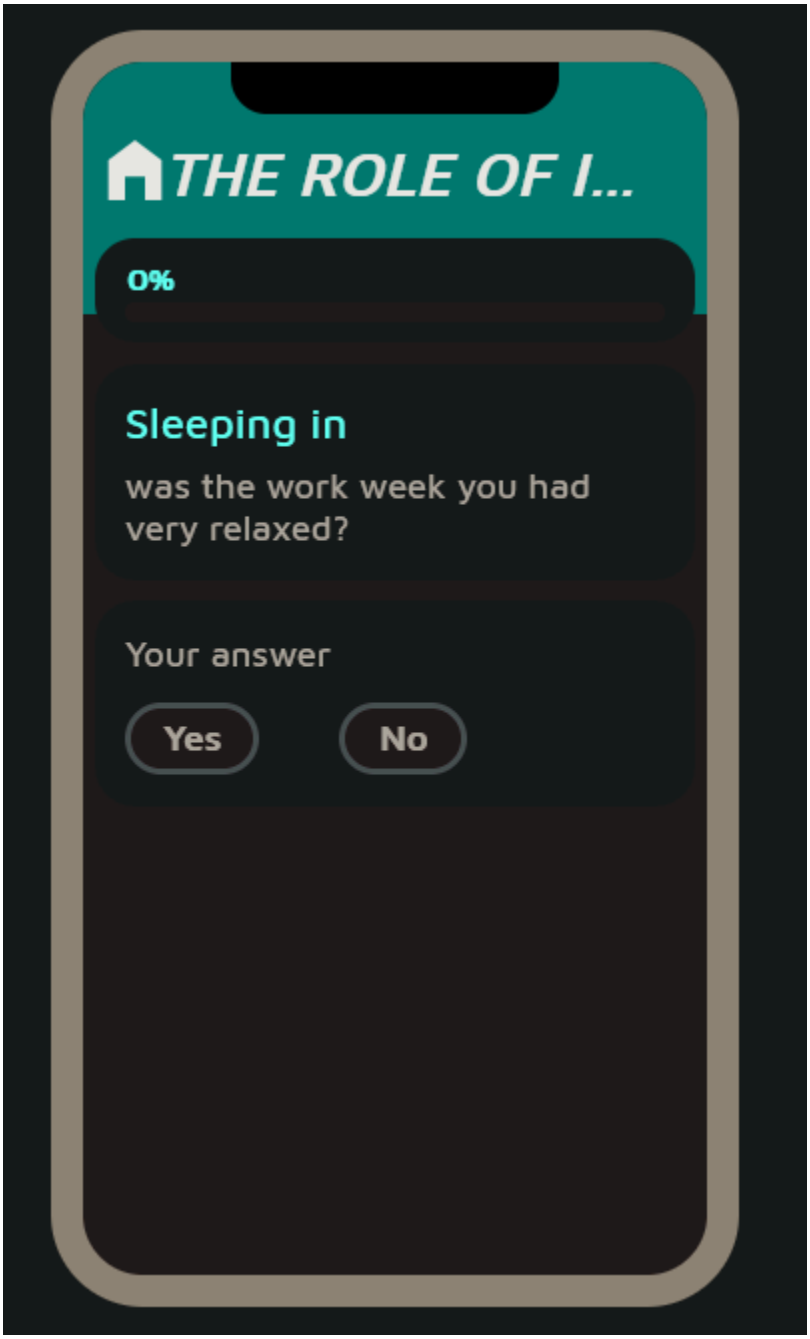


Figure 2

Example of Interpretation Bias Task Item: Comprehension Question for Ambiguous Scenario

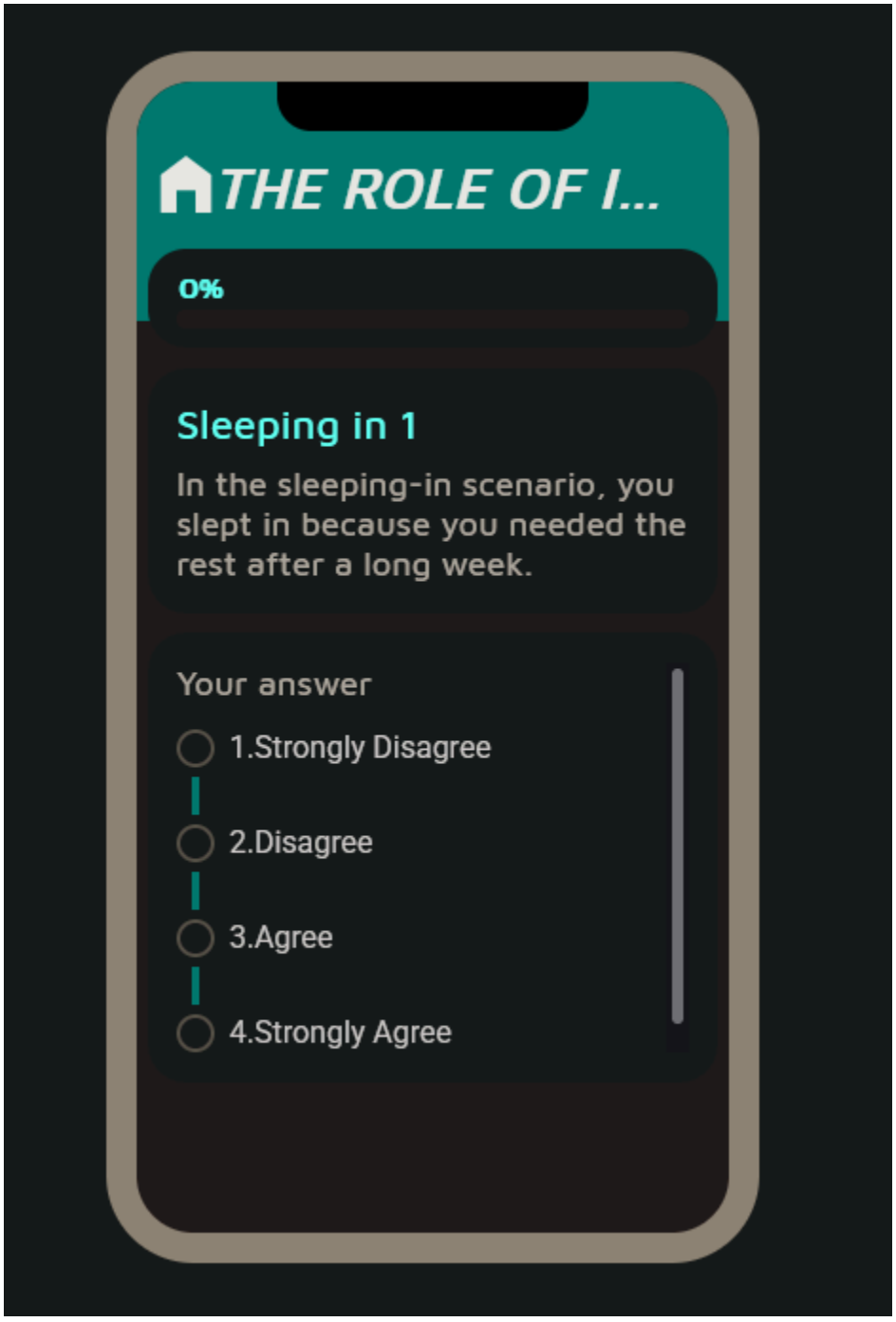


Once participants read and responded to each of the given scenarios, they began with the interpretations section. In this section participants were given an interpretation for one of the scenarios presented in the previous section. They were asked to recall the scenario, and indicate whether they agreed with each interpretation using the provided 4 point-likert scale. Each scenario had 4 interpretations the participants needed to respond to. A fatigue biased

interpretation, a neutral interpretation, and 2 foil interpretations. The 4 interpretations for a scenario were presented together. An example of one of these interpretations can be seen below in Figure 3.

Figure 3

Example of Interpretation Bias Task Item: Interpretation of Scenario with 4 Point Likert Scale Response



In order to score interpretation bias, the difference was found between the mean score of all neutral items and mean score of all the negative items.

2.3.5 Multidimensional Health Locus of Control Scale

Based on social learning theory and locus of control theory by Jullian Rotter, the Multidimensional Health Locus of Control Scale was developed by Wallston et. al, and has been subsequently used for assessing how individuals attribute health outcomes in multiple different studies (Wallston et al., 1978 as cited by Mozafari et al., 2024).This measure comes in 3 forms, form A, Form B and Form C. Both form A and form B measure locus of health control in 3 subscales: internal, external: chance, and external: powerful others. Form C replaces external: powerful others for external: god. Out of the 3 forms, form A was chosen mainly for its availability, as it was not possible to locate a copy of form B or C as of writing. Form A has shown good validity in measuring aspects of locus of health control, and satisfactory reliability (Wallston, 2005;Kassianos et al., 2016). However, it was noted by Kassianos et al. (2016) that the psychometric properties of form A and form B may not be equivalent, which may skew results if the study were replicated using for B. The questionnaire contains 18 statements pertaining to the 3 subscales, where respondents need to indicate if they agree or disagree with each statement. Responses are recorded in a 5-point likert scale, 1 being strongly disagree and 5 being strongly agree. Scores are calculated per subscale ranging from 6 to 36.

2.4 Data Analysis

2.4.1 Data Preparation

The collected data was exported from the TIIM platform and cleaned in R-studio to prepare for analysis. The intro and outro sections were copied into new data frames to streamline the cleaning. All timestamp columns were removed before creating new data frames for each individual questionnaire. Answers were transformed into numeric data for scoring.

2.4.2 Scoring

After preparation, columns were added to each data frame to calculate the scores for each of the questionnaires. For both the fatigue and the MHC subscales, scoring was calculated using the sum of the Likert scale responses. Neither of the questionnaires required reverse coding. For fatigue and the IBT task, the intro and outro scores were taken from the data frame and added to a new data frame in order to calculate the significance between pre-training and post-training scores.

2.4.3 Exclusions

Data from participants that had not completed the pilot study were excluded from analysis.

2.4.4 Analysis

Fatigue and IBT Change

To answer the first and second research questions, paired t-tests were run to determine whether there was a significant difference in the means between the pre-training and post training scores for both the fatigue measure and the IBT task scores. Additionally, a Cohen's D analysis was run on the scores to determine the effect size and direction.

MHC Moderation

To answer research questions 3 through 5, each of the subscales of the MHLC were used in 2 linear mixed effects models (6 total models). To allow completion of the CBM-I training to be used on the fixed effects, the data frame was converted into long format. These models used either fatigue score or IBT score as the dependent variable. Completion of the CBM-I training moderated by the MHLC subscale was the independent variable. Participant ID was added as a random effect. After each linear mixed effects model was created, the assumptions were checked using the check_model() function from the performance package, r-squares were calculated, and a 95% confidence interval was calculated for each variable. Likelihood ratio testing the full model against a null model (model with only random effects) to determine model fit.

3. Results

3.1 Demographic Data

49 participants signed up for the pilot study, with 35 of those completing the final portion. Of these 35 participants,15 were female, 19 were male, and 1 identified as non-binary. The majority of participants were students (27), while 6 were employed full time, 1 was employed part time, and 1 was unemployed. The highest level of education of the majority of the participants was secondary/high school with 23 participants. Of the others, 5 had received a bachelor's degree, 4 had achieved a master's degree, 2 had completed vocational school/trade school, and 1 had completed a 2-year degree.

3.2 Descriptive statistics

Pre-training fatigue scores ranged between 20 points and 4 points, with a mean score of 12.25. Post-training fatigue scores ranged between 24 points and 6 points, with a mean score of 11.25 points. Pre-training IBT scores ranged from 0.8 (fatigue bias) to -1.1 (neutral bias) with a mean IBT score pre-training of -0.1042. Post-training, the scores ranged from 0.5 to -1.0 with a mean score of -0.1583. The descriptive statistics for each of the MHC subscales can be seen in Table 1. It should be noted that following the launch of the pilot study it was found that 1 question from the Chanler Fatigue Scale was not included, skewing comparison to norm groups.

Table 1

Descriptive Statistics of Multidimensional Locus of Health Control Subscale Scores (n = 35)

Subscale	Mean	Min	Max	SD
Internal	18.57	14	26	2.65
Chance	17.37	9	25	3.52
Powerful Others	14.31	8	19	2.85

3.3 CBM-I Training Effects on Fatigue

The paired t-test showed that from pre-training (*M* = 12.11*, SD* = 4.00*)* to post-training (*M* = 11.23*, SD* = 4.07*)* there was a small measurable decrease in fatigue, but was not statistically significant, $t(34) = 1.48$, $p = 0.1478$. Cohen's D also suggested a small effect size of 0.22.

3.3.1 IHLC Moderation

The linear mixed effect model showed a slight moderation effect of the IHLC score on training effect, but a wide confidence interval makes the significance of these results questionable (B = 0.44, CI = [0.01, 0.87]). Furthermore, analysing the fit of the model showed high collinearity in the training and the interaction effect. Furthermore, multiple data points with high influence were found. The marginal R-squared (0.03) suggests the fixed effects explained a small portion of the variance in outcomes in the model. Likelihood ratio testing suggested a good model fit with low statistical significance ($X2(3) = 6.32$, $p = 0.096$), giving no conclusive

evidence that the null model does not fit the data better than the full model. The simple slopes analysis predicted a statistically significant moderating effect of IHLC scores 1 standard deviation below the mean (B = -2.04, p = 0.02), but no results of significance were predicted for mean levels of IHLC (B = -0.89, p = 0.13) or scores 1 standard deviation above the mean (B = 0.27, p = 0.74). This suggests that there could be an observable interaction at lower levels of IHLC, but that mean or higher levels lack statistical power.

Table 2

Linear Mixed Effects Model for IHLC Interaction with CBM-I Training on Fatigue Change

Effect	Estimate	SE	95% CI	
			LL	UL
Intercept	14.63	4.91	5.09	24.17
Training	-9.04	4.12	-17.09	-0.98
IHLC	-0.14	0.26	-0.64	0.37
Training:IHLC	0.44	0.21	0.01	0.87

Conditional R-squared: 0.661, Marginal R-squared = 0.034

Figure 4

Simple Slopes Graph: Cognitive Bias Training Effect at Different Levels of Internal Health Control Scores

Note: low IHLC = 15.9 (-1SD), mean IHLC = 18.6, high IHLC = 21.2 (+1SD)

3.3.2 CHLC Moderation

The model for the moderating analysis of the CHLC subscale resulted in a small, but not statistically significant moderating effect of the CHLC score (B = 0.29, CI = [-0.04, 0.62]. Furthermore, the model was subject to high collinearity for both the training effect (VIF > 30) and the moderation effect (VIF > 30). The marginal R-squared value suggests that the fixed effects do explain some of the outcome. Furthermore, the results of likelihood ratio testing suggest the full model fits better than the null model ($X2(3) = 9.86$, $p < 0.05$). The outcome of the likelihood ratio test combined with the high conditional R-squared (0.65) lend evidence for the full model being a good fit. The simple slopes analysis predicted a significant interaction effect at a CHLC score 1 standard deviation below the mean (B = -1.89, p = 0.03), but non-significant interaction effects at the mean score (B = -0.89, p = 0.14) or at a score 1 standard deviation above the mean (B = 0.12, p = 0.89).

Table 3

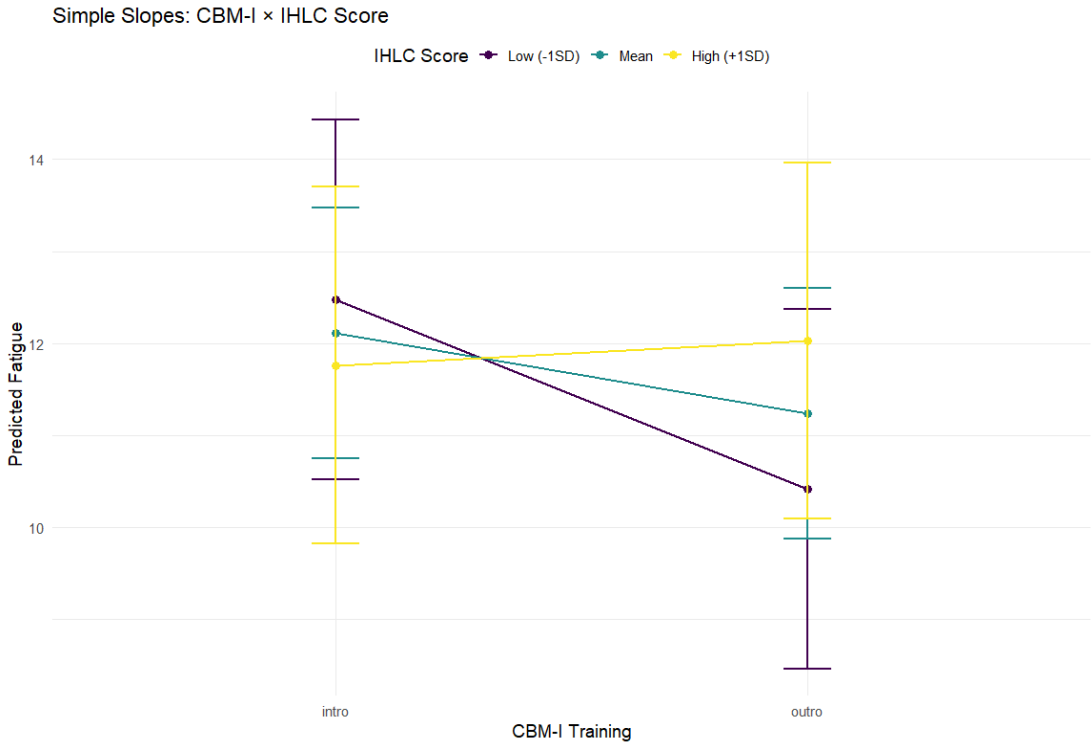
Linear Mixed Effects Model for CHLC Interaction with CBM-I Training on Fatigue Change

Effect	Estimate	SE	95% CI	
			LL	UL
Intercept	8.25	3.33	1.80	14.70
Training	-5.87	2.97	-11.7	-0.05
CHLC	0.22	0.19	-0.14	0.59
Training:CHLC	0.29	0.18	-0.04	0.62

Conditional R-squared: 0.649, Marginal R-squared: 0.123

Figure 2

Simple Slopes Graph: Cognitive Bias Training Effect at Different Levels of Chance Health Control Score



Note: low CHLC = 13.9 (-1SD), mean CHLC = 17.4, high CHLC = 20.1 (+1SD)

3.3.3 PHLC Moderation on Fatigue Change

PHLC was shown to have very little interaction with training effectiveness (b = 0.02, CI = [-0.40, 0.44]). Additionally, the model violated assumptions of colinearity and was affected by multiple high influence observations. The high conditional R-squared (0.62) combined with the low marginal R-squared (0.03) indicates the random effects explained more variance in outcomes than the fixed effects. The likelihood ratio showed no conclusive evidence for the full model fitting better than the null model, ($X2(3) = 3.37$, $p = 0.34$). The simple slopes analysis resulted in no statistically significant interaction effects at any level of PHLC ($p > 0.1$).

Table 4

Linear Mixed Effects Model for PHLC Interaction with CBM-I Training on Fatigue Change

Effect	Estimate	SE	95% CI	
			LL	UL
Intercept	8.25	3.33	2.06	15.85
Training	-1.18	3.15	-7.36	4.99
PHLC	0.22	0.24	-0.25	0.69
Training:PHLC	0.02	0.21	-0.40	0.44

Conditional R-squared: 0.620, Marginal R-squared: 0.037

3.4 CBM-I Training Effect on Interpretation Bias

The paired t-test comparing the change in IBT scores resulted in no significant difference from pre-training (M = -0.08, SD = 0.43) to post-training (M = -0.12 , SD = 0.32), $t(34) = 0.50$, $p = 0.62$. The effect size was also shown to be negligible, $d = 0.09$.

3.4.1 IHLC Moderation

Analysis of the interaction of IHLC scores on the training effect resulted in a small and non-significant interaction effect (b = 0.02, CI = [-0.05, 0.07]). Marginal and conditional R-squared values were low (0.344 and 0.004 respectively), indicating both the fixed effects and random effects explain only a small portion of the variance in outcomes. Furthermore, likelihood ratio testing indicated that the fit of the full model was not a significant improvement over the null model ($X2(3) = 0.41$, $p = 0.94$) suggesting a poor model fit.

Table 5

Linear Mixed Effects Model for IHLC Interaction with CBM-I Training on Fatigue Biased Interpretations Change

Effect	Estimate	SE	95% CI	
			LL	UL
Intercept	0.06	0.5	-0.84	0.96
Training	-0.23	0.53	-1.28	0.82
IHLC	-0.01	0.02	-0.06	0.04
Training:IHLC	0.01	0.28	-0.05	0.07

Conditional R-squared: 0.344, Marginal R-squared: 0.004

3.4.2 CHLC Moderation

The results of the linear mixed effects model showed CHLC scores had a small and statistically insignificant interaction effect on the training outcome (b = 0.02, CI = [-0.03, 0.06]. The combination of a low conditional R-squared (0.35) and marginal R-squared (0.03) suggest the model does not properly fit the data. This is further suggested by a low and insignificant result from the likelihood ratio test ($X2(3) = 1.86$, $p = 0.60$).

Table 6

Linear Mixed Effects Model for CHLC Interaction with CBM-I Training on Fatigue Biased Interpretations Change

Effect	Estimate	SE	95% CI	
			LL	UL
Intercept	-0.19	0.32	-0.83	0.44
Training	-0.32	0.37	-1.07	0.42
CHLC	0.01	0.02	-0.03	0.04
Training:CHLC	0.02	0.02	-0.03	0.06

Conditional R-squared: 0.353, Marginal R-squared: 0.03

3.4.3 PHLC Moderation

The linear mixed effects model showed a negligible and statistically insignificant interaction between PHLC and CBMI-I training. The marginal (0.01) and conditional (0.344) R-squared suggest the model does not accurately represent the data. This is further confounded by the results of the likelihood ratio test ($X2(3) = 0.52$, $p = 0.91$).

Table 7

Linear Mixed Effects Model for PHLC Interaction with CBM-I Training on Fatigue Biased Interpretations Change

Effect	Estimate	SE	95% CI	
			LL	UL
Intercept	-0.13	0.34	-0.78	0.52
Training	-0.15	0.39	-0.91	0.61
PHLC	< 0.01	0.02	-0.04	0.05
Training:PHLC	0.01	0.02	-0.04	0.06

Conditional R-squared: 0.344, Marginal R-squared: 0.01

4. Discussion

This pilot study was conducted in order to investigate if interpretation bias modification (CBM-I) could be used as an effective treatment for reducing fatigue and fatigue bais, an important goal as it has been shown that people who suffer from Chronic Fatigue Syndrome display fatigue biased interpretations (Gorini & Pravettoni, 201; Hughes et al., 2016). CBM-I has previously been shown to be effective in reducing biased interpretations in anxiety, and is a suitable treatment method for patients with high levels of fatigue (Yiend et al. 2005, as cited in MacLeod, 2012; Geerts et al., 2022). Health locus of control has been shown to impact the effectiveness of some health interventions (Mozafari et al., 2024). Despite it being understood that health locus of control affects treatment outcomes, there was no research investigating if this connection extends to CBM-I training. In order to fill this hole in the current literature, it was investigated if health locus of control moderated the training effects of CBM-I. This led to the creation of the digital CBM-Intervention using the TIIM platform from the University of Twente. A 3-day intervention was created where participants needed to complete 30 CBM-I tasks. Fatigue and fatigue bias was measured before and after completing the intervention. Additionally, health locus of control scores were collected before participants started the intervention. The before and after training fatigue and fatigue bias measures were analysed using a paired t-test and Cohen's D test. Moderation of the health locus of control subscales was measured with linear mixed effect models. The results of this study provided did not support significant effects of CBM-I training on reducing fatigue or bias reduction, nor moderation by the health locus of control subscales.

4.1 Effectiveness of CBM-I Training at Reducing Interpretation Bais

The results of the t-test and Cohen's D showed, as well as the results of the linear mixed effect models resulted in a negligible and statistically insignificant effect of training on fatigue bais. The results seem to indicate that the training did not have any effect on fatigue bais, giving an answer to the first research question. These results might have been impacted by the small sample size (35). Furthermore, these findings may suggest flaws in the scale created to measure fatigue bais.

As this was one of the first studies to test the effectiveness of CBM-I to reduce fatigue bais, there is no direct literature to make accurate comparisons. These results do not align with the general outcomes of CBM-I training as seen in the meta-analysis by Martinelli et al. (2022),

suggesting potential differences in how CBM-I based interventions interact with biases relating to the modification of biases related to somatic symptoms versus what has been observed currently with biases related to emotional symptoms like anxiety and depression.

4.2 Effectiveness of CBM-I Training at Reducing Self-reported Fatigue

The results of the study suggested the training might have had a small effect on self-reported fatigue, but these results were ultimately statistically insignificant. So while there is a potential training effect, these findings were not conclusive. This could be due to a number of methodological factors. As this was a pilot study with a total population of 35 participants, it is likely that the statistical power of the results was too low to find meaningful results. However, it could also be the case that the 3 days of CBM-I training was too short in order to produce meaningful changes in fatigue. A small effect and high p-value are indicators of low statistical power, but could also be evidence that an effect was present from the 3 days of training. Thus if the training is extended there is a possibility the observed effect becomes stronger and more statistically significant.

As this is one of the first investigations into CBM-I's effects on fatigue, there are no direct comparisons to be made to prior studies. Indirectly, the trends found in this study seem to be congruent with the findings of Mathews & Mackintosh (2000) and (Salemink et al., 2009) that showed the modification of interpretation bias was capable of reducing anxiety symptoms. However, unlike the mentioned research, the results of this study suggested a reduction in symptom severity with no change in interpretation bias. The reason for this should be investigated in future research.

4.3 Interaction Between MHLC subscales and CBM-I Training Effect

No conclusive evidence was found indicating an interaction between health locus of control and the effectiveness of CBI-Training. While some trends could be seen in self-reported fatigue change, the same could not be said for bias reduction. However, this is most likely a result of an overall lack of effect of the CBM-I intervention on basis reduction.

4.3.2 Internal Health Locus of Control Reducing CBM-I Training Effect

As there was no observable effect of the CBM-I training on fatigue biased interpretations, a moderating effect of IHLC score was not possible to identify. However, when it came to modifying self-reported fatigue the results indicated a reduction effect of IHLC. While the wide confidence intervals of the linear mixed effect model and the questionable fit of the model do

make these results unreliable, the simple slopes analysis does suggest that low IHLC scores correlate with an increase in training effect. This trend would contradict the expectation that higher IHLC scores would lead to better training results and the general findings of (Mozafari et al., 2024). However, unless these findings can be replicated with higher statistical significance, no real implications can be made from these results.

4.3.2 Chance Health Locus of Control Reducing CBM-I Training Effect

The results of the moderation analysis displayed a slight reducing effect of CHLC scores. However, the confidence interval of these results does include 0 ([-0.04, 0.62]) making these results just barely insignificant. This does suggest that, with refinements to the methodology, continued investigation could show conclusive evidence for the expected reduction in training effect of CHLC.

4.3.3 Powerful Others Health Locus of Control Reducing CBM-I Training Effect

Moderation analysis of the PHLC subscale indicated a lack of significant interaction with the effect of CBM-I training. This suggests that the expectations that PHLC would reduce the effectiveness of training were incorrect. However, due to the lack of statistical significance of the other 2 subscales, these results are inconclusive.

4.4 Future Research

Further research into using CBM-I to modify fatigue biased interpretations should look into altering the procedure of the intervention (e.g, amount of sessions, amount of tasks in sessions) as well as investigate alterations to the scenarios of the CBM-I task. Additionally, future research should consider measuring the MHLC scores after completion of the training as well, as some research indicates the possibility of altering health locus of control (Mozafari et al., 2024). Lastly, mediation analysis similar to what was done by Salemink et al. (2009) to investigate whether the change in self reported fatigue is mediated by a change in interpretation bias.

4.5 Strengths of the Study

With little direct research into the use of Cognitive Bias Modification to alter fatigue-biased interpretations, this pilot study is one of the first to investigate this link. This allowed the pilot study to be distributed to a wide variety of participants and allowed the creation of a tailored measure for fatigue biased interpretations. The use of the TIIM platform made the creation of the pilot study and its distribution much simpler than creating an app from scratch.

The ability to centralize creation, distribution, and data exportation allowed for more time to be put into the creation of materials.

Furthermore, this freedom allowed for the design of highly tailored materials for use in the task. This allowed for materials such as the CBM-I training items and the interpretation bias task to be designed to be specifically distributed through an e-health platform such as the TIIM platform.

4.5 Limitations

4.5.1 Materials

While the lack of previous research did allow for increased freedom for design, it also meant a lack of previous tools for measurement. The IBT task was created by the researchers based partly on the design of Hughes et. all specifically for this pilot study. While this allows for a tailored questionnaire for use with the TIIM application, it also runs the risk of being unreliable and/or invalid. This is especially important to consider with the results suggesting the training had a reduction effect on fatigue while bypassing the fatigue bias. This phenomena could be explained if the task designed was flawed in some way, whether that be validity or something else entirely.

Furthermore, upon re-examination of the design of the IBT task including some informal participant feedback, it was clear that some improvements could be made. As it is designed currently, the amount of scenarios included combined with some similarity of scenarios caused some issues for participants when it came time to complete the interpretation section of the task. Some participants detailed experiences confusing certain scenarios with others. Others said they sometimes forgot the details of some scenarios completely. Whether this affected the reliability of the task was not investigated, but reorganizing or reducing the IBT would still improve user experience going forward. If validity and reliability can not be reasonably maintained after reducing the task from 20 items to 10 items, it would be recommended splitting the task in half; giving the first 10 scenarios followed by the interpretations for those 10 items. Then repeating with the last 10 items and interpretations. Additionally, improvements could be made to the content of some of the items, as there was some note on the similarity of the contexts of the scenarios.

4.5.2 TIIM Platform

While it was noted how the TIIM platform allowed for easy design and distribution for the pilot study, there were also some grievances in using it. Primarily, the platform did not allow modules to be opened after a certain amount of time after a participant begins the study. While a workaround was found for this eventually, the feature would be appreciated. Additionally, at some point during the design processes the ability for researchers to use screening questions before participants were allowed in the study stopped functioning.

4.5.3 Time

The biggest limitation of this study was time. In order to meet set deadlines, less time was available for designing materials and data collection than what would have been preferred. This caused some reductions to be made in the time period data was collected that resulted in setbacks during the design processes of the CBM-I and IBT materials along with creation of the e-health intervention. The consequences of this resulted in less participation than what could have been achieved without constraints on time.

4.6 Conclusion

This study explored the potential effectiveness of CBM-I as an ehealth intervention for alleviating fatigue and reducing fatigue-based interpretation bias. Simultaneously, health locus of control was examined as a potential moderator of the effectiveness of the intervention. The findings of the study found a statistically insignificant effect of CBM-I in reducing feelings of fatigue, but nothing was seen for reducing fatigue bias. Additionally, insufficient evidence was found to show any training interaction of health locus of control. Potential leads for future research were identified, with some suggestions that the internal health control might reduce the effectiveness of training. However, until refinements have been made to the bais measure, and these results have been replicated with sufficient significance, these trends are theoretical and unverified.

References

Abubakar Tijjani Salihu, Hill, K., & Shapour Jaberzadeh. (2022). Neural mechanisms underlying state mental fatigue: a systematic review and activation likelihood estimation meta-analysis. *Research Square (Research Square)*. https://doi.org/10.21203/rs.3.rs-1388628/v1

Arroll, M., Attree, E., Dancey, C., Griffith, C., & Bansal, A. (2014). Psychosocial factors involved in memory and cognitive failures in people with myalgic encephalomyelitis/chronic fatigue syndrome. *Psychology Research and Behavior Management*, *7*, 67. https://doi.org/10.2147/prbm.s50645

Arron, H. E., Marsh, B. D., Kell, D. B., M. Asad Khan, Jaeger, B. R., & Pretorius, E. (2024). Myalgic Encephalomyelitis/Chronic Fatigue Syndrome: the biology of a neglected disease. *Frontiers in Immunology*, *15*. https://doi.org/10.3389/fimmu.2024.1386607

Beard, C., & Amir, N. (2008). A multi-session interpretation modification program: Changes in interpretation and social anxiety symptoms. *Behaviour Research and Therapy*, *46*(10), 1135–1141. https://doi.org/10.1016/j.brat.2008.05.012

Cleveland Clinic. (2023). *Fatigue*. Cleveland Clinic. https://my.clevelandclinic.org/health/symptoms/21206-fatigue

Enwere, C. A., & Afunugo, D. M. (2024). Impact of Locus of Control on Psychological Well-Being Among Male and Female Adolescents in Anambra State. *Futurity of Social Sciences*, *2*(3), 182–201. https://doi.org/10.57125/fs.2024.09.20.10

Everaert, J., Podina, I. R., & Koster, E. H. W. (2017). A comprehensive meta-analysis of interpretation biases in depression. *Clinical Psychology Review*, *58*, 33–48. https://doi.org/10.1016/j.cpr.2017.09.005

Geerts, J., Pieterse, M., Goos Laverman, Femke Waanders, Oosterom, N., Slegten, J., Elske Salemink, & Bode, C. (2022). Cognitive Bias Modification Training Targeting Fatigue in Patients With Kidney Disease: Usability Study (Preprint). *Data Archiving and Networked Services (DANS)*. https://doi.org/10.2196/preprints.43636

Gorini, A., & Pravettoni, G. (2011). An overview on cognitive aspects implicated in medical decisions. *European Journal of Internal Medicine*, *22*(6), 547–553. https://doi.org/10.1016/j.ejim.2011.06.008

Hughes, A. M., Chalder, T., Hirsch, C. R., & Moss-Morris, R. (2016). An attention and interpretation bias for illness-specific information in chronic fatigue syndrome. *Psychological Medicine*, *47*(5), 853–865. https://doi.org/10.1017/s0033291716002890

Jones, E. B., & Sharpe, L. (2017). Cognitive bias modification: A review of meta-analyses. *Journal of Affective Disorders*, *223*, 175–183. Science Direct. https://doi.org/10.1016/j.jad.2017.07.034

Kaiser, B. (2024). Locus of Control and Mental Health: Human Variation Complicates a Well‐Established Research Finding. *American Journal of Human Biology*. https://doi.org/10.1002/ajhb.24147

Kassianos, A. P., Symeou, M., & Ioannou, M. (2016). The health locus of control concept: Factorial structure, psychometric properties and form equivalence of the Multidimensional Health Locus of Control scales. *Health Psychology Open*, *3*(2), 205510291667621. https://doi.org/10.1177/2055102916676211

Kaynak, H., Turan, A., & Demir, Y. (2022). Locus of Control as a Mediator of the Relationships Between Motivational Systems and Trait Anxiety. *Psychological Reports*, 003329412211397. https://doi.org/10.1177/00332941221139707

Lehmann, M. (2021). *Targeting thinking bias regarding fatigue with Cognitive Bias Modification in renal patients*. http://essay.utwente.nl/87678/

Lim, E.-J., & Son, C.-G. (2020). Review of case definitions for myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS). *Journal of Translational Medicine*, *18*(1). https://doi.org/10.1186/s12967-020-02455-0

Lucchiari, C., & Pravettoni, G. (2013). The role of patient involvement in the diagnostic process in internal medicine: A cognitive approach. *European Journal of Internal Medicine*, *24*(5), 411–415. https://doi.org/10.1016/j.ejim.2013.01.022

MacLeod, C. (2012). Cognitive bias modification procedures in the management of mental disorders. *Current Opinion in Psychiatry*, *25*(2), 114–120. https://doi.org/10.1097/yco.0b013e32834fda4a

MacLeod, C., & Mathews, A. (2012). Cognitive Bias Modification Approaches to Anxiety. *Annual Review of Clinical Psychology*, *8*(1), 189–217. https://doi.org/10.1146/annurev-clinpsy-032511-143052

Marieke de Gier, Oosterman, J. M., Hughes, A. M., Moss‐Morris, R., Hirsch, C., Beckerman, H., Vincent de Groot, & Knoop, H. (2024). The presence of attentional and interpretation biases in patients with severe MS‐related fatigue. *British Journal of Health Psychology*. https://doi.org/10.1111/bjhp.12723

Martinelli, A., Grüll, J., & Baum, C. (2022). Attention and interpretation cognitive bias change: A systematic review and meta-analysis of bias modification paradigms. *Behaviour Research and Therapy*, *157*, 104180. Science Direct. https://doi.org/10.1016/j.brat.2022.104180

Mathews, A., & Mackintosh, B. (2000). Induced emotional interpretation bias and anxiety. *Journal of Abnormal Psychology*, *109*(4), 602–615. https://doi.org/10.1037/0021-843x.109.4.602

Mathews, A., Ridgeway, V., Cook, E., & Yiend, J. (2007). Inducing a benign interpretational bias reduces trait anxiety. *Journal of Behavior Therapy and Experimental Psychiatry*, *38*(2), 225–236. https://doi.org/10.1016/j.jbtep.2006.10.011

Miles, A., Voorwinden, S., Mathews, A., Hoppitt, L. C., & Wardle, J. (2009). Cancer fear and the interpretation of ambiguous information related to cancer. *Cognition & Emotion*, *23*(4), 701–713. https://doi.org/10.1080/02699930802091116

Mozafari, S., Yang, A., & Talaei-Khoei, J. (2024). Health Locus of Control and Medical Behavioral Interventions: Systematic Review and Recommendations. *Interactive Journal of Medical Research*, *13*, e52287. https://doi.org/10.2196/52287

Ragg, M. (2003). *Locus of control in chronic fatigue syndrome: Does it matter?* University of Canterbury. Psychology.

Rotter, J. B. (1966). Generalized Expectancies for Internal versus External Control of reinforcement. *Psychological Monographs: General and Applied*, *80*(1), 1–28.

Salemink, E., van den Hout, M., & Kindt, M. (2009). Effects of positive interpretive bias modification in highly anxious individuals. *Journal of Anxiety Disorders*, *23*(5), 676–683. https://doi.org/10.1016/j.janxdis.2009.02.006

Savioni, L., & Triberti, S. (2020). Cognitive Biases in Chronic Illness and Their Impact on Patients' Commitment. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.579455

van de Putte, E. M., Engelbert, R. H. H., Kuis, W., Sinnema, G., Kimpen, J. L. L., & Uiterwaal, C. S. P. M. (2005). Chronic fatigue syndrome and health control in adolescents and parents. *Archives of Disease in Childhood*, *90*(10), 1020–1024. https://doi.org/10.1136/adc.2005.074583

van't Klooster, J.-W., Rabago, L. M., Klaassen, B., & Kelders, S. M. (2024). Challenges and opportunities in mobile e-coaching. *Frontiers in Digital Health*, *5*. https://doi.org/10.3389/fdgth.2023.1304089

Vogel, M. (2019). *Retraining implicit fatigue among university students through CBM via an eHealth app*. http://essay.utwente.nl/78326/

Wallston, B. S., Wallston, K. A., Kaplan, G. D. ., & Maides, S. A. (1976). Development and validation of the Health Locus of Control (HLC) Scale. *Journal of Consulting and Clinical Psychology*, *44*(4), 580–585. https://doi.org/10.1037/0022-006x.44.4.580

Wallston, K. A. (2005). The validity of the multidimensional health locus of control scales. *Journal of Health Psychology*, *10*(5), 623–631. https://doi.org/10.1177/1359105305055304

Wallston, K. A., Strudler Wallston, B., & DeVellis, R. (1978). Development of the Multidimensional Health Locus of Control (MHLC) Scales. *Health Education Monographs*, *6*(1), 160–170. https://doi.org/10.1177/109019817800600107

Wolbers, R., Bode, C., Siemerink, E., Siesling, S., & Pieterse, M. (2021). Cognitive Bias Modification Training to Improve Implicit Vitality in Patients With Breast Cancer: App Design Using a Cocreation Approach. *JMIR Formative Research*, *5*(3), e18325. https://doi.org/10.2196/18325

Würtz, F., Krans, J., Blackwell, S. E., Cwik, J. C., Margraf, J., & Woud, M. L. (2021). Using Cognitive Bias Modification-Appraisal Training to Manipulate Appraisals about the Self and the World in Analog Trauma. *Cognitive Therapy and Research*, *46*(1), 232–246. https://doi.org/10.1007/s10608-021-10257-x

Wylie, G. R., Genova, H. M., DeLuca, J., & Dobryakova, E. (2017). The relationship between outcome prediction and cognitive fatigue: A convergence of paradigms. *Cognitive, Affective, & Behavioral Neuroscience*, *17*(4), 838–849. https://doi.org/10.3758/s13415-017-0515-y

Appendix A: Interpretation Bias Task Items

Items

INTRO

A challenge at work
You're faced with a challenging task at work. You spend a lot of time and energy to complete the task before you're work day

finishes.

In the challenge at work scenario, you completed the task by breaking it down into small chunks. (neutral)
In the challenge at work scenario, you were able to push through your fatigue and finish the task before you left that day. (negative)
In the challenge at work scenario, you were able to finish before the end of the day, leaving you satisfied with your accomplishment. (foil)
In the challenge at work scenario, you were able to finish on time, but when you got home, you fell asleep immediately. (foil)

Post-work relaxation
You've had a long day at work, and you're feeling mentally and physically drained. Once you get home, you sit down and relax before...

din_er
In the Post-work Relaxation scenario, you took a quick break to recharge. (neutral)
In the Post-work Relaxation scenario, you needed to sit down as soon as you got home because you were too tired to do anything else. (negative)
In the Post-work Relaxation scenario, you just wanted to do something fun before you need to cook. (foil)
In the Post-work Relaxation scenario, you wanted to sit for a second, but you were just so drained that you needed to take a long break. (foil)

Presentation woes
You have to present in front of a group, but you're already feeling mentally fatigued. After you finish, you notice some people...

wh_spering

In Presentation Woes, you believed people were discussing how well my presentation went. (Neutral)
In Presentation Woes, you believed people were pointing out how tired I sounded. (Negative)
In Presentation Woes, you believed people were talking about something unrelated to the Presentation. (Neutral Foil)
In Presentation Woes, you believed people were talking about how unkept I looked. (Foil)

Unproductive day
You have a slow day where you didn't complete as much as planned that morning. You decide to reset and grab a...

co_fee
In the Unproductive Day scenario, you didn't have a lot to do because it was a slow morning. (neutral)
In the Unproductive Day scenario, you were unproductive because you hadn't woken up completely yet. (negative)
In the Unproductive Day scenario, you got distracted by a conversation you were having with a coworker. (foil)
In the Unproductive Day scenario, you couldn't get any work done because you still haven't had your morning coffee. (foil)

Just in time
You're running late for an important meeting because you overslept. When you arrive, you notice people...

Star_ng

In the Just in Time scenario, you felt your colleagues understood that people are late sometimes. (neutral)
In the Just in Time scenario, you thought people were looking at you because they're annoyed you overslept. (negative)
In the Just in Time scenario, you thought you caught your colleague's attention by coming in mid-meeting. (foil)
In the Just in Time scenario, your colleagues were wondering why you looked like you just woke up. (foil)

Post-work hangout
After work, a friend invites you to a local event, but you had a busy...

d_y
In the Post-work Hangout scenario, you thought that the event would be a good way to meet new people and unwind. (neutral)
In the Post-work Hangout scenario, you decided not to go. You were too tired to socialize. (negative)
In the Post-work Hangout scenario, you decided not to go because you still had your work clothes on. (foil)
In the Post-work Hangout scenario, you decided to go despite your fatigue.(foil)

Sleeping in !

After a busy week at work, you wake up later on your day...

Of_

In the sleeping-in scenario, you slept in because you didn't need to get up. (neutral)
In the sleeping-in scenario, you slept in because you're always sleep-deprived. (fatigue foil)
In the sleeping-in scenario, you slept in because you needed the rest after a long week. (Fatigue)
In the sleeping-in scenario, you slept in because your alarm didn't go off. (neutral foil)

Getting fit
You decide to start a new exercise routine to have a healthier lifestyle. After a little while, you start to feel sore and...

th_rsty
In getting fit, you felt that the soreness was from getting stronger. (neutral)
In getting fit, you felt that the soreness was from being really out of shape. (foil)
In getting fit, you felt that the soreness was a normal response to hard exercise. (foil)
In getting fit, you felt that the soreness was from not being able to keep up when I’m tired. (negative)

Long lines
You finish getting groceries for the day and go to check out. When you get to the front you notice the lines are longer than...

usu_ls
In the Long Lines scenario, you saw the lines and was curious as to why the store was so busy today. (neutral)

In the Long Lines scenario, you were frustrated because being close to that many people is exhausting. (negative)
In the Long Lines scenario, you were concerned that your ice cream would melt. (foil)
In the Long Lines scenario, you were upset that you had to be out of the house for a lot longer than planned. (foil)

Work Life Balance
After a long day of work. You are about to shut everything down and relax. You then get a message from a colleague asking if you could look something over. You tell him that you can't right now and you will look at it

tom_rrow
In the Work-Life Balance scenario, you refused to do it now because you were already ready to leave. (neutral)
In the Work-Life Balance scenario, you told him you'll look at it tomorrow because you were way too tired to do it at the time. (negative)
In the Work-Life Balance scenario, you told him you'll look at it tomorrow because you need to feed your pet. (foil)
In the Work-Life Balance scenario, you refused because you need to get home and sleep. (foil)

OUTRO

Family Dinner !
After a long week of work, your family invites to dinner on the...

Weeke_d

In the Family Dinner scenario, you thought that it would be a good way to relax with your family. (neutral)
I can still enjoy the food and conversation, even if I'm tired. (Fatigue)
In the Family Dinner scenario, you thought that you would be too tired to actually engage with everyone. (Foil)
In the Family Dinner scenario, you thought that you would rather not see your family this weekend. (oil)

Lost Item !

You go grocery shopping after a long day at work. As you reach the cashier, you realize there's an item you...

forg_t

In the Lost Item scenario, you forgot the item because you were distracted. (neutral)
In the Lost Item scenario, you forgot the item because you are a bit forgetful when you're tired. (negative)
In the Lost Item scenario, you forgot the item because the store's layout is a bit confusing. (foil)
In the Lost Item scenario, you forgot the item, but are too tired to go back to grab it. (foil)

Growing pains !

You decide to try and learn a new skill, but you realize its a bit harder than you first...

th_ught

1. In the Growing Pains scenario, you struggled you are still in the processes of learning. (neural)
2. In the Growing Pains scenario, you struggled because you were tired from practicing today. (Fatigue)
3. In the Growing Pains scenario, you struggled because you aren't the best at it learning new things. (foil)
4. In the Growing Pains scenario, you struggled because you were mentally tired at the time. (foil)

Big deadline !
You've been working on a big project for a few hours today. You notice your productivity slows down and decide to take a...

Bre_k

In big you…
Took a break to reset and come back to the project with a fresh mind. (Neutral)
can’t focus anymore; this workload is too much when I’m this tired. (Fatigue)
Took a break to grab a coffee and a snack to treat yourself. (foil)
think it's impossible to finish when I’m so mentally exhausted. (foil)

Email Lost !
You notice during your lunch break, you notice that you forgot to reply to an email you got this morning. Before you finish lunch you set a...

Remi_der

In the Email Lost scenario, you forgot to reply because you lost track of time. (neutral)
In the Email Lost scenario, you forgot to reply because you were still sleepy in the morning. (fatigue)
In the Email Lost scenario, you didn't reply because the email wasn't really that important. (Foil)
In the Email Lost scenario, you didn't reply because you were too tired to really care this morning. (foil)

Friendly walk !
During your break, your friend invites you to take a walk and grab lunch from a nearby....

C_fe

In Friendly Walk, you thought…
In the Friendly Walk scenario, the walk sounded nice, but you were already tired from working. (negative)
In the Friendly Walk scenario, the walk sounded like a nice way to get some air. (neutral)
In the Friendly Walk scenario, you didn't want to walk to go eat. You're starving and need to eat asap. (foil)
In the Friendly Walk scenario, you refused. You don't enjoy walks (foil)

Busy day !
You just came back from running errands all day, and decided to order some food for...

d_nner

In the Busy Day scenario, you decided to order dinner because you were too tired to cook. (Fatigue)
In the Busy Day scenario, you ordered dinner as a reward for yourself. (Neutral)
In the Busy Day scenario, you ordered dinner because you really wanted to. (Foil)
In the Busy Day scenario, you ordered dinner because you could not get off the couch from how exhausted you were. (foil)

Overtime !

An important deadline is coming up, and you decide to spend a day completing some of the bigger parts of the...

pr_ject

In the Overtime scenario, you put in the extra effort so you can spend the next couple of days recovering from the stress. (Fatigue)
In the Overtime scenario, you put in the extra effort so you can easily finish in the next couple of days. (neutral)
In the Overtime scenario, you put in the extra effort so you can go home and sleep. (foil)
In the Overtime scenario, you finished what you could now, so you can procrastinate the rest. (foil)

Just in time !

You are running late for your train, and you decide to run the last few meters before the doors close. You make it just in time, sit down, and let out a big...

S_gh

In Just in time:

1. In the Just in Time scenario, you run to make your train, sit down and sigh because you are out of breath (fatigue)
2. In the Just in Time scenario, you run to make your train, sit down and sigh out of exhaustion (foil)
3. In the Just in Time scenario, you run to make your train, sit down and sigh out of a sense of accomplishment (foil)
4. In the Just in Time scenario, you run to make your train, sit down and sigh out of relief (neutral)

Sleeping in !

After a busy week at work, you wake up later on your day...

Of_

In the sleeping-in scenario, you slept in because you didn't need to get up. (neutral)
In the sleeping-in scenario, you slept in because you're always sleep-deprived. (fatigue foil)
In the sleeping-in scenario, you slept in because you needed the rest after a long week. (Fatigue)

In the sleeping-in scenario, you slept in because your alarm didn't go off. (neutral foil)

Appendix B: CBM-I Training Items

Day 1

An important deadline is coming up, and you decide to spend a day completing some of the bigger parts of the project. Afterwards, you feel…

Proud

Did you feel proud after completing some of the bigger parts of the project?

On holiday, you decide to visit a local museum. You spend hours walking around, marveling at the different displays. When you finally get home in the evening, you feel…

Fulfilled

Did you feel fulfilled after walking through the local museum?

You decide to start going to the gym consistently 3 times a week. After the first week, you feel soreness in your leg muscles. This is because you are getting…

Stronger

Are you gettting stronger because you have been going to the gym consistently?

You're feeling a bit tired while studying or working. You push through and realize that you are…

Motivated

You realize you made a small error at work or school. You spend extra time correcting it and feel…

Responsible

You've been out doing errands for hours. As you return home, you feel…

Satisfied

Did you feel satisfied after running errands for hours?

You need to talk to someone about something important. Your heart starts beating fast, you think this is because you are...

Nervous

You've had a long, demanding week at work or school. On Friday evening, you reflect and feel…

Proud

Did you feel proud after the long demanding week at school or work?

After spending some time tidying up your room, you look around and feel…

Refreshed

Did you feel refreshed after tidying up your room?

You spend a long time preparing a homemade meal for yourself or others. As you sit down to eat, you feel…

Accomplished

Did you feel accomplished after preparing a homemade meal for yourself?

You take a few minutes to tidy up your kitchen. As you finish, you step back and notice that you feel…

Proud

Did you feel proud after tidying up your kitchen?

You spend an hour folding a large pile of laundry. After looking at the neatly stacked clothes, you feel…

Satisfied

After putting in days of effort, you finally complete a long-term project. You step back and feel a sense of…

Accomplishment

A friend or colleague asks for your help with something they're struggling with. After spending a while helping them, you feel…

Useful

You had a long day filled with various activities. In the evening, you sit down and reflect on your day. You realize that despite feeling physically tired, you have been quite…

Productive

You are running behind schedule for an important appointment. Instead of panicking, you take a deep breath and remain…

Collected

Did you feel collected after you took a deep breath instead of panicking?

After dinner, you take a moment to wash the dishes. As you finish, you step back and notice that you are…

Satisfied

You are faced with a challenging task that requires effort and patience. After working through it step by step, you realize you are…

Resilient

You decide to try a new hobby or skill, even though you're not sure how well you'll do. As you put time and effort in, you notice that you are…

Learning

You are tasked with presenting something at work or in class. Although you feel nervous at first, once you start speaking, you feel…

Confident

Did you feel confident after presenting something in front of your class or at work?

You are enjoying a picnic when unexpected rain begins to fall. You move quickly to avoid the rain. After finding a spot to rest you notice you are…

Soaked

Something unexpected comes up in your day. At first, you feel unsure, but then you realize you are…

Capable

You wake up after a night of sleep. You take a deep breath and notice that you feel…

Refreshed

Did you feel refreshed after waking up after a night of sleep?

You attend a gathering where you don't know everyone. As you talk to different people, you notice that you are getting…

Compliments

You have a task that requires focus and effort. After getting started, you are feeling…

Competent

You go for a walk even though you weren't sure if you had the energy. Afterward, you feel a sense of…

Achievement

Did you feel a sense of achievement after going for a walk?

You go grocery shopping and carry your bags home. At the end of the trip, you are feeling…

Capable

A friend asks you to meet up after work or class. You are unsure if you have the energy but decide to go. As the conversation flows, you realize you are feeling quite…

Engaged

Did you feel engaged after meeting with your friend?

Yesterday, you went for a walk with a friend. This morning, you notice your legs are stiff. You think today will be…

Chill

Normally, you go to the gym on Tuesday mornings, but you decide to skip it today because you were too?

Preoccupied

Day 2

You've been putting in extra effort to learn a new skill. After some practice, you realize you are…

Progressing

Are you progressing after putting in extra effort to learn a new skill?

You face a tough challenge at work, but after some effort, you overcome it, leaving you feeling…

Empowered

Did you feel empowered after overcoming a tough challenge at work?

You finish a large home improvement project that took time and effort. You finally sit down and feel…

Proud

You encounter a problem and work through it until you find a solution. You feel…

Resourceful

You're faced with unexpected changes, but you quickly adapt to the issue, leaving you feeling…

Flexible

You're in a distracting environment, and you put a lot of effort into staying focused on your work. You feel…

Determined

Did you feel determined after staying focused in a distracting environment?

You assist a stranger in need, and after doing so, you feel…

Fulfilled

You face a setback in your goals, but you put in extra effort to work toward them and feel…

Resilient

You spend some time explaining a concept to someone, and they finally understand it. You feel…

Satisfied

You realize you made a mistake and take responsibility for it. After spending extra time fixing the mistake, you feel…

accountable

You've been taking steps to improve your self-esteem, and today you feel…

Confident

Did you feel confident after taking steps to improve your self-esteem?

You've been consistently working out, and you feel good about the progress you've made. You start to feel…

Energized

Did you feel energized after consistently working out?

Leading up to an important deadline, you've been spending more time working than usual. You notice you start to get sleepy sooner than normal. This is probably due to…

work

You are juggling multiple tasks at once. Despite the pressure, you manage to stay focused and feel…

Efficient

Did you feel efficient after managing to juggle multiple tasks at once?

A friend goes through a tough time, and you offer your support. After a long conversation with them, you feel…

Helpful

You're running a bit late for your bus. You decide to run, and you catch the bus right before it leaves. You sit down and feel…

Relieved

Did you feel relieved after making it to the bus right before it left?

An unexpected situation arises that could cause panic. You feel…

Collected

You've been sticking to a healthy routine, even though it's been challenging. At the end of the week, you feel…

Accomplished

Did you feel accomplished after sticking to a healthy routine even though it was challenging?

A colleague or friend asks you for help with a personal issue. You offer your assistance and feel…

Compassionate

You face a situation that makes you anxious, but you push through it and feel…

Brave

Did you feel brave after pushing through a situation that made you feel anxious?

You have a project due soon and need to complete it quickly. Despite the pressure, you are organized and feel…

Calm

You've had a long, demanding week at work or school. On Friday evening, you reflect and feel a sense of…

Accomplishment

You are meeting up with an old school friend. You ask them if they would meet you locally. They will think you are...

Busy

You have been invited to a wedding this weekend. It's not close to home, so you would have to travel by car and stay overnight at a hotel nearby. You think the weekend will be...

Enjoyable

You have had a busy day at work and have a number of tasks to get done before the end of the day. You ask a colleague for help because you are...

Busy

Today, you spent a long time grocery shopping and bought ingredients for dinner. When you get home, you are...

Hungry

You've been out doing errands for hours. As you return home, you feel…

Satisfied

You prepare a homemade meal for yourself or others. As you sit down to eat, you feel…

Proud

On holiday, you decide to visit a local museum. You spend hours walking around, marveling at the different displays. When you finally get home in the evening, you feel...

Fulfilled

Normally, you go to the gym on Tuesday mornings, but you decide to skip it today because you were too...

Busy

Day 3

After a stressful week, you and your friend are making plans, and they pitch an idea of spending a day hiking a local trail. You find that idea...

Fun

One day, you finally decide to fix the annoying squeaking your bedroom door is making. You spend a couple of hours figuring out what's causing the problem. You get the tools out and fix it yourself. Afterwards, you feel...

Satisfied

Did you feel satisfied after you spend a couple of hours fixing the annoying squeaking bathroom door?

You had an exhausting day at work. For lunch, you decide to go to a local food truck for a change. You stand in line for 20 minutes waiting to get your food. Once you get your food and sit down, you feel...

Excited

Normally, you go to the gym on Tuesday mornings, but today you are really tired. You still go to the gym, afterwards you feel…

Refreshed

Did you feel refreshed after you went to the gym although you were tired?

During a particularly busy day at work, you decide to take a walk during your break. When you get back from your walk, you feel...

Refreshed

You decide to start going on walks consistently 3 times a week. After the first week, you feel soreness in your leg muscles. This is because you are getting...

Stronger

Are you getting stronger because your legs are feeling sore after going on walks for a week?

After getting back from grocery shopping, you are exhausted. You realize that you forgot something essential and need to go back. After getting it, you are now…

Happy

You spent the whole day working on an important assignment, and you finally get home and eat. After washing up and sitting down at the end of the day, your body feels...

Relaxed

You overslept and are running a bit late for your bus. You decide to run and catch the bus right before it leaves. You sit down and feel…

Relieved

You go for a walk even though you weren't sure if you had the energy. Afterward, you feel a sense of…

Pride

Did you feel a sense of pride after going on a walk although you were not sure if you had the energy?

You are faced with a challenging task. After working through it step by step, you realize you are…

Patient

Do you feel patient after you managed to work through a difficult task step by step?

During a stressful and tiring workday, a colleague asks for your help with something they're struggling with. As you assist them, you feel…

Helpful

You are running late for an appointment and have taken public transport to get there. You arrive at your station to find the lifts and escalators are out of order. Passengers have been advised to either get off at the next stop for disabled access or use the stairs. You think if you take the stairs you will probably be...

Fine

You've had a very busy day at work and now its time for lunch break. After eating, you feel…

Energized

Did you feel energized after eating lunch during this busy day at work?

You take a 10-minute break to stretch and relax during a busy workday. Afterward, you feel…

Recharged

After a long day, you finish folding a pile of laundry. Looking at the neatly stacked clothes, you feel…

Satisfied

After spending a long time tidying up your room, you are exhausted, but when you look around you feel…

Proud

You've been out doing errands for hours. As you return home, you feel…

Satisfied

Did you feel satisfied after you've been out doing errands for hours?

You had a long day filled with various activities. In the evening, you sit down and reflect on your day. You realize that despite feeling physically tired, you have been quite…

Productive

Did you feel productive after you had a long day filled with various activities, despite being physically tired?

You usually get the bus to work but today you are feeling energetic and decided to walk. When you come home from work you feel more tired than usual. You think tomorrow you will feel....

Better

On holiday, you decide to visit a local museum. You spend hours walking around, marveling at the different displays. When you finally get home in the evening, you feel...

Fulfilled

Leading up to an important deadline, you've been spending more time working than usual. You notice you start to get sleepy sooner than normal. You think that the effort is…

Valuable

After a tiring day at school, a friend has just asked you to go for a walk with them. You think the walk would be...

Enjoyable

You take a quick 20-minute nap after a physically demanding day. Afterward, you feel…

Restored

Did you feel restored when you took a quick 20-minute nap after a physically demanding day?

You have been working hard all day to get the house ready for some guests who are coming to stay tomorrow night. You feel...

Accomplished

You wake up after a night of sleep. You take a deep breath and notice that you feel…

Refreshed

Did you feel refreshed after you woke up after a night of sleep?

You do some light stretching or yoga after a busy day. Afterwards, you feel…

Revitalized

You are going on holiday tomorrow and have had a busy day packing. When your alarm wakes you up in the morning, you feel...

Excited

Appendix C: R-code

```
library(dplyr)
library(data.table)
library(car)
library(splines)
library(ggplot2)
library()
library(MASS)
library(stringr)
library(remotes)
library(ggeffects)
library(lme4)
library(broom.mixed)
library(tidyverse)

library(performance)
library(papaja)
library(effsize)
library(robustlmm)
library(ggalt)
library(influence.ME)
library(interactions)
library(tidyverse)
setwd("C:/Users/ijgib/Documents/School shit/Thesis/Data")
data <- fread("Data_rawF.csv", header = TRUE)
head(data)
data_consent <-data[, 1:9]
data1 <-data[, -c(2:11)]
data_intro <- data1[, 1:205]
data2 <- data1[, -c(2:471)]
```

```
data_outro <- data2[, 1:143]
data_sona <- data2[, 148:149]
data_demo <- data_intro[,1:9]
data_intro <-data_intro[, -c(2:9)]
tstamp_cols <- grepl("Timestamp", names(data_intro), ignore.case = TRUE)
intro_clean <- subset(data_intro, select = !tstamp_cols)
tstamp_cols_outro <- grepl("Timestamp", names(data_outro), ignore.case = TRUE)
outro_clean <- subset(data_outro, select = !tstamp_cols_outro)
tstamp_cols_demo <- grepl("Timestamp", names(data_demo), ignore.case = TRUE)
demo_clean <- subset(data_demo, select = !tstamp_cols_demo)
intro_fat_data <- intro_clean[, c(1, 3:11)]

Completion_data <- data[, c(1, 215, 305, 391, 475, 623)]
names(Completion_data) <- c("ID", "Intro", "Training 1", "Trainig 2", "Training 3", "Outro")




#intro_fat_data <- na.omit(intro_fat_data)
intro_fat_data1 <- intro_fat_data %>%
  mutate(across(where(is.character), ~ as.numeric(str_extract(., "\\d+"))-1))
intro_fat_data1 <- intro_fat_data1 %>%
  mutate(fatigue_total = rowSums(across(c(2:10))), na.rm = FALSE)
intro_fat_data[intro_fat_data == ""] <- NA

outro_fat_data <- outro_clean[, 1:10]
#outro_fat_data[outro_fat_data == ""] <- NA
#outro_fat_data <- na.omit(outro_fat_data)
outro_fat_data1 <- outro_fat_data %>%
  mutate(across(where(is.character), ~ as.numeric(str_extract(., "\\d+"))-1))
outro_fat_data1 <- outro_fat_data1 %>%
```

```
  mutate(fatigue_total = rowSums(across(c(2:10))), na.rm = FALSE)

fatigue_score <- merge(
  intro_fat_data1[, c("ID Number", "fatigue_total")],
  outro_fat_data1[, c("ID Number", "fatigue_total")],
  by = "ID Number",
  all = TRUE,
  suffixes = c("_intro", "_outro")

)
fatigue_score <- fatigue_score %>%
  mutate(fatigue_differene = fatigue_total_intro - fatigue_total_outro)



IBT_intro <- intro_clean[, c(1, 34:73)]
IBT_outro <- outro_clean[, c(1, 33:72)]

names(IBT_intro)[duplicated(names(IBT_intro))]

IBT_intro1 <- IBT_intro %>%
  mutate(across(where(is.character), ~ as.numeric(str_extract(., "\\d+"))))

IBT_outro1 <- IBT_outro %>%
  mutate(across(where(is.character), ~ as.numeric(str_extract(., "\\d+"))))

intro_negative_items <- c("A Challenge at Work 2", "Post-work Relaxation 2", "Presentation
Woes 2", "Unproductive Day 2", "Just in time 2",
                          "Post-work Hangout 2", "Sleeping in 3", "Getting Fit 4", "Long Lines 2",
"Work-Life Balance 2")
```

```
intro_neutral_items <- c("A Challenge at Work 1", "Post-work Relaxation 1", "Presentation Woes 1", "Unproductive Day 1", "Just in time 1",
                         "Post-work Hangout 1", "Sleeping in 1", "Getting Fit 1", "Long Lines 1", "Work-Life Balance 1")
intro_foil_items <- c("A Challenge at Work 3", "Post-work Relaxation 3", "Presentation Woes 3", "Unproductive Day 3", "Just in time 3",
                         "Post-work Hangout 3", "Sleeping in 2", "Getting Fit 2", "Long Lines 3", "Work-Life Balance 3",
                         "A Challenge at Work 4", "Post-work Relaxation 4", "Presentation Woes 4", "Unproductive Day 4", "Just in time 4",
                         "Post-work Hangout 4", "Sleeping in 4", "Getting Fit 3", "Long Lines 4", "Work-Life Balance 4"
                         )
IBT_intro2 <- IBT_intro1 %>%
  mutate(negative_mean = (rowSums(across(all_of(intro_negative_items))))/10)
IBT_intro2 <- IBT_intro2 %>%
  mutate(neutral_mean = (rowSums(across(all_of(intro_neutral_items))))/10)
IBT_intro2 <- IBT_intro2 %>%
  mutate(foil_mean = (rowSums(across(all_of(intro_foil_items))))/10)
IBT_intro2 <- IBT_intro2 %>%
  mutate(IBT_Score = negative_mean - neutral_mean)


outro_negative_items <- c("Family Dinner 2", "Lost Item 2", "Growing Pains 2", "Big Deadline 2", "Email Lost 2", "Friendly Walk 1",
                          "Busy Day 1", "Overtime 1", "Just in Time 1", "Sleeping In 3")
outro_neutral_items <- c("Family Dinner 1", "Lost Item 1", "Growing Pains 1", "Big Deadline 1", "Email Lost 1", "Friendly Walk 2",
                         "Busy Day 2", "Overtime 2", "Just in Time 4", "Sleeping In 1")
outro_foil_items <- c("Family Dinner 3", "Lost Item 3", "Growing Pains 3", "Big Deadline 3", "Email Lost 3", "Friendly Walk 3",
```

```
                "Busy Day 3", "Overtime 3", "Just in Time 2", "Sleeping In 2","Family Dinner 4",
"Lost Item 4",
                "Growing Pains 4", "Big Deadline 4", "Email Lost 4", "Friendly Walk 4",
                "Busy Day 4", "Overtime 4", "Just in Time 3", "Sleeping In 4"
)
IBT_outro2 <- IBT_outro1 %>%
  mutate(negative_mean = (rowSums(across(all_of(outro_negative_items))))/10)
IBT_outro2 <- IBT_outro2 %>%
  mutate(neutral_mean = (rowSums(across(all_of(outro_neutral_items))))/10)
IBT_outro2 <- IBT_outro2 %>%
  mutate(foil_mean = (rowSums(across(all_of(outro_foil_items))))/10)
IBT_outro2 <- IBT_outro2 %>%
  mutate(IBT_Score = negative_mean - neutral_mean)

IBT_score <- merge(
  IBT_intro2[, c("ID Number", "IBT_Score")],
  IBT_outro2[, c("ID Number", "IBT_Score")],
  by = "ID Number",
  all = TRUE,
  suffixes = c("_intro", "_outro")
)
IBT_score <- IBT_score %>%
  mutate(IBT_difference = IBT_Score_intro - IBT_Score_outro)



MHC_data <- intro_clean[, c(1, 82:99)]
MHC_data_clean <- MHC_data %>%
  mutate(across(where(is.character), ~ as.numeric(str_extract(., "\\d+"))))

MHC_names <- paste0("MHC-", 1:18)
setnames(MHC_data_clean, c(2:19), MHC_names)
```

```
Internal <- c(1,6,8,12,15,17)
Chance <- c(2,4,9,11,15,16)
Pow_Oth <- c(3,5,7,10,14,18)
Internal_Items <- paste0("MHC-", Internal)
Chance_Items <- paste0("MHC-", Chance)
POthers_Items <- paste0("MHC-", Pow_Oth)

MHC_data_clean <- MHC_data_clean %>%
  mutate(Internal_score = rowSums(across(all_of(Internal_Items))))
MHC_data_clean <- MHC_data_clean %>%
  mutate(Chance_score = rowSums(across(all_of(Chance_Items))))
MHC_data_clean <- MHC_data_clean %>%
  mutate(Powerful_Others_score = rowSums(across(all_of(POthers_Items))))

IBT_MHC <- merge(
  IBT_score[, c("ID Number", "IBT_difference")],
  MHC_data_clean[, c("ID Number", "Internal_score", "Chance_score",
"Powerful_Others_score")],
  by = "ID Number",
  all = TRUE
)

Fatigue_MHC <- merge(
  fatigue_score[, c("ID Number", "fatigue_differene")],
  MHC_data_clean[, c("ID Number", "Internal_score", "Chance_score",
"Powerful_Others_score")],
  by = "ID Number",
  all = TRUE
)
```

```
#Data Analysis
#Making one big data set
fatigue_score <- na.omit(fatigue_score)




fin_dat <- merge(
  fatigue_score[, c("ID Number", "fatigue_total_intro", "fatigue_total_outro",
"fatigue_differene")],
  IBT_score[, c("ID Number", "IBT_Score_intro", "IBT_Score_outro", "IBT_difference")],
  by = "ID Number",
  all = TRUE
)

fin_dat <- merge(
  fin_dat,
  MHC_data_clean[, c("ID Number", "Internal_score", "Chance_score",
"Powerful_Others_score")],
  by = "ID Number",
  all = TRUE
)
fin_dat <- na.omit(fin_dat)
ID_comp <- fin_dat$`ID Number`
demo_comp <- subset(demo_clean, `ID Number` %in% ID_comp)
demo_comp$`What is your gender?` <- as.factor(demo_comp$`What is your gender?`)
demo_comp$`What is your highest level of education completed?`<-
as.factor(demo_comp$`What is your highest level of education completed?`)
demo_comp$`What is your current occupational status?` <- as.factor(demo_comp$`What is your
current occupational status?`)
```

```
summary(demo_comp)



long_fin <- fin_dat %>%
  pivot_longer(
    cols = c(fatigue_total_intro, fatigue_total_outro),
    names_to = "time",
    names_prefix = "fatigue_total_",
    values_to = "fatigue"
  )

long_fat <- long_fin %>%
  mutate(
    time = factor(time, levels = c("intro", "outro")),
    time_dum = as.numeric(time) - 1,
    ID = factor(`ID Number`)
  )

long_fin2 <- fin_dat %>%
  pivot_longer(
    cols = c(IBT_Score_intro, IBT_Score_outro),
    names_to = "time",
    names_prefix = "IBT_Score_",
    values_to = "IBT",
  )

long_ibt <- long_fin2 %>%
  mutate(
    time = factor(time, levels = c("intro", "outro")),
    time_dum = as.numeric(time) - 1,
```

```
  ID = factor(`ID Number`)
 )


#new Analysis
#null-fatigue
fat_null <- lmer(fatigue ~ 1 + (1| ID), data = long_fat)
#null-ibt
ibt_null <- lmer(IBT ~ 1 + (1 | ID), data = long_ibt)
#Internal-Fatigue
fat_in <- lmer(fatigue ~ time*Internal_score + (1 | ID), data = long_fat)
summary(fat_in)
confint(fat_in, level = 0.95, method = "profile")
anova(fat_in, fat_null, test = "LRT")
sim_slopes(fat_in, pred = time, modx = Internal_score, jnplot = TRUE)
pred_int <- ggpredict(fat_in,
                      terms = c("time", "Internal_score [15.9, 18.6, 21.2]"))

ggplot(pred_int, aes(x = x, y = predicted,
                     color = group, group = group)) +
  geom_point(size = 3) +
  geom_line(linewidth = 1) +
  geom_errorbar(aes(ymin = conf.low, ymax = conf.high),
                width = 0.1, linewidth = 0.8) +
  scale_color_viridis_d(
    name = "IHLC Score",
    labels = c("Low (-1SD)", "Mean", "High (+1SD)")) +
  labs(
    x = "CBM-I Training",
    y = "Predicted Fatigue",
    title = "Simple Slopes: CBM-I × IHLC Score"
```

```
  ) +
  theme_minimal(base_size = 14) +
  theme(legend.position = "top")



check_model(fat_in)
r2(fat_in)
#Chance-Fatigue
fat_c <- lmer(fatigue ~ Chance_score*time + (1 | ID), data = long_fat)
summary(fat_c)
confint(fat_c, level = 0.95, method = "profile")
anova(fat_c, fat_null, test = "LRT")
sim_slopes(fat_c, pred = time, modx = Chance_score, jnplot = TRUE)
pred_cha <- ggpredict(fat_c,
                      terms = c("time", "Chance_score [13.9, 17.4, 20.1]"))
ggplot(pred_cha, aes(x = x, y = predicted,
                     color = group, group = group)) +
  geom_point(size = 3) +
  geom_line(linewidth = 1) +
  geom_errorbar(aes(ymin = conf.low, ymax = conf.high),
                width = 0.1, linewidth = 0.8) +
  scale_color_viridis_d(
    name = "CHLC Score",
    labels = c("Low (-1SD)", "Mean", "High (+1SD)")) +
  labs(
    x = "CBM-I Training",
    y = "Predicted Fatigue",
    title = "Simple Slopes: CBM-I × CHLC"
  ) +
  theme_minimal(base_size = 14) +
  theme(legend.position = "top")
```

```
r2(fat_c)
check_model(fat_c)
# Pothers-fatigue
fat_po <- lmer(fatigue ~ Powerful_Others_score*time + (1| ID), data = long_fat)
summary(fat_po)
confint(fat_po, level = 0.95, method = "profile")
check_model(fat_po)
anova(fat_po, fat_null, test = "LRT")
sim_slopes(fat_po, pred = time, modx = Powerful_Others_score, jnplot = TRUE)
r2(fat_po)


#internal-Ibt
ibt_in <- lmer(IBT ~ Internal_score*time + (1| ID), data = long_ibt)
summary(ibt_in)
confint(ibt_in, level = 0.95, method = "profile")
anova(ibt_in, ibt_null, test = "LRT")
r2(ibt_in)
check_model(ibt_in)
#chance-ibt
ibt_c <- lmer(IBT ~ Chance_score*time + (1| ID), data = long_ibt)
summary(ibt_c)
confint(ibt_c, level = 0.95, method = "profile")
anova(ibt_c, ibt_null, test = "LRT")
r2(ibt_c)
#powerful others-ibt
ibt_po <- lmer(IBT ~ Powerful_Others_score*time + (1| ID), data = long_ibt)
summary(ibt_po)
confint(ibt_po, level = 0.95, method = "profile")
anova(ibt_po, ibt_null, test = "LRT")
r2(ibt_po)
```

```
summary(fin_dat)
sd(fin_dat$fatigue_total_intro)
sd(fin_dat$fatigue_total_outro)
sd(fin_dat$IBT_Score_intro)
sd(fin_dat$IBT_Score_outro)
sd(fin_dat$Internal_score)
sd(fin_dat$Chance_score)
sd(fin_dat$Powerful_Others_score)

t.test(fin_dat$IBT_Score_intro, fin_dat$IBT_Score_outro, paired = TRUE, alternative =
"two.sided")
t.test(fin_dat$fatigue_total_intro, fin_dat$fatigue_total_outro, paired = TRUE, alternative =
"two.sided")
cohen.d(fin_dat$IBT_Score_intro, fin_dat$IBT_Score_outro, paired = TRUE)
cohen.d(fin_dat$fatigue_total_intro, fin_dat$fatigue_total_outro, paired = TRUE)
```