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Reducing daily stress: Breaking a habit

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General introduction

01

STRESS

Experiencing stressful events throughout your life can seem as inevitable as death and taxes. Yet the extent to which an individual experiences psychological strain due to these stressful events or stressors varies. It is generally assumed that individuals experience psychological strain when they evaluate situations as either threatening or taxing, and when they consider their coping resources to be insufficient [1, 2]. The list of potential stressors is inexhaustible and includes, for instance, marital conflict, death of a relative, financial hardship, and social isolation.

The most frequently studied stressful event is work stress. This is not surprising as concerns about work stress appear to be on the rise and work stress has even been considered a modern day epidemic [3]. Specifically, it has been argued that recent major changes in the workplace have put increasing demands on employees [3, 4]. One such change relates to the rapid technological progress of the past four decades with the development of the computer, Internet, and smartphones. These developments have provided unlimited communication possibilities, but have put employees at risk by enabling them to maintain nonstop contact with work and to work at any moment, anytime [3]. Indeed, throughout Europe, increases in job demands have been observed [5, 6]. Furthermore, these reports indicate increases in workload, time pressure, job insecurity, and decreases in job control. These factors are recognized to be important sources of stress [7]. Notably, stress is the second most commonly reported work-related health problem and 22% of the Europeans experience work stress [6]. In the Netherlands one third of the employees indicate that work load and work stress are the main reason for their recent work-related absence [8]. Moreover, the annual costs for Dutch employers of this work stress related absenteeism is estimated to be 1.8 billion Euros [9]. Stress is thus both highly prevalent and costly for society.

STRESS AND HEALTH

In response to challenges in the environment—whether it concerns daily hassles or major life events—the human body protects itself by activating the necessary physiological systems such as the autonomic nervous system (ANS) and the hypothalamic-pituitary-adrenal (HPA) axis [10, 11]. Changes in such physiological systems allow the body to deal with stressful situations. For example, heart rate and blood pressure are elevated through the release of catecholamines, which ensures that the body has sufficient oxygen and nutrients to undertake action (e.g., flee from the stressful situation). Once the stressor has past, the activated physiological systems

are deactivated and are returned to their normal level of activity. This process is called 'allostasis' and is considered useful as it helps individuals adapt to the environment [10, 11]. However, these adaptive physiological responses can strain the body through repeated activation or when the physiological response persists after the stressor is gone (resulting in prolonged exposure to stress-related physiological activity). In short, frequent and prolonged stress can cause chronic overactivity or dysregulation in the allostatic systems, and this in turn has a negative effect on both mental health [11-15] and physical health [12, 16, 17], including cardiovascular health [18-24].

To illustrate, in a large-scaled case control study with patients with a first myocardial infarction and controls, Rosengren et al. [23] showed that experiencing *some* stress at work or in general (i.e., defined as either stress at work or at home) was associated with increased odds of acute myocardial infarction with 1.38 and 1.45, respectively. Moreover, experiencing *continuing* stress increased the odds more than two-fold. Two meta-analyses [21, 22] describe similar increased risks for cardiovascular disease (CVD) when individuals report experiencing job strain or work stress. Importantly, there is evidence to support a dose-response relation. Specifically, more frequent work stress [20] and increased reports of work stress in different domains (e.g., demotion, business failure) [18] are associated with an increased risk of CVD. The danger of multiple stressors was also highlighted by Orth-Gomér and Leineweber [24]. They showed that individuals, who were exposed to a combination of work and marital stress, had an increased risk of both a first and recurrent cardiac event compared to individuals who experienced no stress (i.e., risk increased by a factor of ten and six, respectively). Together, these studies show that frequent or chronic stress negatively affects (cardiovascular) health.

It is acknowledged that the negative effect of stress on health occurs in the long run through prolonged physiological stress responses [10, 12, 25]. Yet up until two decades ago, most research focused on how increased physiological activity *during* a stressful situation affected health [26]. Such a *reactivity view of stress* is considered insufficient as it fails to account for *prolonged* physiological activation [26-28]. In recent years, it has become increasingly clear that the stress-disease link may be better explained by stress-related thoughts, like anticipation and rumination. These thoughts keep the stressful event active in one's mind and thereby prolong the stress-related physiological activation [25, 27].

PERSEVERATIVE COGNITION

Even though the majority of research has focused on increased physiological responses

as a result of stressful events, physiological stress responses can also be activated and prolonged by thinking about these stressful events [25, 27-29]. This is particularly important, because the duration of stressful events is usually short compared to the actual amount of time that individuals can think about these events. To explain, completing an exam can be considered stressful for some individuals and this event may last for a few hours. However, individuals may spend days thinking about this event either prior to or afterwards (with thoughts like 'I am going to fail' or 'I am sure I flunked my exam, I am such an idiot'). In addition, individuals may think about future stressful events, but—in reality—those anticipated or imagined stressors often do not occur [30]. For example, you may have worried continuously about getting a negative reaction from your superior after failing to meet a deadline, but in reality your supervisor acted understandingly. By continuously thinking about these (potential) stressful events, the physiological stress response is prolonged and this process is described in the perseverative cognition (PC) hypothesis [25, 31-33]. According to this hypothesis, PC—such as worry—mediates the positive relation between the experience of stressful events and (cardiovascular) health problems by prolonging the exposure to the stressor in ones' mind. In support of this hypothesis, a recent meta-analysis showed that worry was associated with stress-related physiological activity, including low heart rate variability (HRV) [34]. HRV refers to the variability in timing between each heartbeat [35] and low levels of HRV are a known risk factor in the development of CVD [36, 37]. To summarize, stress prolongs stress-related physiological activity by continuously thinking about (potential) stressful events and this can ultimately have negative health effects.

UNCONSCIOUS PERSEVERATIVE COGNITION

In recent years, the PC hypothesis has been extended to include the notion that prolonged physiological stress responses can also be caused by PC that occurs outside an individuals' conscious awareness [38, 39]. This so called 'unconscious stress' is defined as "the ongoing activated cognitive representation of one or more psychological stressors that occurs while conscious attention is directed elsewhere" [38, p. 411]. This idea was put forward since a major part of the prolonged stress-related physiological activity, assessed both in experimental studies and in ambulatory ones, remained unexplained after accounting for relevant biobehavioral and psychological factors [28]. There are several reasons to believe that this unexplained stress-related physiological activity may be due to unconscious stress [28, 38, 39].

The first *indirect* evidence comes from sleep studies. Both laboratory studies [40, 41] and studies in daily life [42-44] have shown that worry and perceived stress

are associated with increased physiological arousal during sleep. Clearly, conscious thought or worry is not possible during sleep. This leads us to believe that stress-related cognitive processes continue in an unattended manner when an individual is asleep and that these unconscious stress-representations affect physiological activity. Even so, roughly one third of the studies found no such effect (see [28]). The second type of evidence comes from a study that was conducted in daily life by Pieper, Brosschot, van der Leeden, and Thayer [32]. They showed that daytime worry increased stress-related physiological activity. Importantly, this effect was still visible 2 hr after the worry episode ended and could not be explained by current worry episodes, or by other psychological or biobehavioral factors. This finding suggests that conscious worry does not sufficiently account for the prolonged stress-related physiological activity. The third type of evidence comes from studies using laboratory stressors. These studies showed that high trait rumination was associated with poorer physiological recovery after the stressor and this could not be fully explained by conscious rumination or worry [45, 46]. Altogether these findings suggest that unconscious stress can affect physiological activity, yet the evidence is indirect and therefore still remains inconclusive.

Direct evidence is however limited, because the majority of stress research has focused on the effect of subjective, self-reported, affective experiences and has largely ignored the importance of unconscious processes for health. Yet it is generally established that affective processes—just like cognitive processes [47]— can occur unconsciously or outside an individuals' awareness [48-52]. Indeed, different experiments have shown that affective reactions can be generated using subliminal stimuli (i.e., stimuli that are presented below the awareness threshold). The induced affective reaction—that occurs independent of explicitly reported feelings—has been found to influence preference for neutral stimuli [53, 54] and behavior [55, 56]. Moreover, subliminal priming paradigms have been shown to influence stress-related cardiovascular activity [57-59]. In a recent systematic review almost half of the summarized evidence was in favor of the idea that unconscious stress can increase physiological activity, with only a fraction of the evidence pointing in the other direction (3%) [60]. This conclusion is, however, limited by the fact that the methodology of the included studies differed significantly from each other and because health-relevant physiological parameters (e.g., HRV, blood pressure) were infrequently addressed. Furthermore, a recent study showed that threatening stimuli shown below the conscious awareness threshold increased total peripheral resistance, but not blood pressure [61]. Even though these findings are promising, there is definitely a need for more studies that specifically address whether unconscious stress can prolong physiological activity in real life.

THE NEXT STEP

The majority of emotional processes is likely to occur outside an individuals' awareness [49, 62] and it is therefore also likely that our minds and bodies are influenced by more than what we can explicitly report. So, in the absence of awareness, unconscious stress-representations may be activated frequently or even continuously and these representations in turn may explain a large part of the prolonged physiological stress-response that ultimately result in deteriorated physical health [38].

In the past years, evidence has been collected that supports the association between PC, or conscious stress-representations, and physiological activity [25, 28, 31-34]. Yet there is only tentative evidence to support the extended PC hypothesis, which hypothesizes that unconscious stress-representations affect stress-related physiological activity. The evidence—as discussed above—is indirect and incomplete. Moreover, research on the (extended) PC hypothesis has mostly been cross-sectional, which limits our conclusions regarding both directionality and causality. In the present thesis, we aim to extend the current findings by manipulating PC (both conscious and unconscious) and simultaneously examining its effect on physiological activity.

One way to test whether (unconscious) PC prolongs physiological activity is to decrease it, because the reverse would be unethical. Specifically, we wish to study the extended PC hypothesis outside of the laboratory, that is, in daily life. Even though a laboratory-based study can provide useful insights, the resulting conclusions may be inaccurate because environmental and contextual factors are not taken into account [63, 64]. The generalizability of laboratory findings to real life was already questioned by Brunswik [65] over 70 years ago and he was a strong advocate for studying individuals in their natural environment. Despite this early advocacy for real life studies, the majority of studies have taken place in the confines of the laboratory [63]. Recent technological developments have, however, made it easier to study individuals in real life (e.g., by using smartphones). By examining the relation between (unconscious) PC and physiological activity in daily life we intend to provide empirical evidence for the extended PC hypothesis that is not confined to the controlled laboratory setting.

Below we discuss two interventions that aim to reduce (unconscious) PC. That is, a worry-reduction intervention and a subliminal evaluative conditioning intervention that reduces automatic negative self-evaluations, which are prevalent under stress. If such interventions succeed in lowering unconscious stress, we can examine whether these changes are associated with reductions in prolonged physiological activity, specifically cardiovascular activity. Such data would provide more direct evidence for the hypothesis that unconscious stress causes prolonged physiological activity.

Worry-Reduction Intervention

Studies are warranted that examine whether reducing worries in daily life also impacts health. For two reasons, it is likely that such worry-reduction interventions will not only reduce the worries themselves, but also unconscious stress. First of all, theoretically a positive association is expected between conscious worry and unconscious stress. To explain, the worries themselves can become more or less automatic and habitual. Thus, if the intervention reduces conscious worries, the associated unconscious stress is also expected to decrease. Second of all, several studies show that skills can become automatized through repetition and thus become unconscious (i.e., no longer requiring awareness) [47, 50]. It is conceivable that a worry-reduction intervention, through frequent repetition, can lead to automatization of the targeted cognitive changes and this will likely reduce unconscious stress. Indeed, a review [66] discussed that mental exercises like cognitive training and meditation can cause cognitive-behavioral changes that are supported by changes in the brain, just as with learning new skills (e.g., playing the piano).

Repetition is suggested to be fundamental for changing habits, such as worries [67, 68]. Even though repetition is relatively hard (and costly) to accomplish using traditional face-to-face therapies, it is more feasible when interventions make use of recent technological developments. Interventions that are for example delivered over the Internet are more easily accessible and the training is not restricted to a specific place and time (e.g., therapist office, 1 hr a week) [69]. This means that users of Internet interventions have more repetition possibilities for the new behavior. Importantly, adherence to Internet interventions is good and these interventions can improve mental health [70].

An even more recent advancement is the use of electronic devices—typically smartphones—to deliver interventions in daily life. These ecological momentary interventions (EMIs) have numerous advantages compared to traditional face-to-face therapies [71-73]. First and foremost, EMIs make it possible to train people when the maladaptive behavior is actually occurring. This is important because when people experience stress they are more likely to revert to their habit behavior (e.g., worry) and they are less likely to implement a newly learned behavior routine [74-76]. As worry is a mental habit that is automatically triggered by (potentially) stressful experiences, it might be particularly important for worry-reduction interventions to target these worries directly when they occur. Second, by training people in daily life (i.e., when the maladaptive behavior occurs), the EMI allows for the formation of a new and more adaptive link between context and behavior. Third, EMIs are cost-effective and can be delivered to anyone, anywhere, as long as that person is in possession of or has

access to a smartphone. Reviews suggest that EMIs can be effectively used to improve mental health [73, 77] (see *Chapter 3* for a full discussion on the effectiveness of EMIs). To sum up, EMIs can be used to train people—repeatedly—throughout their daily lives and specifically in those instances when individuals worry.

Summarizing, Internet interventions as well as EMIs seem suitable to study to what extent reducing worries and unconscious stress in daily life affects physiological activity, as these types of interventions focus on training new skills in the environment where the problems actually occur. Implementing Internet- and smartphone-delivered worry-reduction interventions in daily life will enable us to study the validity of the extended PC hypothesis in an ecologically valid way.

Subliminal Evaluative Conditioning Intervention

Besides studies that focus on reducing conscious worries and the associated unconscious stress, there are also methods to target unconscious stress directly. Specifically, subliminal evaluative conditioning (SEC) [78] can be used to directly target unconscious mental representations of threats to oneself that are prevalent in stressful situations. In this conditioning paradigm the self (using words like ‘I’ or ‘Me’) is repeatedly and subliminally coupled with positive affective words. Initial studies suggest that a single session of this procedure can be successfully used to increase implicit self-esteem [78, 79]. Implicit self-esteem is hereby defined as the automatic or unconscious association with the self-concept [80]. To date, no research has examined whether SEC also affects physiological activity, but subliminal priming paradigms have been shown to influence stress-related cardiovascular activity [57-59]. Levy, Hausdorff, Hencke, and Wei [57] for example showed that elderly individuals who were primed with positive age stereotypes had attenuated blood pressure and skin conductance responses during a stressful task. A reverse pattern was observed when individuals were primed using negative age stereotypes. These findings suggest that a subliminal paradigm can affect stress-related physiological activity and it is conceivable that SEC has similar effects (considering the procedural overlap). Thus, SEC may have the potential to change both unconscious mental representations of threats to oneself and stress-related physiological activity. Once we have demonstrated that SEC indeed reduces unconscious stress-representations and stress-related physiological activity in controlled circumstances (i.e., laboratory), the intervention can subsequently be implemented and further examined in daily life. It could potentially be used as a short and cost-effective intervention (i.e., programmed on a smartphone).

AIMS AND OUTLINE

This thesis aims to provide a more complete insight in how stress affects health. Specifically, we aim to test the (extended) PC hypothesis by examining whether interventions designed to reduce conscious worry (*Chapters 2, 4, and 5*) and unconscious stress (*Chapters 4-6*) improve health-related parameters. To reduce worry and unconscious stress, two different strategies are employed. First, we examine whether repeatedly training people in their daily life is effective (*Chapters 2-5*). Second, we study whether unconscious stress can be directly manipulated by targeting automatic negative self-evaluations, which are prevalent under stress (*Chapter 6*). Manipulating these stress-representations will enable us to draw conclusions about causality and directionality.

In *Chapter 2* we test an Internet-based worry-reduction intervention in the general population and examine its effectiveness in reducing conscious worry and subjective health complaints.

In *Chapter 3* we carry out a systematic review and meta-analysis to get an up-to-date and comprehensive overview of the effect of smartphone-based interventions on mental health and positive psychological outcomes.

In *Chapter 4* we discuss the feasibility and preliminary effectiveness of a smartphone-based worry-reduction intervention with mindfulness exercises in high worrying students. The effectiveness of the intervention is further examined in a large-scaled randomized controlled trial in people suffering from work stress in *Chapter 5*. In both chapters we examine whether the intervention led to reductions in both conscious and unconscious stress thereby possibly mediating improvement in ambulatory assessed cardiovascular activity.

In *Chapter 6* we present the results of three different experiments in which we aim to reduce automatic negative self-associations in high worrying students by repeatedly and subliminally coupling the self to positive trait attributes. The effect of this subliminal evaluative conditioning procedure is examined on unconscious stress and cardiovascular activity.

At last, in *Chapter 7* the main findings of the different studies are summarized and discussed. Moreover, the thesis' limitations, implications (both theoretical and clinical), and future directions are presented.

