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„"Psychological Stress and Meditation - Effects of Regular Meditation Practice on Stress Reactivity and Stress Recovery Time"

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Abstract

In this day and age, the detrimental effects of psychological stress on health are becoming increasingly prominent. Regular meditation practice appears to be promising for diminishing psychological stress. In the present study, it was investigated whether there is a significant difference between experienced meditators and meditation-naïve individuals regarding their stress reactivity and stress recovery time. The used stressor was the sound of an Aztec death whistle along with two human screams, which had been tested considering its effectiveness for stress induction beforehand. In order to gain insight about participants' individual physiological stress levels, participants' skin conductance response as well as their heart rate was tracked. I hypothesized that meditators would show a smaller increase in skin conductance response as well as a smaller increase in heart rate than the meditation-naïve participants when being confronted with a psychosocial stressor. Similarly, my assumption was that after the stressor has disappeared, meditators would return to their skin conductance response baseline and their heart rate baseline faster than the meditation-naïve participants. The used stressor caused significant physiological stress reactions in both test groups. Both groups showed similar stress reactivity as well as stress recovery time in terms of skin conduction response and heart rate. Suggestions for future research are discussed.

Keywords: stress, meditation

Introduction

The functioning of our body's stress response can be vital to our survival: it mobilizes our physiology for fast action and focussed attention in a threatening situation (Jansen et al., 1995). This sort of physiological reaction to danger was highly adaptive in times when physical threats were a usual occurrence, for example, when facing a dangerous predator or during a violent tribal conflict. Nowadays, at least in western societies, the usual stressors are not so much direct threats to people's lives but rather troubles like being stuck in traffic jam or tension between co-workers. Our autonomous nervous system, however, has not adapted to the conditions of modern life yet. Therefore, it can overreact to non-life-threatening stressors. For example, one's yelling boss might cause the same sort of stress response as a roaring lion does. Thus, the same hormonal cascade can be triggered in both cases preparing one's body to fight, flee or freeze. While in the latter scenario this kind of physiological reaction is highly desirable, in the former one it might not be beneficial at all. In fact, although the stress response has evolved as an adaptive process, an inappropriately strong and too long lasting stress response is maladaptive. Extended and repeated arousal of the stress response can have damaging consequences for body and psyche, such as coronary heart disease (Richardson et al., 2012) or depression (Kessler, 1997). Therefore, it seems to be desirable to examine ways to be able to keep one's stress response within an appropriate and healthy range. One promising method in this regard is meditation. A fair amount of research indicates that particularly mindfulness meditation can be a powerful tool in order to diminish stress (e.g., Hoge et al., 2018; Bamber et al., 2016). Likewise, several findings on loving-kindness meditation also suggest its effectiveness in terms of reducing stress (Carson et al., 2013; Hoge et al., 2013). In order to better understand the relationship between stress and meditation, stress is going to be examined in more detail below.

In order to provide a more fluent reading experience, I refrained from simultaneously using both female and male pronouns. All pronouns, if not explicitly stated otherwise, refer equally to both sexes.

Stress

The term “stress” was first introduced into the health sciences in 1926 by Hans Selye (Everly & Lating, 2012). Selye (1956) used the term “stress” to describe anything that threatens our internal equilibrium, also known as homeostasis (Cannon, 1929). The response to this threat to our homeostasis is called “stress response”. This stress response can become measurable as physiological stress reactivity, which describes the changes in physiological stress markers of an individual, such as skin conductance response or heart rate, in response to a stress-inducing stimulus (Linden et al., 1996). The time these physiological stress markers need to return to their pre-stress level is called stress recovery time.

Any stimulus that evokes a stress response is called a “stressor”. In general, there are two major types of stressors: biogenic stressors and psychosocial stressors (Everly & Lating, 2012). Biogenic stressors can directly cause physiological arousal without the need for a cognitive evaluation of a situation, for example, the intake of caffeine or experiencing extreme heat or cold. Psychosocial stressors, on the other hand, are stimuli which need to be cognitively interpreted as a threat in order to trigger a stress response: for example, being stuck in a traffic jam is not necessarily threatening, yet its evaluation as something negative can turn it into a psychosocial stressor (Everly & Lating, 2012).

This notion of psychosocial stressors is in line with Lazarus’s and Folkman’s (1984) definition of stress: they argue that a yielding concept for the understanding of stress would be considering it as a transaction between a person and his environment. They go on to define stress as “a particular relationship between the person and his environment that is appraised by the person as taxing or exceeding his resources and endangering his well-being” (p. 19).

According to this perspective, it is one's way of looking as well as one's evaluation of one's stressors that determine how one copes with them and how heavy they weigh on oneself. By changing one's perspective towards stressors, the relationship one has with those stressors is changed as well. Consequently, by altering one's perspective on a stressor, one should be able to exert a certain kind of control on the extent to which a stressor takes up one's resources and threatens one's well-being. At this point, meditation comes into play.

Meditation

The practice of meditation goes back at least three thousand years. While its early roots lie in Hinduism, the practice of meditation in some form or another can be found in every major religion. Throughout the millennia, many different meditation techniques have evolved. Therefore, a very broad definition of meditation is needed in order to encapsulate the wide range of various meditation techniques.

In general, meditation can be defined as "a family of self-regulation practices that focus on training attention and awareness in order to bring mental processes under greater voluntary control and thereby foster general mental well-being and development and/or specific capacities such as calm, clarity, and concentration." (Shapiro & Walsh, 2006). It is this very increase of voluntary control over mental processes that may cause the aforementioned changes in perspective towards a stressor.

Cardoso et al. (2007) have conceived an operational definition for meditation. In order for a procedure to be characterized as meditation, it must include five elements: 1) It should be a specific, clearly defined technique that involves 2) at some point during the process some form of muscle relaxation as well as 3) "logic relaxation", i.e. refraining from analysis or assessment of possible psychophysical effects that may arise during meditation. 4) The desired meditative state should be self-induced by the meditator. 5) "Self-focus skill", i.e. the procedure should teach the meditator the ability to focus one a certain focal point within his perception (for example, the sensations of one's own breath) or enable the meditator to observe all consciously perceived stimuli without focusing on one in particular.

These definitions of meditation focus notably on the mechanisms that come into play during meditation. According to Gunaratana & Gunaratana (2011), however, the meditator's attitude is a pivotal precondition for successful meditating as well. This includes the following aspects: *1) Don't expect anything:* meditators should relinquish any idea they have about how a successful meditation should be, as such sorts of expectations can interfere with the meditation process. *2) Don't strain:* meditators should not force anything since meditation can only be successful when relaxed *3) Don't rush:* patience is essential as the meditation process needs time. *4) Don't cling to anything, and don't reject anything:* that is, don't cling to or reject any perception during the meditation process*, 5) Let go:* relaxing and being open to changes are vital for a successful meditation practice. *6) Accept everything that arises:* all sorts of experiences, both positive and negative, which are encountered during meditation should be accepted equally. *7) Be gentle with yourself:* accepting oneself and one's current situation are the basis for development through meditation . *8) Investigate yourself:* this refers to approaching one's meditation practice with an exploratory spirit .*9) View all problems as challenges:* problems during the practice should be seen as opportunities to grow and develop. *10) Don't ponder:* losing oneself in one's own thoughts prevents the meditator from focusing on the meditation itself. *11) Don't dwell upon contrasts:* Comparing oneself to others should be avoided as one might react with arrogance or envy to it.

In sum, both the mechanisms and the meditator's attitude are important for a successful meditation practice. Now, since there are different kinds of meditation techniques, the most popular ones are going to be described briefly in the following section.

Mindfulness Meditation. Mindfulness meditation (MM) has its roots in Buddhist tradition and was introduced to Western society by the Buddhist monk Thich Nhat Hanh (Kang et al., 2009). From this point onward, the popularity of MM in western countries has grown tremendously.

Jon Kabat-Zinn (2013) defines MM as paying attention to the experience of the present moment, on purpose and nonjudgmentally. MM basically means observing everything that one perceives at one moment in time, including sensory data received from the five senses, thoughts, sensations, emotions etc. without labeling these perceptions as neither good, bad, right nor wrong. By means of this kind of intentional, nonjudgmental awareness to the experience of the present moment, the meditator might eventually learn to see things for what they really are, i.e. only perceptions which are neutral and impermanent at their core (Gunaratana & Gunaratana, 2011). The practice of MM can entail becoming aware of reflexive reactions as they happen, and consequently, changing one's automatic reactions to events. Generally, there are two styles of MM: focused attention meditation (FAM) and open monitoring meditation (OMM).

FAM involves directing one's attention to a particular object such as the flow of one's own breath. In doing so, one attentively observes the sensations as well as the natural rhythm of the breath without changing it (Lutz et al., 2008). In order to maintain this focus, the meditator must constantly make sure that his attention is focused on his breath. Whenever the meditator's attention starts wandering, which can happen quite often especially in the beginning of the FAM practice, he is supposed to gently redirect his attention to the breath and the sensations that go along with it. As a consequence of a regular practice, practitioners of FAM cultivate the skills of maintaining constant attention on an object (for example, the breath), quickly noticing when their attention drifts off to undesired objects (for example, anxious thoughts) as well as redirecting their attention to the desired object (Lutz et al., 2008). Examples for FAM are meditation techniques such as the early stages of Zazen (i.e., sitting in a lotus position and focusing on one's own breath) and Transcendental Meditation (i.e., sitting in a comfortable position and mentally repeating a meaningless mantra).

The second style of MM is called open monitoring meditation (OMM). This practice is more advanced than FAM since its practice already requires the ability of focused attention. By practicing OMM, one observes whatever appears in one's field of awareness, for example, thoughts, sensations, emotions, associations etc. The crucial part of this practice is not to react to these perceptions, but to just monitor them with an attitude of equanimity. Whenever one's attention starts drifting, one is supposed to calmly direct one's attention back to one's field of awareness. Through this practice, one is able to gain greater knowledge about one's own habitual thoughts and emotional patterns as well as their relationship with each other (Lutz et al., 2008). Examples of OMM are Vipassana meditation and the advanced stages of Zazen. Vipassana meditation involves observing all arising contents of consciousness with an attitude of equanimity while bearing in mind the ultimate impermanence of all things. Practitioners of the advanced stages of Zazen, on the other hand, observe their moment-to-moment experience without holding on to it, neither mentally nor emotionally.

Loving-kindness Meditation. Loving-kindness meditation (LKM), or *metta* as it is originally called in Pali, derives from Buddhist practice and aims at cultivating a benevolent and friendly attitude towards oneself, but also to other people and beings (Gunaratana, 2017). This meditation practice usually starts with wishing oneself well by reciting phrases such as "May I be happy and peaceful. May I be healthy. May I be grateful." These benevolent phrases are then extended to beloved fellow human beings, for example, family and friends, and eventually, these phrases are directed towards all living beings, for example, "May my mother be happy and peaceful etc., May all beings be happy and peaceful." (Gunaratana, 2017). However, the idea behind reciting these benevolent phrases is not that they may somehow become reality. The purpose of LKM is rather that the practice of wishing oneself and others well fosters the cultivation of positive emotions such as love and happiness as well as qualities like benevolence and friendliness towards others and oneself.

Meditation and Stress

Within the entire range of various meditation techniques, MM is probably the most popular one when it comes to becoming more resilient to stress. In 1979, Jon Kabat-Zinn developed the first mindfulness-based stress intervention which he called mindfulness-based stress reduction (MBSR). MBSR includes MM practices such as merely focusing on one's breath (FAM) as well as the body scan which derives from Vipassana meditation (OMM) (Kang et al., 2009). And indeed, there is a lot of evidence indicating that MM can be a valuable method for enhancing one's stress resistance. Jain et al. (2007) found that a short training in MM based on MBSR can diminish stress and improve positive mood states. A study by Munoz et al. (2016) yielded similar results demonstrating that after an intervention of MBSR training participants showed lower levels of stress as well as increased hope compared to participants without meditation practice. Moreover, Ostafin et al. (2006) examined participants who had participated in a ten-days long Vipassana meditation course. These participants reported a significant decrease in stress even three months after the course had ended. Additionally, this stress-reducing effect was not dependent on daily meditation practice between course completion and the follow-up. This indicates that the practice of MM, in this case Vipassana meditation, may develop a sort of mental faculty which facilitates coping with stress. In line with this, Jain et al. (2007) suggest that MM fosters a specific way of diminishing ruminative and distractive thoughts and behaviors through a mechanism unique to MM. Accordingly, this mechanism may ultimately be responsible for stress reduction in meditators.

Similarly, Transcendental Meditation has been shown to reduce stress in male prisoners (Nidich et al., 2016) and was successful in diminishing stress in teachers as well as support staff working in a therapeutic school for students with behavioral problems. (Elder et al., 2014) In addition, Goleman & Schwartz (1976) discovered that participants practicing Transcendental Meditation showed a faster recovery from stress in terms of skin conductance response and heart rate after watching a stress-inducing video clip. And likewise, after conducting a meta analysis of the research on Zazen meditation, Chiesa (2009) came to the conclusion that practicing Zazen was also found to reduce stress.

LKM appears to be an effective practice for decreasing stress as well: in a study by Arch et al. (2014), the researchers demonstrated that participants who had practiced LKM showed diminished physiological and subjective stress reactivity to the Trier Social Stress Test. Besides, after having practiced LKM for eight weeks, chronic low back pain patients showed significant lower stress levels compared to a control group (Carson et al., 2005). Beyond that, Hoge et al. (2013) found longer telomeres in women who were practicing LKM on a regular basis compared to those in a control group. As shorter telomeres have been linked to chronic stress and may provide a biomarker for determining an individual's ability to cope with stress (Epel et al., 2004, Kotrschal et al., 2007), LKM may be a valuable technique to prevent detrimental effects of stress even on a cellular level.

In sum, it can be stated that the aforementioned different variations of MM meditation are effective methods for counteracting stress. In a similar vein, LKM's effects on stress reduction seem promising as well.

Stress and Skin Conductance Response

One reliable way to measure stress is tracking an individual's skin conductance response (SCR). Whenever sweat glands become more active, they exude fluid through pores towards the skin surface. Thus, the balance of positive and negative ions in the exuded fluid is altered and electrical current flows more readily, resulting in measurable changes in skin conductance (Boucsein, Baltissen & Euler, 1984). This change in skin conductance is known as SCR.

Therefore, skin conduction fluctuates dependent on the skin's sweat gland activity. The skin's sweat glands, on the other hand, along with sweat secretion and the respective changes in skin conductance, cannot be consciously controlled and are regulated by the sympathetic nervous system (Martini et al., 2007). Whenever the sympathetic nervous system becomes more active, i.e. a person's stress level rises, the sweat glands increase their activity as well, which in turn, raises that person's SCR. Thus, SCR can be a measure of physiological and psychological arousal (Carlson, 2013).

Heart Rate and Stress

The number of heartbeats per minute is called heart rate (HR). In an untrained person, it amounts to 60-80 beats per minute in a resting state (Friedrich, 2016). This cardiac output is crucially influenced by the autonomic nervous system (ANS), more precisely by the sympathetic branch and the parasympathetic branch of the ANS. Parasympathetic activity slows down HR, while sympathetic activity accelerates it (Hottenrott, 2009). An increase of stress within the body is characterized by an increase in sympathetic activity. Thus, the experience of stress leads to a higher HR. As a consequence, the measurement of HR provides a reliable indicator of stress exposure (Carnethon et al., 2008; Grillon et al., 2007).

The present study

Based on the findings stated above, the aim of this research was in part to replicate the findings of Goleman and Schwartz (1976) who had observed a faster stress recovery time of meditators compared to non-meditators in terms of both SCR and HR. This study tested whether meditators differ from non-meditators in terms of recovery time towards their baseline SCR as well as recovery time towards their baseline HR after a stress-inducing stimulus. In the same way, it was tested whether meditators are distinct from non-meditators regarding changes in SCR and HR during this stress-inducing stimulus. In line with the research mentioned above, I expected meditators to display a faster recovery time towards their baseline of both SCR and HR, as well as a generally lower change in SCR and HR during stress induction compared to non-meditators. Accordingly, it is hypothesized that:

H1a: Meditators will show lower SCR reactivity to a psychosocial stressor than non-mediators.

H1b: Meditators will show lower HR reactivity to a psychosocial stressor than non-mediators.

H2a: Meditators will show shorter SCR recovery time than non-mediators after being confronted with a psychosocial stressor.

H2b: Meditators will show shorter HR recovery time than non-mediators after being confronted with a psychosocial stressor.

Method

Participants

The sample consisted of 34 participants (16 female, 18 male; M_{age} = 30.66; SD_{age} = 12.28) of whom 17 reported to meditate on a regular basis, i.e. at least once a week. These meditators ranged from less experienced meditators ($Min_{\text{meditation experience}}$ = 6 months) to particularly experienced ones ($Max_{\text{meditation experience}}$ = 300 months). Their average meditation experience was 81.06 months and standard deviation for meditation experience was 75.40 months. These meditation-experienced participants (6 female, 11 male) were recruited by contacting various meditation groups as well as through writing members of a Viennese Facebook meditation group. The members of the mentioned Facebook group (2 female, 5 male) received 10 Euros as a compensation for their participation. The remaining 17 participants (10 female, 7 male) were generally interested in meditation, however, they had never meditated on a regular basis. These meditation-naïve participants were recruited by means of a post in the Vienna

University psychology Facebook group, in which they were offered a free crash course in meditation after the testing procedure.

Design

The experiment was designed as a mixed design study with two groups: one group consisting of meditators, and another group, which was made up of meditation-naïve individuals. As both SCR and HR are fairly reliable measures of stress, and in addition non-invasive ones, I chose them as objective measurements in order to examine stress-related differences between meditators and non-meditators. As shown in figure 1, there were three phases, in which SCR and HR were measured. During the first phase, the participants' SCR baseline as well as their HR baseline were measured (baseline phase). In the second phase (stress phase), stress was induced and the participants' SCR and HR were measured. And lastly, in phase three (post-stress phase) the participants' stress recovery time in terms of SCR and HR was measured. The SCR and HR values were used as dependent variables, the test group and test phase were used as independent variables.

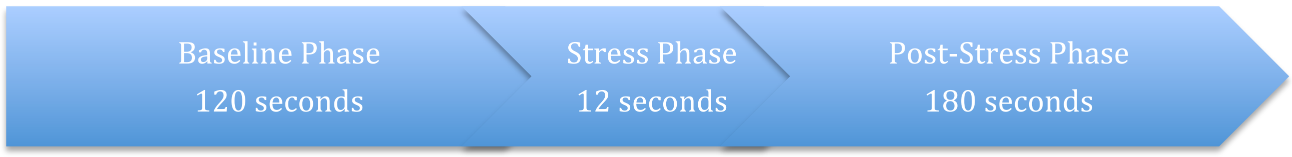

Figure 1. Phases of the stress test and their duration.

Task and Apparatus

Participants sat comfortably on a chair in a silent room with normal electrical lighting. They were instructed to leave their right hand lying flat and calmly on the table in front of them. Their entire task consisted of watching a video with the length of 5:12 minutes on a screen while wearing earphones.

Stress was induced by making the participants listen to unpleasant sounds on their earphones for 12 seconds while they were looking at the black screen of a smart phone. During the first 6 seconds they heard the sound of the Aztec death whistle, while during the last 6 seconds the participants heard one male and one female painful scream. Both the death whistle sounds and the two human screams were taken from Youtube videos.

In order to measure participants' SCR, the Mindfield E-Sense Skin Response sensor was used. This sensor takes measurements of a person's SCR via two electrodes which are clipped on a person's middle and index finger. That way, it measures the SCR data of every second in micro-Siemens (μS), which it transfers to an application on a connected smart phone. As the Mindfield E-Sense application, in which the video was played, shows on the lower right of the screen how much time is left until the next part of the video begins, this part of the screen was covered by a circular green sticker. This was done since otherwise participants could have been prepared for when the stress induction would have been about to start, which could have biased the results.

Participants' HR was tracked by electrodes attached to a chest strap of the brand Suunto. The electrodes of the chest strap sent the HR data to a wirelessly connected watch (Suunto Ambit3 Run Black HR, Suunto, Finland). From there, the data was transferred to a computer via USB connection.

Procedure

The study was conducted in a small room within the department of psychology of the University of Vienna. Before the study started, participants were informed about the procedure of the experiment. Thereafter, they signed an informed consent and filled out a form asking about personal information concerning their age and gender. Besides, they were supposed to write down in this form the length of meditation practice, the kind(s) of meditation they practice, the regularity of the practice, as well as the length of their meditation sessions. Then, a chest strap was attached to them, and via the corresponding wristwatch it was checked whether the electrodes were tracking the participant's HR correctly. Subsequently, the participant's right index and middle finger were disinfected with a conventional disinfectant to avoid measuring inaccuracy. Afterwards, they were connected to two electrodes, placing them on the upper third of their index and middle finger. Likewise, they were asked to keep their right hand lying flat and calmly on the table in front of them during the experiment.

Eventually, they put on earphones and started watching a video on the E-Sense smart phone application. The first minute of the video, participants were shown a picture with a relaxing scene (see Appendix). During the second minute of the video, all the participants could see in the video was a black screen. At minute 2:01 the stress induction began. Participants were still shown the black screen, however, they now heard 6 seconds of loud Aztec death whistle sounds, 3 seconds of a male scream and 3 seconds of a female scream. After these 12 seconds of stress induction had passed, phase 3 of the experiment began, which was 3 minutes long. With the onset of phase 3, the picture with the relaxing theme, which had been shown during the first minute, appeared again. During the entire phase 3, this picture was all that was shown on the screen.

After the experiment had ended, the participants put off the two electrodes clipped to their fingers as well as the chest strap. The chest strap's electrodes were then sanitized with a conventional disinfectant. Lastly, the participants were supposed to rate how stressful they perceived the stress induction to be on a 5-point Likert scale ranging from 1 (not stressful at all) to five (very stressful).

Results

The used stressor consisted of the sound of an Aztec death whistle along with one male and one female scream. It was tested considering its effectiveness for stress induction beforehand by conducting a mixed model ANOVA with a two level within-subject factor (baseline phase and stress phase), and one between-subject factor (group). I assumed that the presented stressor would cause a significant increase in participants' SCR. This hypothesis was confirmed by the results of the mixed model ANOVA, $F(1, 30) = 40.05$, $p < .001$, part. $\eta^2 = .57$. Accordingly, there had been a significant increase in participants' SCR when hearing the stressor.

Analogously to the procedure above, I had also conducted a mixed model ANOVA with a two level within-subject factor (baseline phase and stress phase), and one between-subject factor (group) in order to test whether the stressor would cause significant changes in participants' HR. As the results showed, this was the case, $F(1, 29) = 6.29$, $p = .02$, part. $\eta^2 = .18$.

Beyond that, participants were asked afterwards for their subjective stress perception of that stressor on a 5-point Likert scale ranging from 1 (not stressful at all) to 5 (very stressful). The mean was 3.47, the median was 4 and the standard deviation amounted to 1.22. Additionally, a t-test comparing the group mean with the value 3 as the mean of the Likert scale indicated that the stress experienced by the participants was significantly higher than the scale's mean, $t(31) = 2.18$, $p = .04$. Accordingly, the used stressor also caused participants to experience a relatively high subjective level of stress. Thus, it could be validated as a stress-inducing stimulus.

Before starting with the analysis, SCR and HR means, standard deviation, minimum and maximum of each phase were calculated for every participant individually. Outliers were identified by using bar charts due to the fact that the Kolmogorov-Smirnov test is rather unreliable for small samples (Field, 2017). In order to analyze the data, a trial version of SPSS 26 and a full version of SPSS 23 were used.

Out of a total sample of 34 participants, two participants had to be excluded from further analysis. These two participants were outliers in terms of both their skin conductance response and their heart rate. One of the two participants had been part of the meditation group, the other one had been part of the non-meditator group. Both participants showed abnormally high SCR and HR values compared to the other participants, which became obvious by creating bar charts of the participants' SCR and HR values. Apart from that, one of these two participants mentioned after the experiment that she was a highly sensitive person. The other outlier reported after the testing that she was having an extremely stressful day. Therefore, it made sense to remove these two participants from further analysis.

Moreover, the Suunto chest strap failed to track the heart rate of one participant in the non-meditator group. Therefore, the final sample of analysis was 32 (16 meditators, 16 non-meditators) for SCR, and 31 (16 meditators, 15 non-meditators) for HR.

The two main variables SCR and HR were measured at three measurement points, which were the baseline phase, the stress phase and the post-stress phase. In the following, the most important descriptive characteristic values are depicted.

Table 1

The most important descriptive characteristic values of the study

Test phase	*n*	*M*	*SD*	*MD*	*Min*	*Max*
Baseline SCR	32	2.94	2.15	2.02	1.11	10.83
Stress phase SCR	32	3.17	2.26	2.16	1.20	10.56
Post-stress phase SCR	32	2.89	2.14	2.04	1.02	10.70
Baseline HR	31	71.43	10.11	70.38	52	107
Stress phase HR	31	71.81	10.73	71	59	108
Post-stress phase HR	31	71.29	8.97	70.95	52	106

Skin Conductance Response

In hypothesis 1, it had been expected that meditators would exhibit a significantly lower stress reactivity during the stress phase than non-meditators. Specifically, H1a had predicted that meditators would show a significantly lower increase in their SCR when being confronted with an auditive stressor. Hypothesis 2a had predicted that regular meditation practice entails a faster stress recovery time demonstrated by a faster decrease in SCR compared to the SCR decrease of non-meditators.

In order to test H1a and H2a, a mixed model ANOVA with three level within-subject factor and one between-subject factor was calculated with SCR as the dependent variable measured in all three repeated measurements (baseline phase, stress phase and post-stress phase). The data used for this analysis were the SCR baseline mean value of each participant, the SCR stress phase mean value of each participant, as well as the SCR post-stress phase mean value of each participant. In addition, test group was defined as the between-subjects factor and age was defined as a covariate. In terms of the used data, the differences of the values of both SCR measurements were normally distributed, yet the homogeneity of variances had been violated. However, both groups were of the same size. Therefore, an ANOVA can still be considered a robust test in this case. Moreover, the regression slopes of the covariate with the dependent variable across the groups were homogenous. Additionally, as the results of Mauchly-Test showed, the variances of the differences between phases were equal.

The results of the ANOVA shown in figure 2 indicated that there is no significant impact of the covariate age on SCR, $F(1, 29) = 1.07, p = .31$. Besides, there was no significant interaction between age and testing phase, $F(2, 58) = 1.10, p = .34$. Likewise, there was no significant interaction between groups and testing phase regarding SCR, $F(2, 58) = 1.15$, $p = .32$. However, there was a significant main effect of the within-subject factor, $F(2, 58) = 5.29, p = .01$, part. $\eta^2 = .15$. Contrasts revealed that stress phase SCR values were significantly higher than SCR values of the baseline phase, $F(1, 29) = 5.14, p = .03$, part. $\eta^2 = .15$. On the other hand, post stress phase SCR values were significantly lower than stress phase SCR values, $F(1, 29) = 5.46, p = .03$, part. $\eta^2 = .16$. In addition, there was no significant main effect of the between-subject factor, $F(1, 29) = 0.80, p = .38$. Lastly, age as a covariate had no significant influence on SCR values, $F(1, 29) = 1.08, p = .31$.

Consequently, there appears to be no significant difference between meditators and non-meditators in terms of stress reactivity when it is operationalized as an increase in SCR controlled for age. Thus, H1a was not confirmed. In a similar vein, no significant difference in terms of stress recovery could be found between the two groups. Therefore, H2a was disconfirmed as well.

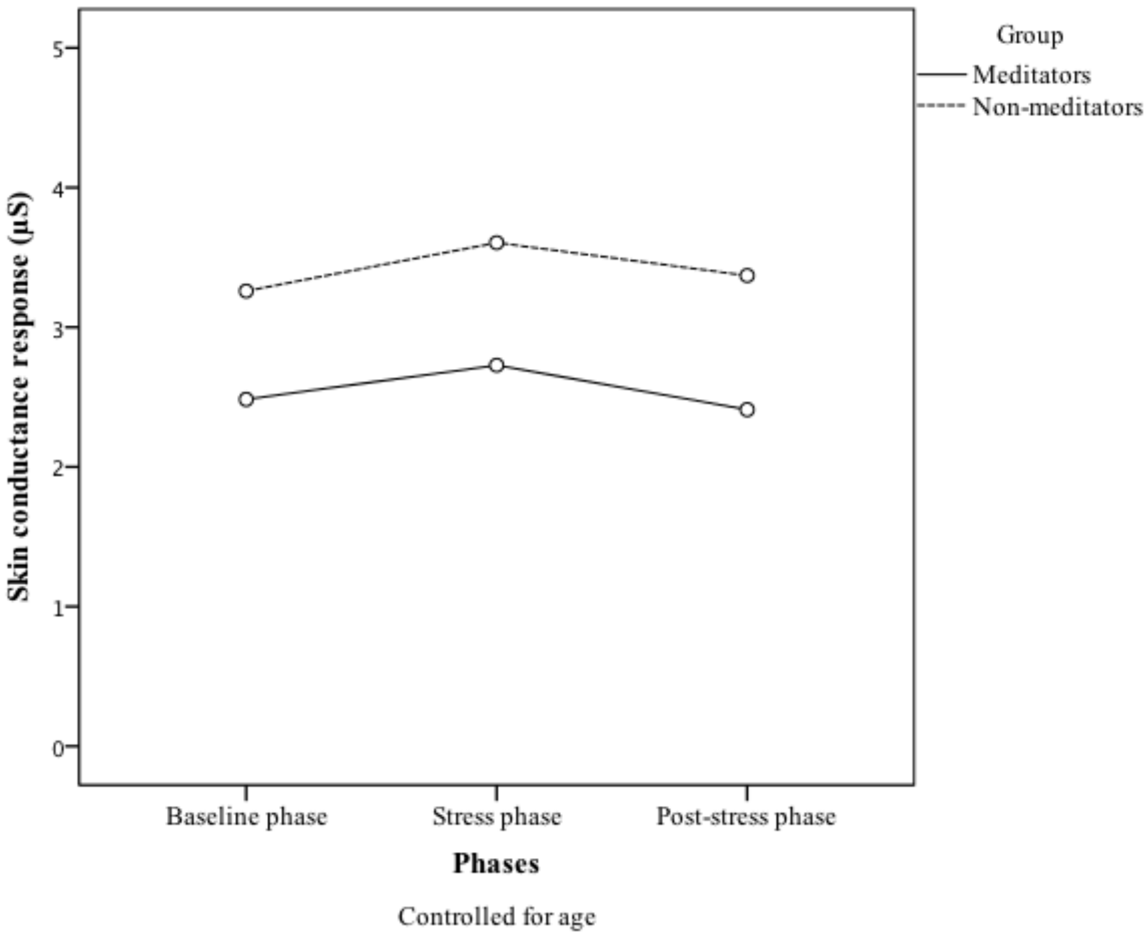

Figure 2. Comparison of the baseline mean (SCR), the stress phase mean (SCR) and the post-stress phase mean between the meditator group and the non-meditator group controlled for age.

A further analysis was conducted in order to test whether the two groups differed in stress recovery time to their baseline mean. In order to test this hypothesis, the amount of seconds participants needed to return to the their baseline mean was compared between both groups. Participants who entered the post-stress phase with their SCR being already at their baseline level obtained a value of 0 seconds. Participants who did not return to their SCR baseline mean at all during the post-stress phase received a value 180 seconds. The used data was not normally distributed. By conducting a square root transformation, the data was normally distributed and a t-test for independent samples was conducted. According to Levene's test, homogeneity of variances was fulfilled. There was no significant difference between the two groups in terms of reaction time, $t(30) = -0.11$, $p = .91$. As a consequence, H2a was again disconfirmed.

Heart Rate

H1b had predicted that meditators would show a significantly lower increase in their HR when being exposed to an auditive stressor. Hypothesis H2b had predicted that regular meditation practice leads to faster stress recovery demonstrated by a faster decrease in HR after the stressor has ended. The procedure of testing H1b and H2b was analogous to the procedure carried out previously in order to test H1a and H2a. The only difference in doing so was that in the case of H1b the data being analyzed was the participants' HR, and not their SCR. The homogeneities of variances were not violated according to Levene's-test. The homogeneities of the variances of the differences were not violated either according to Mauchly-test. The normal distribution for the dependent variable across groups was fulfilled. Therefore, a mixed model ANOVA with a three level within-subject factor and one between-subject factor was calculated with HR as the dependent variable measured in all three repeated measurements (baseline phase, stress phase and post-stress phase).

There was no homogeneity of regression slopes across groups for the covariate age. Age correlated with HR values in the meditator group positively, whereas it did not correlate in the non-meditator group. Therefore, age could not be inserted in the model as a covariate.

First of all, there was no significant interaction between the within-subject factor phases and the between-subject factor group, $F(2, 58) = 0.79$, $p = .46$. There was no significant main effect for phases, $F(2, 58) = 2.88$, $p = .06$. Furthermore, there was no significant main effect for groups, $F(1, 29) = 1.94, p = .17$. These results shown in figure 3 suggest that there is no significant difference between meditators and non-meditators considering their stress reactivity when it is operationalized as increase in HR in response to a stressor. Likewise, no significant difference between meditators and non-meditators regarding their HR stress recovery could be observed. Consequently, H1b and H2b were not confirmed.

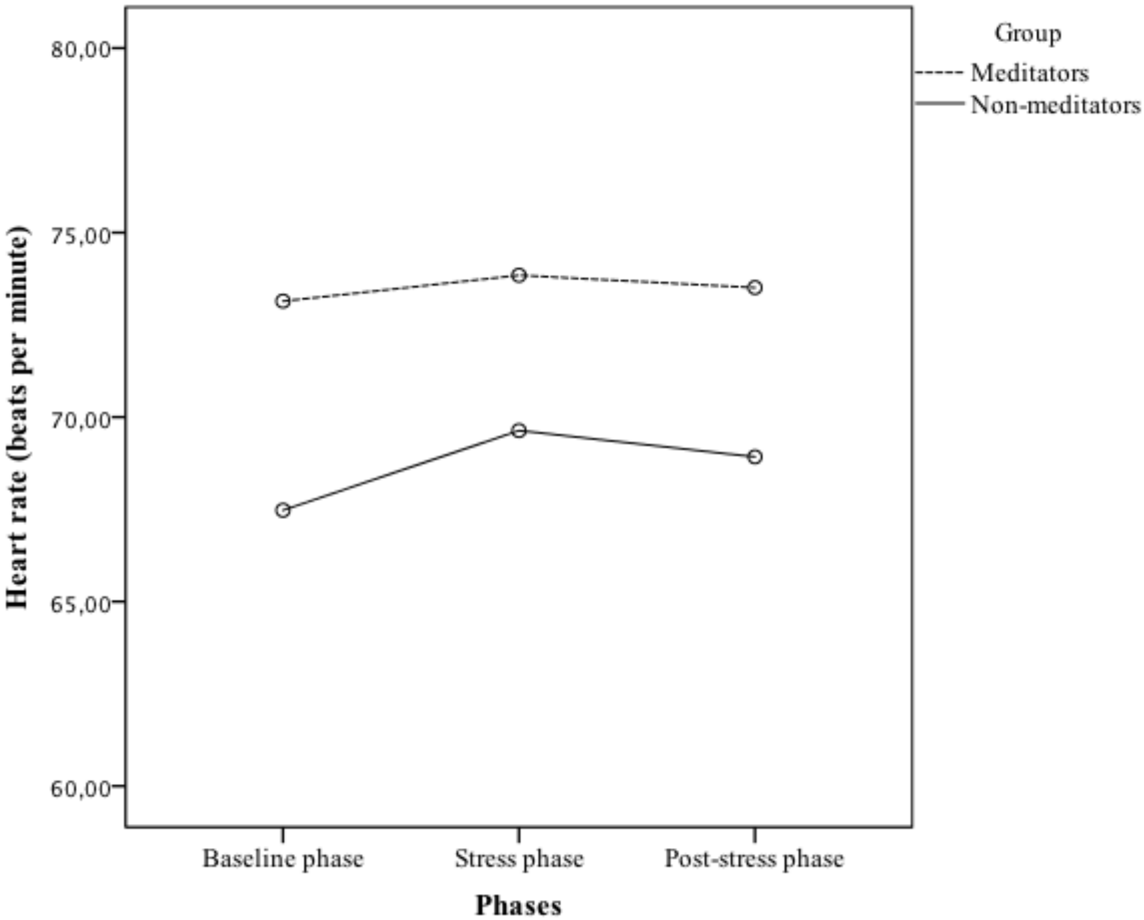

Figure 3. Comparison of the baseline mean (HR), the stress phase mean (HR) and the post-stress phase mean between the meditator group and the non-meditator group.

A further analysis was conducted in order to test whether the two groups differed in stress recovery time to their baseline mean. In order to test this hypothesis, the amount of seconds participants needed to return to the their baseline mean was compared between both groups.

Participants who entered the post-stress phase with their HR being already at their baseline level obtained the value of 0 seconds. Participants who did not return to their HR baseline mean at all during the post-stress phase received the value 180 seconds. The used data was not normally distributed. By conducting a square root transformation, the data was normally distributed and a t-test for independent samples was conducted. According to Levene's test, homogeneity of variances was fulfilled. There was no significant difference between the two groups in terms of reaction time, $t(29) = -0.11$, $p = .91$. Hence, H2b was disconfirmed once again.

Discussion

One of the study's major goals was to replicate some of the findings of Goleman & Schwartz (1976) who had demonstrated that meditators display a faster stress recovery than non-meditators regarding both their SCR and HR. These findings could not be replicated in the present study. Beyond that, the study aimed at investigating whether meditators show lower stress reactivity than non-meditators while using their SCR and HR as stress parameters. Within the framework of this study, no significant differences in terms of stress reactivity could be found between meditators and non-meditators.

Skin Conduction Response and Heart Rate

As outlined in the results section, there was no significant difference between the two groups' stress reactivity neither in terms of their SCR nor regarding their HR. The fact that there was no significant difference considering HR stress reactivity between meditators and non-meditators is in line with the findings of Gamaiunova et al. (2019). These researchers compared, amongst other factors, HR stress reactivity between long-term meditators and meditation-naïve individuals. Their results showed no significant difference between meditators and non-meditators regarding HR stress reactivity either.

Beyond that, it is not even clear whether lower stress reactivity in terms of HR or also SCR would be such an adaptive quality. Reacting to a stressor with anxiety and the physiological arousal that goes along with it is adaptive since it mobilizes our organism for fast action and focused attention in order to trigger the appropriate coping mechanisms (Lazarus & Averill, 1972). As especially mindfulness meditation trains the meditator's mind to be attentive to the present moment, this practice may well accelerate the meditator's stress response to the sudden appearance of a stressor. However, if this stress reaction is maintained even after the stressor has disappeared, it becomes maladaptive (Epstein, 1962). Hence, a fast stress recovery seems to be fairly desirable.

Another main purpose of this study was to test my hypothesis that meditators would demonstrate faster stress recovery in terms of both their SCR and HR than non-meditators. As pointed out earlier, the results did not support this hypothesis. At first glance these results might seem surprising, since previous research had produced different results. Goleman & Schwartz (1976) observed a faster stress recovery in terms of SCR and HR in meditators compared to non-meditators. Besides, Gamaiunova et al. (2019) found a faster HR stress recovery of meditators compared to non-meditators as well. Aside from that, Rosenkranz et al. (2016) observed a smaller concentration of salivary cortisol in meditators compared to non-meditators immediately after a stressor had disappeared. Likewise, Hoge et al. (2018) identified an attenuated stress response to the Trier Social Stress Test (TSST) in terms of blood cortisol levels in subjects who had received a MBSR class compared to the meditation-naïve control subjects.

One of these four abovementioned studies put participants under stress by showing them work-related accidents in a wood mill (Goleman & Schwartz, 1976). Interestingly though, the remaining three of these four studies all induced stress by using the TSST, which aims at inducing social-evaluative stress (Gamaiunova et al., 2019; Hoge et al., 2018; Rosenkranz et al., 2016). The induction of social-evaluative stress can be considered as ego-threatening, which is why it makes sense that meditators showed a lower stress response to it than non-meditators. Buddhist meditation practices often lead to changes in self-image rendering it less rigid than before (Epstein, 1988). These changes in self-image, in turn, help to deal with ego-threatening experiences in a less defensive fashion (Brown et al., 2008). This notion is in line with findings by Goldsmith et al. (2014) as well as findings by Woods & Proeve (2014) who showed that particularly MM is strongly negatively correlated with shame proneness. Thus, the decreased tendency to feel shame developed through MM might be the reason why in these three aforementioned studies mediators displayed lower stress levels than non-meditators.

In the present study, on the other hand, no social-evaluative stress induction was used. The encountered stressor was rather a compilation of human screams and human scream-like sounds. Therefore, the stressor did not necessarily represent an ego-threatening experience for the participants like in the studies utilizing the TSST. Consequently, the meditator's protection against stress through ego-threat could not mitigate their stress response in a meaningful way. This might be the reason why there was neither a significant difference between meditators and non-meditators in terms of their SCR and HR stress reactivity nor regarding their SCR and HR stress recovery.

Nonetheless, the question remains why Goleman & Schwartz (1976) found meditators' SCR and HR to recover faster from a stressor than non-meditators. One important difference between this study's meditator participants and the present study's meditator participants is that Goleman & Schwartz exclusively recruited individuals who had practiced Transcendental Meditation for more than two years. In the present study, only two of the meditator participant claimed to practice Transcendental Meditation on a regular basis. Hence, the possibility that the effects of Transcendental Meditation practice could have been responsible for these meditators' faster HR stress recovery compared to meditation-naïve subjects cannot be excluded. Therefore, future research that examines Transcendental Meditation practice's effect on non-social-evaluative stress HR recovery is needed.

Limitations

First and foremost, there is an obvious limitation of the study, which is the notable age difference between the two test groups. While the non-meditator group consisted exclusively of students (M_{age} = 22.63; Min_{age} = 18; Max_{age} = 30), the meditator groups' participants were considerably older (M_{age} = 38.69; Min_{age} = 24; Max_{age} = 64), and did not include hardly any students. This fact raises the question as to which extent these two groups are comparable. Therefore, age was introduced as a covariate in the analysis of SCR. The results showed that there was no significant influence of the covariate age on SCR. For the statistical analysis of HR, however, the assumptions for using age as a covariate were not met. However, there were no group effects in the entire analysis anyways.

One possibility for the non-significant results of my statistical analyses of H1 and H2 might have been the fact that I had no accurate way of measuring how proficient these meditators actually were in regard to their ability to meditate. The amount of time they had already been meditating was an indication of their proficiency, yet no guarantee. Some participants might have been stagnating in their meditation practice, or worse, some might just have meditated the wrong way. For instance, unlike any physical exercise or movement whose execution can be evaluated by merely watching it, it is simply not possible to assess if someone meditates correctly by just watching him. Similarly, if a person wants to learn some kind of sports movement, this person has the possibility to just observe how a professional executes this movement. Consequently, by the visual information on the proper sports movement that person has now gained, he has the knowledge to learn and master this sports movement by self-correcting according to the visual information on the movement. In meditation, however, it is not possible for the meditation student to observe what his teacher precisely does in order to meditate with proficiency. Any meditation student is dependent on his teacher's capability of explaining the meditation practice as well his own ability to make right sense out of this explanation.

This leads me to the issue of not having taken into account whether the study's participants had undergone formal meditation training. There is plenty of information on meditation out there, particularly on the internet, which may or may not be helpful for developing a skilled meditation practice. Accordingly, if one follows flawed instructions for acquiring a skill, one most probably will not learn the skill correctly. As a consequence, it is possible that a number of participants might simply not have learned how to meditate the right way. For this reason, future researchers in this field may consider using participants who have obtained formal meditation training by a certified meditation teacher.

Besides, my measurement of their ability to meditate relied on their self-report only. Hence, it may be that their self-report did not always do justice to their actual meditation proficiency. Thus, it may be questionable whether the meditator sample I used was an actual representation of legitimate meditators.

However, determining a person's meditation proficiency objectively is still not within the realm of possibility. At the one hand, neuroscience has made some progress in this regard, for example, indicating that a substantial number of proficient meditators shows an EEG characterized by increased power in theta and alpha bands and decreased frequency at least in the alpha band while displaying an overall slowing in frequency (Aftanas & Golocheikine, 2005; Andresen, 2000; J. M. Davidson, 1976; Delmonte, 1984a; Jevning, Wallace, & Beidebach, 1992; Schuman, 1980; West, 1979, 1980; Woolfolk, 1975). Besides, neuroimaging studies suggest that successful meditation practice is related to a relative increase in activation in the frontal and prefrontal cortex (Cahn & Polich, 2013). Nonetheless, it is still unclear to which extent these findings are actually caused by a proper meditation practice. Aspects such as age and personality factors remain as possible confounding variables, which could have also been responsible for the aforementioned neural patterns.

Hopefully, future research will be able to solve this issue and thereby offer a reliable objective measurement for meditation proficiency.

Furthermore, even though the HR tracking device took measurements every second, its data output was the averaged value of a ten second interval, respectively. Thus, there was only one value for each ten seconds in the HR data output. Accordingly, the values of the HR recovery time to HR baseline mean, may not represent the actual stress phase HR recovery time to HR baseline mean. For example, let us assume that according to the data, a participant returned to his HR baseline mean 20 seconds after the stress phase had ended. This participant could have returned to his HR baseline mean eleven seconds or twenty seconds after the end of the stress phase. However, this cannot be determined by the data. Therefore, there are certainly measuring inaccuracies within the data which represent a clear limitation of this study.

Future Research

Bearing in mind the aforementioned limitations, a couple of suggestions for future research can be made. On the one hand, future researchers investigating meditators' and non-meditators' stress reactivity and stress recovery time might consider using test groups which are similar in terms of age. Likewise, it would be recommendable recruiting a bigger sample than I did in the present study.

Furthermore, it would notably increase the validity of the data if only those meditators were taken as participants who have completed formal meditation training by a certified meditation trainer of some sort. For instance, this could be individuals having undergone a MBSR training program or individuals who have been instructed in meditation in a Zen monastery. Otherwise, one could of course also train meditation-naïve participants for a certain period of time in meditation and compare them to non-meditators afterwards.

Lastly, it would surely be intriguing to conduct a study comparing the stress reactivity and stress recovery time of practitioners of Transcendental Meditation, practitioners of other kinds of MM and non-meditators using a non-social-evaluative stressor. Thereby, one might shed light on the issue discussed above whether there is a significant difference regarding stress recovery time between practitioners of Transcendental Meditation and practitioners of other MM techniques after having faced a non-social-evaluative stressor.

Implications

Due to the limitations pointed out earlier, the results of the study should be treated with caution. Until future research has not thoroughly investigated meditation's effects on a person's stress reactivity and stress recovery time, it is still too early to draw practical conclusions. On the other hand, the present study's results suggest that the stressor consisting of sounds of the Aztec death whistle and two human screams may be used for stress induction in future research.

This study aimed at contributing to the body of research about meditation practice and its physiological effects on reacting to acute stress. No significant effects of meditation practice on stress reactivity and stress recovery in terms of SCR and HR could be observed. However, there were some potential weaknesses regarding the sample. Therefore, it cannot be said with absolute confidence that the result do justice to the actual effects of meditation on stress reactivity and stress recovery time.

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Appendix A: Material

Figure A1: Baseline phase video sequence (minute 00:00-01:00)

Figure A2: Baseline phase video sequence (minute 01:01-02:00):

Figure A3: Stress phase video sequence (minute 02:01-02:12)

Figure A4: Post stress phase video sequence (minute 02:13-05:12)

Appendix B: Deutsche Kurzzusammenfassung

Die schädlichen Effekte psychologischen Stresses auf die Gesundheit werden in der heutigen Zeit zunehmend deutlicher. Eine regelmäßige Meditationspraxis erscheint vielversprechend darin, psychologischen Stress senken zu können. In der vorliegenden Studie wurde untersucht, ob es eine signifikanten Unterschied zwischen erfahrenen Meditierenden und Nicht-Meditierenden hinsichtlich ihrer Stressreaktivität und ihrer Stresserholungszeit gibt. Der eingesetzte Stressor in dieser Studie, nämlich der Klang einer aztekischen Todespfeife samt zwei menschlicher Schreie, wurde im Voraus hinsichtlich seiner Effektivität zur Stressinduktion getestet. Um einen Einblick in das physiologische Stressniveau der Versuchsteilnehmer zu erhalten wurde ihr Hautleitwert sowie ihre Herzfrequenz erhoben. Ich vermutete, dass Meditierende einen geringeren Anstieg ihres Hautleitwerts und ihrer Herzfrequenz verzeichnen würden als Nichtmeditierende, nachdem sie einem psychosozialen Stressor ausgesetzt wurden. Ferner war es meine Annahme, dass sobald der Stressor verschwunden ist, Meditierende schneller zu ihrer Hautleitwertbasislinie sowie ihrer Herzfrequenzbasislinie zurückkehren würden als nichtmeditierende Teilnehmer. Beide Gruppen zeigten eine ähnliche Stressreaktivität und Stresserholungszeit bezüglich ihres Hautleitwerts und ihrer Herzfrequenz. Vorschläge für zukünftige Forschung werden diskutiert.