Reducing daily stress: Breaking a habit

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General discussion

07

INTRODUCTION

Human beings are prone to experience stress [5, 6] and this is of interest because research has repeatedly shown that experiencing stress has a negative effect on health [11-17], including cardiovascular health [18-24]. The negative health effect is recognized to occur as a result of prolonged physiological stress responses (like prolonged decreases in heart rate variability [HRV]) [10, 12, 25]. Most research to date has focused on increased physiological responses as a direct result of experiencing stressful events [26], yet physiological responses can also be activated and prolonged by thinking about the stressful events [25, 27-29]. This process is captured in the perseverative cognition (PC) hypothesis, which suggests that the negative relation between stress and health may be better explained when accounting for the mediating role of PC, such as worry [25]. Evidence supporting the association between PC, or conscious stress-representations, and stress-related physiological activity has been accumulating [31-34]. Recently, the PC hypothesis was extended with the suggestion that stress-representations may also be activated in the absence of awareness—in other words—unconsciously [38, 39]. These unconscious stress-representations in turn are theorized to explain a large part of the prolonged stress-related physiological activity [38, 39]. Evidence for the extended PC hypothesis is, however, limited and mostly indirect [32, 40-46, 57-61].

The main aim of this thesis was to find direct evidence for the extended PC hypothesis in real life. To put it differently, we aimed to examine whether (unconscious) PC can prolong physiological activity and increase subjective health complaints (SHC). To address this question, we first examined whether a short Internet-based worry-reduction intervention reduced conscious worry and improved SHC. Next, we set out to reduce both conscious and unconscious PC in primarily at risk individuals using (a) a smartphone-based worry-reduction intervention and (b) a subliminal evaluative conditioning (SEC) intervention. We examined the effect of the (unconscious) PC manipulations on health related parameters, thereby allowing us to draw conclusions about directionality and causality. In this final chapter we summarize and discuss the main findings from the included studies. Furthermore, we discuss the theoretical and clinical implications of the findings, the strengths and limitations, and we present directions for future studies.

OVERVIEW OF MAIN FINDINGS

In *Chapter 2* we examined whether there was a causal relation between conscious PC and self-reported SHC in the general adult population. To accomplish this we aimed to manipulate worry using a simple 6-day worry-postponement intervention that was previously found to be effective. In this intervention participants were instructed to notice their worries and to postpone these worries to a special 30-min worry period in the early evening. This was the first study to offer the worry-postponement intervention via the Internet, thereby making a simple and cost-effective intervention available to a larger community of self-labeled worriers. Data of 351 participants were included in the analyses. The cross-sectional findings showed that there was a positive association between worry and SHC, which replicated previous findings [25, 31, 33, 86, 88]. The experimental (or interventional) findings were, however, contrary to our expectation; that is, no support was found for the hypothesis that the intervention resulted in a larger decrease in trait and daily worry, SHC, or negative affect compared to participants in the control condition who simply registered their worries. Since the intervention was ineffective at reducing worry, we were unable to test whether reducing worry had a positive effect on (self-reported) health. Thus, in this study we failed to test if worry indeed caused SHC. This lack of effect may have been caused by participants' failure to become competent in postponing their worries within the intervention period. Only 24% of the participants who were instructed to postpone their worrying felt that their ability to do so was adequate. Considering the habitual nature of worrying, it is conceivable that individuals may require considerably more time and practice to replace their habit to worry with alternative ways of responding.

Ecological momentary interventions (EMIs) offer viable methods to promote treatment frequency in a relatively easy way to 'break' cognitive habits, such as worry. Not only are EMIs of interest because people can be trained *directly* when they experience complaints such as worry, but EMIs also allow individuals to practice repeatedly throughout the day, which may promote the effectiveness of the intervention [67, 265, 266]. These basic EMI characteristics are specifically of interest when aiming to break the habit to worry, because breaking non-adaptive habits can either be done by changing the environment that individuals are in (thereby removing the cue that initiates the habit) [267, 268] or by forming new responses in the existing environment [269, 270]. As it is virtually impossible to remove all cues that elicit an individual's habit to worry, it may be more effective to use an EMI to help an individual initiate and maintain more adaptive, alternative responses in the actual environment [271, 272]. Yet little is known about the effectiveness of EMIs. In *Chapter 3* we therefore systematically

assessed and meta-analyzed the effect of EMIs on mental health problems and positive psychological well-being. A small to medium effect of EMIs was found on mental health and the effect was not significantly different for anxiety, depression, perceived stress, or positive psychological outcomes. Larger effects—compared to stand-alone EMIs—were found when individuals received support from a mental health professional (MHP) in addition to the EMI. The findings must, however, be interpreted with caution considering (a) the low reported study quality, (b) the relatively small sample sizes, and (c) because the effect was smaller in between-subject studies compared to within-subject studies (and within-subject studies are at a greater risk for type-II errors). There is definitely a need for randomized controlled trials (RCTs) with an adequate number of participants to carefully examine the potential of EMIs. Still, the initial data suggests that EMIs are an easy and cost-effective strategy to improve mental health and positive psychological well-being in both healthy and clinical populations.

There is now evidence that EMIs can be used to improve mental health problems, but to date no study has examined whether EMIs can also be used to reduce (unconscious) PC and improve physiological health. It is theoretically plausible that EMIs can be specifically useful when attempting to break the habit to worry. As the EMI can serve as a direct reminder in daily life to display adaptive habit behavior [271, 273, 274] and—through repetition—can help to break the habit to worry [67, 265, 266]. In *Chapter 4* we report the findings of a pilot study using a daily worry-reduction EMI with mindfulness exercises. The main goal of the study was to examine the feasibility and preliminary effectiveness of the 4-week intervention that trained people repeatedly throughout the day to break the habit to worry. In terms of effectiveness we were particularly interested if this EMI could improve physiological indications of stress, namely HRV levels. For this purpose, high worrying students were randomized to either the worry-reduction EMI with mindfulness exercises or to an active-control condition that consisted of daily emotion registrations. The primary outcomes of interest of this pilot study were feasibility and ambulatory assessed HRV as marker of physiological stress responses. The training was feasible and participants completed on average 70% of all the training sessions. This suggests that offering five short and easy to complete training sessions per day was appropriate. Importantly, the training was easy to do, was taken seriously, and doing the training did not interfere significantly with the daily lives of the participants. Both the worry-reduction EMI and the emotion registration resulted in an increase in HRV from pre- to post-intervention. No effects were found on heart rate (HR), worry, anxiety, acceptance, and affect (both implicit and explicit). However, the effect sizes for trait worry and acceptance were small to medium and in the expected direction. These first findings showed that HRV improved

in individuals who received the worry-reduction intervention as well as in individuals who merely repeatedly registered their emotions. Yet only an effect was expected in the condition that received the worry-reduction intervention with mindfulness exercises. These findings could mean two different things. On the one hand, it could indicate that both strategies are effective in reducing physiological stress responses. On the other hand, it could mean that both interventions were ineffective. The observed HRV increase could have been caused by non-specific aspects of the design (e.g., due to an initial HRV decrease as a result of anticipation or novelty of the measurements) or the increase in HRV was simply a spurious finding possibly as a result of the small sample size. The latter could also have obscured a small superior effect of the worry-reduction intervention. To determine which of the explanations was legitimate, the EMI needed to be examined in another study including a no-treatment waitlist control condition (to test whether the interventions were effective and rule out the explanation of nonspecific effects) and a larger number of participants (to rule out spurious findings and to be able to detect relatively small differences between the two treatments).

To this end, a RCT was conducted and the findings are discussed in *Chapter 5.* The RCT was comparable to the pilot study, but now included a waitlist control condition and individuals with high levels of work stress were specifically targeted. Individuals with high levels of work stress were targeted, because these individuals are at risk to show physiological stress (i.e., low levels of HRV) and the chances of the worry-reduction intervention to impact HRV are therefore considered high. A total of 136 participants were randomized across the three conditions. The effect of the daily worry-reduction EMI with mindfulness exercises was examined on ambulatory assessed HRV and unconscious stress. The results showed—against our expectation—that the EMI did not have an effect on either HRV or unconscious stress. Additionally, exploratory analyses indicated that the EMI also did not affect HR, work stress, worry, anxiety, depression, or mindfulness. So, the EMI proved ineffective at improving the proposed mediators of the stress-health relationship, that is, worry and unconscious stress. Therefore, we were unable to test whether conscious and unconscious stress-representations caused physiological activity. Nevertheless, exploratory analyses—which are not reported—indicated that conscious stress-representations were associated with physiological activity. In line with previous studies (for a full overview, see [34]) and the PC hypothesis [25], we found that higher levels of state worry frequency and trait worry were associated with lower levels of HRV. However, in contrast with the extended PC hypothesis [38, 39], no significant associations were found between unconscious stress-representations and physiological activity.

In Chapter 6 we examined whether a direct manipulation of implicit mental

representations (of self-esteem)—which are indicative of unconscious stress—affected cardiovascular activity and reactivity to a stressor. Across three experiments we aimed to reduce automatic negative self-associations by repeatedly and subliminally coupling self-related words like 'I' to positive affective words like 'smart' (i.e., SEC). The first experiment was specifically set up as a replication of a study by Dijksterhuis [78] and examined whether SEC could be used to increase implicit self-esteem in the general student population. In Experiments 2 and 3 we examined whether such a self-esteem manipulation reduced cardiovascular (re)activity in high worrying students. In three experiments (with a total sample size of 242) we thoroughly tested the hypothesized effects of SEC. Notably, in *none* of the three experiments did we replicate the previously reported positive effects of SEC on self-esteem, despite using the same manipulation and procedure. In addition, no effects were found of SEC on unconscious stress—operationalized as implicit affect—and cardiovascular (re)activity. In this study we were thus unable to test whether an implicit mental representation (of self-esteem) had an effect on physiological activity, because implicit self-esteem was not significantly increased as a result of the manipulation. We did find that individuals with low levels of trait self-esteem had an increased cardiovascular reaction in response to the stressor (compared to individuals with high trait self-esteem). In contrast with the extended PC hypothesis, this stressor-induced increase in cardiovascular activity did not fluctuate with variations in implicit self-esteem. This sole finding is, however, insufficient to completely disregard the extended PC hypothesis, because it is based on exploratory analyses and addressed only one possible operationalization of unconscious stress.

IMPLICATIONS

Theoretical Implications

In this thesis we aimed to manipulate conscious PC (*Chapter 2*) and unconscious PC (*Chapters 4-6*) to examine whether such manipulations would affect health-related parameters in the laboratory and in daily life. It was our intention to manipulate these stress-representations, because it would allow us to draw conclusions about causality and directionality. Throughout this thesis, however, we were unsuccessful in manipulating both conscious and unconscious PC, and therefore we were unable to examine the effect of such manipulations on health-related parameters. Thus, we failed to find direct proof for the extended PC hypothesis in daily life.

Partial support for the PC hypothesis was, however, found in *Chapter 2*. In line with previous studies [25, 31, 33, 86, 88], we found that individuals with higher levels of trait worry had higher levels of SHC at baseline. Yet this evidence is cross-

sectional and so we cannot be sure that worry caused SHC or that experiencing SHC caused individuals to worry. Notably, this association was not independent of negative affect (meaning that the positive association disappeared after controlling for a persons' negative affectivity). A related finding is reported by Thomsen et al. [275], who showed that the association between rumination and self-reported health in the elderly population was mediated by negative affect, specifically, sadness. This could suggest that repetitive thinking caused or prolonged negative affective states, which in turn resulted in decreased health. However, the association between PC and health-related parameters was not always mediated or fully mediated by negative affect [88, 276-281]. It is currently unclear what caused these differences in findings. Differences in study population could potentially have caused the divergent findings, although this would require further investigation. The results were thus mixed and no firm conclusions can be drawn on the unique contribution of PC in the association with health-related parameters.

Stronger evidence for the PC hypothesis comes from prospective data and in *Chapter 2* we additionally show that, in the control condition (in which participants did not receive an intervention), daily worry on the first three registration days was prospectively related to SHC at post-intervention. This suggests that worry is indeed a risk factor for experiencing SHC and this lends support for the PC hypothesis (i.e., finding is in line with previous studies [86, 88, 275, 282, 283]). This relation, however, was again not independent of negative affect. Although the latter is in contrast with prospective data of most available studies [86, 88, 275, 282, 283], it does correspond to an observation that the effect of a worry-reduction intervention on SHC was no longer significant after controlling for negative affect at baseline—potentially indicating that the relation between PC and SHC is influenced or moderated by a persons' negative affectivity [86]. In *Chapters 2, 4, 5,* and *6* we were unfortunately unable to examine whether the effect of a worry-reduction intervention on health was independent of negative effect, because the described interventions failed to change (unconscious) PC. Therefore, it remains uncertain whether PC are directly related to health (independent of negative affect) and, more importantly, whether reductions in PC can improve health. Not only is there a limited evidence base to draw conclusions from, but the conclusions from the present and previous studies are further limited due to differences in the operationalization of PC (e.g., trait worry, state worry, modern health worries) and negative affect (e.g., negative affect, trait anxiety). These operational differences may explain the mixed findings, considering that a review by Brosschot, Gerin, and Thayer [25] concluded that trait worry was more consistently associated with health outcomes. There is thus clearly a need for more studies that examine whether the act

of worrying itself affects health or whether it is merely the experience of negative affect or distress. Even though PC and negative affect are thought to be associated [81, 284], it is important to determine the unique contribution of each individual feature as this information can help to guide intervention development.

The interventions thus failed to reduce both conscious and unconscious stress-representations, which were proposed to mediate the effect on health-related outcomes. Still, even though the proposed mediators were not affected, a positive effect of the worry-reduction intervention with mindfulness exercises could have been expected. To explain, there is evidence that health benefits can occur as a result of mindfulness-based practice [206, 207, 285, 286], potentially through different mediating pathways [202]. Mindfulness-based practice, through improved attentional control and emotional regulation, has been shown to impact other CVD risk factors such as physical activity and diet (i.e., for a detailed discussion, see [202]). So, a positive effect of the intervention on health-related parameters could have emerged despite the lack of change in conscious and unconscious stress-representations. Nevertheless, contrary to previous findings [206, 207, 285, 286], no such effects were observed in this thesis.

Obviously, the fact that we were unable to find evidence for the extended PC hypothesis does not confirm the null hypothesis that there is no association between (un)conscious stress and health. The absence of change in unconscious stress-representations is likely due to the use of manipulations that were insufficient or too mild, especially for a highly stressed sample, or due to an unsuccessful implementation of the manipulations in the sample. Moreover, with respect to assessing unconscious stress, the instruments that were used may have limited construct validity and assessed only some of the possible operationalizations of unconscious stress [38]. To our knowledge, there were no evidence-based interventions available for reducing both conscious and unconscious stress-representations. Therefore, we selected elements that were theoretically most likely to affect these stress-representations. We specifically reasoned that frequent daily repetition was important. Thus, intervention components were selected that could be easily and repeatedly implemented in daily life. Nevertheless, both the 6-day Internet-based worry-postponement intervention and the 4-week smartphone-based worry-reduction intervention with mindfulness exercises proofed to be unsuccessful. The inefficacy could have been due to the length of the training (sessions). As described in *Chapter 2*, the 6-day intervention period may not have been long or strong enough for participants to learn how to postpone their worries. Therefore the intervention period was elongated and the number of daily training sessions was increased in *Chapters 4* and *5*. Still, the length of the actual daily training sessions may have been too short to improve stress-representations. Even though a

review found that the overall length of mindfulness trainings was not associated with the size of the effect on psychological distress, the average duration of the weekly training sessions—across the included studies in the review—was quite high (i.e., 121 min) [287]. Therefore, these results do not directly translate to our training, which was considerably shorter (i.e., 7 min on average per training session in *Chapter 5*). To fully learn the principles of mindfulness-based practice it is conceivable that individuals require longer exercises. The length of the training sessions may have been especially problematic in combination with the unstructured format of the training. To explain, individuals were at liberty to choose which of the mindfulness exercises they wished to do and there were no rules governing the sequence of exercises. We specifically choose this strategy, because it would allow individuals to tailor the intervention to their own needs (e.g., choose exercises that fit with their mental and physical state) and environment (e.g., choose exercises that fit with their time schedule). In order for the intervention to be effective it may, however, be necessary to offer individuals explicit guidance on how to get started by providing guidelines on what exercises to do and in what order. Indeed, the formal curriculum of mindfulness based stress reduction programs are structured [187] and these programs are known to be effective [115, 186, 288]. Furthermore, the majority of the mindfulness-based EMIs that were discussed in *Chapter 3* used a structured approach and found positive effects of the intervention on mental health problems. Together, this suggests that a step-by-step, structured approach is worthwhile to consider in future studies. Such an approach can help individuals to fully learn to focus on the present moment and thereby break the habit to worry. Our findings do not refute the importance of daily practice, but they do indicate that future studies should carefully reconsider both the content and the intensity of the intervention. All in all, throughout this thesis we were unsuccessful in examining whether unconscious stress-representations affected health-related parameters, because we failed to manipulate stress-representations. Clearly more studies are needed to determine the validity of the extended PC hypothesis in daily life.

Clinical Implications

Stress and mental health problems are highly prevalent, but access to mental health care to deal with these experiences is limited in both low-income countries and high-income countries including the Netherlands [119, 129, 289]. A dose-response relation exists between the severity of the mental health problems and the use of mental health services [289]. Nevertheless, half of the individuals with severe mental health problems in the Netherlands are not receiving treatment and the numbers are even more concerning for other countries [289]. These findings are likely the result of health care

budgets that are insufficient given the scope and severity of mental health problems [290]. Still, the finding is perplexing when considering that individuals with mild symptoms and even those without apparent disorders are receiving treatment [289]. Altogether, it suggests two things: (a) access to care needs to be improved and (b) care must be correctly allocated to those most in need. Mobile technologies, like EMIs, may be used to address both objectives. To explain, the number of mobile phone users is large and continues to increase [291, 292], so interventions using mobile technology can have a universal reach [124, 293]. Plus, such interventions may be especially useful to treat the 'worried well' and those with mild symptoms [179], thereby freeing resources for individuals with more severe complaints. EMIs can thus be of immense importance for clinical practice and may provide a new way to address deficiencies in health care. This may seem as an ideal future perspective, but we are not there yet as there is limited research on the effectiveness and implementation of such self-management interventions [124, 292].

In *Chapter 3* we took an important first step; that is, we summarized what is known so far on EMIs and we examined the overall effectiveness. All in all, the evidence suggested that EMIs can be used to improve mental health problems and positive psychological well-being. Even though offering an EMI offers the advantage of anonymity and autonomy, receiving some form of guidance does lead to larger effects compared to stand-alone EMIs. This additional help may in turn also stimulate adherence to the intervention, which is likely to further increase the effectiveness. In light of the possibility of offering mental health care using mobile technology, these findings are of paramount importance. However, the number of studies—and thus EMIs—that could be included in the analyses was small, especially when compared to the number of health self-management apps that are available in different app stores (i.e., for depression alone there are over 1500 apps available) [294]. There is thus a massive discrepancy between availability of EMIs and their evaluation. On the rare occasion that an EMI was evaluated, this was often done in small samples thereby limiting definitive conclusions regarding effectiveness. In *Chapters 4* and *5* we add to the limited scientific evidence base by examining the feasibility of our developed EMI in a pilot study and the effectiveness in a large-scaled RCT. As discussed, the stand-alone worry-reduction EMI with mindfulness exercises appeared to be feasible and was taken seriously, although adherence to the training sessions could have been higher in the RCT (i.e., only 63% of all daily training sessions was completed). Despite the fact that the EMI was well received, the null results indicated that it is not beneficial to implement this particular EMI in a population suffering from work stress. More well-designed RCTs and replications of such RCTs are needed to confirm the potential of

EMIs in mental health care, and careful attention should also be paid to potential risks.

In *Chapter 4* and *5* we examined the efficacy of an EMI that used both a worry-reduction intervention and mindfulness exercises. The worry-reduction intervention was ineffective in reducing conscious worry in *Chapter 2*, yet positive effects of this intervention on conscious worry had previously been found [86-89]. We reasoned that a longer intervention period with frequent daily practice and additional mindfulness exercises—which is known to be an effective intervention component [117, 201, 295]—would proof to be more potent in reducing PC. However, the combination of the worry-reduction intervention with mindfulness exercises was not successful in reducing PC in *Chapter 4* and *5*. When interpreting these results it is important to consider that the two intervention components had not been combined before and that the intervention was offered using a new methodology, that is, on a smartphone in daily life. This could imply two things. First, it could indicate that the combination of change- and acceptance-based intervention components was ineffective. Second, it could mean that the combination in principle could be effective in reducing (unconscious) PC, but that the EMI format was unsuitable to effectively deliver the intervention. It remains to be investigated which of the two options is correct. Considering the advantages of EMIs for delivering short and cost-effective interventions, it would be worthwhile to examine the efficacy of an EMI using either worry-reduction or mindfulness (and to compare the effectiveness of the two EMIs). Additionally, it is important to determine whether an EMI format is acceptable when aiming to break the habit to worry. An elaborate cross-over design with different interventions and delivery modalities could be used to answer these questions. In this endeavor it would also be valuable to study the added value of including additional support from a mental health professional to the EMI protocol (for example, to stimulate adherence to the intervention or to check progress). Naturally, support will make an intervention less cost-effective compared to stand-alone EMIs, but support can come in different gradations. Some studies have for example provided a treatment package including both an EMI and face-to-face therapy (e.g., [144, 145, 163, 175]), whereas Watts et al. [167] only provided support at the start of the EMI and other authors have only provided feedback on homework assignments [161, 166]. The type of support thus differs greatly and intervention developers can aim to achieve the most optimal balance between costs and effectiveness. Importantly, conclusive evidence that support is a necessity for all individuals is lacking and it could be that individuals with lower levels of symptoms do not need support at all. It might be useful for future studies on EMIs to include two intervention groups, one with support and one without, thereby providing more concrete evidence on the role of support in EMIs. Psychology students could be considered for an affordable delivery of support,

considering that individuals with limited professional training experience can achieve successful therapeutic change (just like professionals) [296, 297].

Furthermore, in this thesis we found no evidence that SEC could be effectively used as a short intervention to reduce unconscious stress. Considering that no effect of SEC was found in a highly controlled laboratory environment, we did not pursue to explore the usefulness of SEC in daily life. We were thus unable to reproduce previously reported positive SEC effects. It is not the first time that promising effects could not be reproduced [298, 299]. In a shared effort to determine the reproducibility of psychological science, it was indeed found that only 36% of the replication studies had significant results compared to 97% of the original studies [299]. Moreover, the effect sizes were considerably smaller in the replication studies. This underscores the importance of conducting replication studies.

STRENGHTS AND LIMITATIONS

A strength of this thesis is that we aimed to examine the validity of the extended PC hypothesis in daily life using a well-designed, pre-registered, and adequately powered randomized controlled design. This design—if the manipulations had been effective—would have allowed us to make statements about causality and this would have supplemented the mostly indirect evidence base for the extended PC hypothesis [32, 40-46, 57-61]. Furthermore, individuals were studied in their real life situations and we thereby intended to do justice to the complexity of human beings and "capture life as it is lived" [71, 300, p. 580]. Traditional assessment strategies—like retrospective self-report questionnaires—provide useful information, but the method is insensitive to variations in actual behavior during the day and this can be assessed using ecological momentary assessments [301, 302]. Moreover, the in-time assessment of individuals' yielded data that was less influenced by recall bias and more ecologically valid compared to laboratory studies.

A related strength is that we assessed physiological activity in daily life and not in a laboratory-based setting. Even though physiological activity can be assessed reliably and relatively easily in the laboratory with few artifacts due to movement or technical problems, the physiological data that is collected in this highly controlled environment may not translate well to real world functioning [63, 64]. For instance, it was shown that a stressor in daily life—that was personally relevant to the individual—elicited a far greater physiological response compared to five different commonly used laboratory stressors [64]. Ambulatory assessment of physiological activity may thus more accurately reflect how an individual experiences stressful events in ones' life. The

need for ambulatory assessment in the field of psychology is now increasingly being recognized, as evidenced by a special section on the topic in European Psychologist (2009, volume 14, issue 2), a special issue in European Journal of Psychological Assessment (2007, volume 23, issue 4), and with the publication of a handbook describing different research methods in daily life [71].

Other strengths of the reported studies include (a) the use of different techniques to manipulate PC, (b) our examination of the PC manipulations on different outcome measures, namely, explicit and implicit measures, and physiological activity, and (c) our focus on clinically relevant populations that were at risk for experiencing high levels of (unconscious) stress.

One clear limitation of the research in this thesis is that the different PC manipulations failed to change (unconscious) PC and therefore we were unable to examine the possible impact of such manipulations on health. The results thus do not provide conclusive evidence on whether (unconscious) stress-representations directly affect health. Of course the interventions are not only a manipulation of stress-representations and the mindfulness exercises, for instance, can be expected to have effects on health-related parameters through other mediators (e.g., [202]). Identifying mediators or mechanisms through which the intervention can have its effect on health is one way to advance an effective delivery of psychological treatments [182, 303]. In *Chapter 2* we were able to show that PC was prospectively related to self-reported health, but the cause-effect relation between stress-representations and health remains to be determined in future studies.

The second limitation has to do with the methodological difficulties in measuring unconscious or automatic processes. In the present thesis we specifically aimed to assess unconscious stress-representations and we set out to measure this using two different strategies. An affect misattribution paradigm was used (i.e., Implicit Positive and Negative Affect Test [IPANAT]; *Chapters 4-7*) and a measure that is based on automatic attitude activation (i.e., Implicit Association Test [IAT]; *Chapters 5-6*). However, measuring implicit processes is sometimes met with understandable skepticism, raising questions about what such measures represent and whether they are truly measuring what they set out to measure. These discussions fuelled research examining the psychometric qualities of implicit measures and in this endeavor the IAT has received the most attention [304, 305]. Current reviews and meta-analyses suggest that the reliability (both internal consistency and test-retest reliability) and predictive validity of the IAT are acceptable [221, 305, 306]. Yet the findings are mixed for the relation between the IAT and other implicit or explicit measures that attempt to measure the same construct [220, 304-306]. Notably, stronger associations with other implicit

measures emerged after accounting for measurement error [307]. Less psychometric evidence is available for the IPANAT, but a recent review discussed promising evidence [308]. Considering the importance of using reliable assessment strategies for testing hypotheses, more psychometric research is definitely needed. Although there is initial evidence suggesting that implicit processes can be reliably assessed, future studies should attempt to explain the mixed findings so that more firm conclusions can be drawn on the usefulness of current implicit measures.

FUTURE DIRECTIONS

Obviously, as the extended PC hypothesis remains untested, there is a clear opportunity for future research to further examine the validity of a causal relationship between (unconscious) stress-representations and health. Considering the necessity of a reliable PC manipulation for testing the hypothesis, we recommend researchers to carefully review the manipulation of interest and to be attentive that previously reported positive effects cannot always be replicated [299]. Indeed, in *Chapter 2* we were unable to replicate previously reported positive effects of the worry-postponement intervention [86-88] and in *Chapter 6* we failed to find evidence for the efficacy of SEC, which was in contrast with previous reports [78, 79]. Our studies highlight the importance of performing such replications. For instance, based on the null results reported in *Chapter 2*, we were able to adjust the PC manipulation. Specifically, we devised a more comprehensive strategy to manipulate PC in daily life: we (pilot) tested the strategy in *Chapter 4* and implemented it in *Chapter 5*. Against expectations, this strategy was also not effective for manipulating PC. Considering the complexity and habitual nature of PC it might be difficult to find a reliable PC manipulation (especially in daily life). Future studies could also consider testing the hypothesis in individuals with generalized anxiety disorder—a disorder that is characterized by excessive worrying—who are about to undergo an evidence-based psychological treatment for their complaints. It has been shown that cognitive therapy (targeting worry) can reduce anxiety, depression, and worry (e.g., [309-311]); however, such findings do not provide evidence that the change in worry was directly responsible for the change in anxiety and depression. One treatment study, in individuals with generalized anxiety disorder, has shown that an early reduction in conscious PC predicted further treatment responses [312]. Furthermore, a systematic review by van der Velden et al. [313] found some evidence that conscious PC mediated the effect of mindfulness-based cognitive therapy in individuals with depression. These initial findings are interesting, but there is definitely need for more meditational studies that examine whether the change in

worry caused the change in outcome variables. These studies can help advance our understanding of the mechanisms that cause the treatment effect and can thus help us understand why treatments are effective [182, 303]. To identify potential mediators, studies should assess the proposed mediator(s) and outcome variables before, during, and after the treatment. Assessment of mediators and outcome variables *during* the treatment is not always done, but this is necessary to identify the timeline of change in the study variables [182]. So, to examine whether changes in (unconscious) PC are related to changes in health, it is necessary to assess (unconscious) PC and health-related parameters at least before, during, and after the intervention.

In *Chapter 3* we found that EMIs can be used to improve mental health, but in *Chapters 4* and *5* we found no evidence supporting the use of our developed EMI. In this regard, several potential avenues for future research have already been mentioned above that might lead to more effective PC manipulations (e.g., increasing length of training sessions, offering a structured training). In addition, with regard to EMI characteristics, little is known about what works or what works for whom and this provides ample opportunities for future research. As an illustration, the EMI that was tested in *Chapters 4* and *5* was randomly scheduled throughout the day. Alternatively, training sessions could be scheduled in accordance with the individual. Flexibly scheduling could be applied to both the number of training sessions and the timing. For example, on a workday an individual might prefer to do one training session in the evening, whereas on a non-work day an individual might prefer to complete multiple training sessions throughout the day. In the same way it could be possible to take the duration of training sessions into account. By allowing an individuals' preference to shape the EMI, both the adherence to and the satisfaction with the training might actually increase while preserving the advantage of training people in their daily lives. Adopting this strategy would be in line with Internet-based interventions whereby individuals typically log onto a website to receive their training when it is convenient for them and these types of interventions have been found to be effective for a number of disorders [70]. Employing such a strategy would allow an individual to train in daily life, but you might loose the advantage of training people when it matters, that is, in stressful or worrisome situations. Therefore other strategies to promote adherence can also be considered: providing incentives [314], using motivational interviewing [315], providing progress reports to participants (which in turn could also be used to detect non-responders) [316], or using gamification to increase user engagement [317].

When developing new EMIs it is recommended to involve the end-user, because these individuals are to use the intervention and their input will likely improve the acceptability, implementation, and effectiveness of the actual intervention [124,

293]. Recently, tools and guidelines have become available to aid the development and evaluation of EMIs. Olff [124] for instance provided a checklist with different issues that need to be addressed when developing an evidence-based EMI and Whittaker, Merry, Dorey, and Maddison [318] delineated a six-step process for researchers to guide the development and testing of EMIs. This process consists of (a) conceptualization (or intervention mapping), (b) formative research consisting of focus groups or online surveys with the target population to guide the EMI development, (c) pretesting the intervention content, (d) a small pilot study in the target population, (e) a RCT, and (f) a qualitative follow-up to determine how the EMI or the implementation can be improved. These steps are expected to result in a potent intervention, but a clear disadvantage to this approach is the immense time investment. Consequently, the technology behind the EMI may already be outdated by the time the EMI has been fully developed and tested. Importantly, in this period distinct changes may also have emerged in the way people use such technology and this could possibly affect the appropriateness of the EMI [293, 318]. To speed up the development and evaluation other approaches can be considered as well like the Multiphase Optimization Strategy [319]. The strategy—that was specifically developed for eHealth interventions—describes how factorial designs can be used to identify both the most effective intervention components and the optimal dosage of the components before testing the complete intervention in a RCT. The RCT is still the preferred design for testing the effectiveness of the EMI, yet it may not always be practical. In that event other designs can be considered, for instance, an interrupted time series design, a multiple baseline design, or a controlled pre-post design (see [320]). All in all, for researchers it will be necessary to find an appropriate balance between developmental speed and scientific evaluation.

CONCLUSIONS

The studies in this thesis examined the validity of the (extended) PC hypothesis in daily life in at risk individuals. All in all, we failed to find direct support for the hypothesis that (unconscious) PC affects health-related parameters [38, 39]. However, this may be because we failed to adequately manipulate PC and therefore we were unable to examine whether changes in PC were related to changes in health. There is thus need for future studies that use different techniques to manipulate (unconscious) PC, so that the effect on health-related parameters can be studied. Our findings do not support the use of the Internet-based worry-reduction intervention for improving PC and SHC. Yet evidence was found that EMIs can be used to train people during the day and that such interventions can improve mental health. Nevertheless, the EMI that was investigated

in this thesis was considered ineffective and there is definitely room for future studies to carefully determine what works for whom. Moreover, no evidence was found that SEC had a positive effect on unconscious stress or physiological activity. Considering the high prevalence of stress, it is important that researchers focus on gaining a more complete understanding of how stress negatively affects health.