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Effects of internet-based stress management on acute cortisol stress reactivity: Preliminary evidence using the Trier Social Stress Test for Groups (TSST-G)

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ABSTRACT

Previous studies have demonstrated the effectiveness of face-to-face stress management programs in reducing psychological and endocrine responses to acute psychosocial stress exposure. With the present pilot study, we compare the effects of a brief internet-based stress management (IBSM) intervention versus relaxation training on subjective, autonomic, and endocrine stress responses to a standardized psychosocial laboratory stressor (Trier Social Stress Test for Groups, TSST-G). A group of male participants receiving IBSM was compared to a group receiving Progressive Muscle Relaxation (PMR) training and a waiting-list control group. All groups underwent the TSST-G following a 6-week training/waiting period. Both the IBSM and PMR group reported lower subjective stress levels than the control group. However, the IBSM group exhibited the lowest free salivary cortisol responses to the TSST-G, with significantly lower levels than the PMR group. The waiting-list control group exhibited an intermediate cortisol response. These preliminary results suggest that a 6-week internet-based stress management program is effective in reducing the subjective stress levels, and might be associated with an attenuated salivary cortisol response to an acute stressor.

1. Introduction

Chronic stress has been associated with several somatic diseases, such as hypertension, cardiovascular illness including myocardial infarction, stroke, and depression (Cohen et al., 2007). Although the mechanisms by which chronic stress can increase vulnerability and ultimately contribute to illness are not fully understood, heightened reactivity of physiological systems to everyday stressors or an impaired ability to recover from acute stress have been discussed as mediating factors within the allostatic load model (McEwen, 1998). The acute response to psychosocial stress comprises a multitude of adaptive psychological and physiological reactions, including the endocrine response of the hypothalamic-pituitary-adrenal (HPA) axis with the secretion of cortisol (Dickerson and Kemeny, 2004) that can be reliably measured in saliva (Hellhammer et al., 2009; Kirschbaum and Hellhammer, 1994).

In light of the enormous health burden associated with chronic stress, numerous attempts have been made to reduce the negative effects of psychosocial stress in everyday life, ranging from short relaxation and psychoeducation to multi-week standardized intervention programs based on well-established cognitive-behavioral techniques (Richardson and Rothstein, 2008). Several studies have demonstrated the effectiveness of face-to-face cognitive-behavioral stress management in different populations based on the self-reporting of subjective stress levels, stress management skills, and psychological and somatic health status. A meta-analysis on stress-management in occupational settings concluded that the largest effects can be expected from cognitive-behavioral programs, which promote active adaptation of response to stressors, although most nevertheless incorporate relaxation training, a more passive technique (Richardson and Rothstein, 2008). Overall, self-reported evaluation criteria such as perceived stress yield effect sizes in the medium to large range.

However, to date there have been few attempts to evaluate the effects of these interventions based on the acute psychological and

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physiological reactions to standardized psychological stressors. Gaab and colleagues used the 'Trier Social Stress Test' (TSST) (Kirschbaum et al., 1993) and demonstrated reduced salivary cortisol secretion in response to the TSST in students who had participated in a 10-hour group-based cognitive-behavioral stress management training compared to a waiting control group (Gaab et al., 2003). Subsequent studies have replicated these results, consistently showing reduced endocrine reactivity to a standard laboratory stressor (Storch et al., 2007) even 4 months after training (Hammerfald et al., 2006). The papers cited above did not include measures of the sympathetic nervous system (e.g., heart rate). In the meta- analysis of Richardson and Rothstein (2008), only nine studies documented blood pressure data, and two of those studies also measured heart rate. Given the cardiovascular system's importance in relation to health-damaging effects of acute and chronic (psychosocial) stress (Lagraauw et al., 2015), there is a great need for studies investigating the effects of stress-management techniques on all stress systems including the cardiovascular system, especially regarding the heart rate.

Traditional face-to-face stress management interventions are cost-intensive and time-consuming, as most programs require professional guidance during the entire course of the intervention. Internet-based programs have been developed to provide low threshold access to stress management (e.g., Heber et al., 2016). Most of these programs are online adaptations of multi-modal cognitive-behavioral trainings and comprise of several training modules disseminated and presented via the internet.

The effectiveness of internet-based stress management (IBSM) programs has been evaluated in a number of experimental trials. One of the first randomized controlled trials revealed beneficial effects of a 6-week relaxation and cognitive-behavioral online program on perceived stress, depression, and anxiety compared to a waiting-list control group (Zetterqvist et al., 2003). Similar positive effects were reported from an online mindfulness stress-reduction program (Morledge et al., 2013), internet-based stress-prevention in secondary schools (Fridrici and Lohaus, 2009) and college students (Frazier et al., 2015), working adults (Billings et al., 2008), and community-based samples (Heber et al., 2016), although some results are contradictory (e.g., Shimazu et al., 2005). Just one study assessed several physiological stress markers and reported that an IBSM program decreased Chromogranin A and increased Neuropeptide Y, DHEA-S and TNF-a compared to a control condition (Hasson et al., 2005). In sum, the studies so far suggest that IBSM programs exert positive effects on perceived stress and subjective well-being based on the participants' own reports. However, none of them investigated the effects on the participants' physiological reactivity to acute stress exposure. Taking a psychobiological approach, we focused on the program's effectiveness in reducing stress responsiveness and stress-related psychobiological dysregulation in response to a naturalistic stressor (Kudielka and Wüst, 2010).

With the present pilot study, we aimed to directly compare the effectiveness of a 6-week IBSM program and a well-established relaxation training in reducing psychological and physiological stress responsiveness to an acute laboratory psychosocial stressor. In particular, we directly compared the subjective, endocrine, and cardiovascular responses to stress exposure among three groups: an internet-based stress management group, an active control group (internet-based progressive muscle relaxation, PMR program), and a waiting list control group. We chose the PMR relaxation technique as our active control group, as it has proven to be successful (Richardson and Rothstein, 2008) and can be distributed via the internet. We expected lower stress responses in the groups receiving stress management training compared to the waiting control group. Based on the meta-analysis referred to above, we expected the largest effect in the group receiving the cognitive-behavioral IBSM program.

2. Methods

2.1. Participants

Non-smoking, working, male participants (age mean +/- SD: 46.8 +/- 9.2 years) were recruited via a local newspaper advertisement. The study was announced as "an evaluation study of an internet-based stress management program". Participants were screened via telephone interview regarding mental and physical health, and were excluded from the study if they reported having an acute or chronic somatic disease, psychiatric disorder, a traumatic event or suicidal ideation in the past 6 months, taking illegal drugs or psychoactive medication, or if they worked on a shift basis.

In all, 120 participants responded to the newspaper advertisement, of whom 81 were successfully contacted for telephone screening. Sixty participants proved eligible for participation, gave written-informed consent, were randomized to the three experimental conditions (IBSM group: n = 18; PMR group n = 21; Controls n = 21), and started the program by logging on to the study website. Due to 11 participants discontinuing and thus dropping out during the study (IBSM group: n = 2; PMR group n = 5; Controls n = 4), data of 49 participants were available for our analysis of pre-post subjective stress levels and post-intervention endocrine responses to the laboratory stressor (IBSM group: n = 16; PMR group n = 16; Controls n = 17). The study protocol was approved by the institutional review board of the University of Freiburg.

2.2. Study protocol

Potential participants responded to the newspaper advertisement via email. They were then contacted by telephone for the screening interview. Those who fulfilled the eligibility criteria were invited to an initial visit during which they were given information on the study procedures (in groups) and gave written-informed consent. The remaining participants filled a number of questionnaires (see below) to collect demographic data and trait characteristics. Participants were then randomly assigned to one of the two intervention groups or a waiting group. Participants in the intervention groups received access to the website with the online stress management training or the relaxation program and were taught how to start with the online stress management program or the progressive muscle relaxation. Waiting group participants were informed that they had to wait 6 weeks before starting the stress management program.

For the laboratory stress session, which was scheduled approx. 7 weeks later, participants were instructed to eat ordinary meals on the day of testing, to abstain from food 2 h prior to the afternoon session as well as from alcohol, caffeine, excessive physical exercise, and any medication 24 h before testing.

2.3. Internet-based stress management program (IBSM)

The IBSM was conceived as a short-term intervention to improve relevant skills for the management of daily stressful situations, particularly in occupational settings. Hence the modules address both cognitive processes to reduce stress-facilitating thoughts and beliefs and behavioral strategies for managing resources better, such as social support or time management. Thus, the IBSM represents an interactive, electronic adaptation of face-to face cognitive-behavioral stress-management training sessions, such as stress inoculation training by Meichenbaum (1985). The IBSM program comprised six weekly modules based on a cognitive-behavioral approach with the following foci: (1) understanding psychological stress, (2) strategies to deal with acute stress, (3) effective time management, (4) reducing stress-promoting cognition, (5) systematic problem solving, and (6) integration and transfer to every-day situations (for details see Table S1, Online Supplementary Materials). The IBSM was available via the internet with a standard PC, tablet or mobile. Data collected within the program were transmitted via a secure connection and stored for further analyses. Video clips, audio files, animations, and interactive elements were used in each module to maximize the participants' personal involvement and to promote the transfer to their individual situation. Total working time for a single module was approx. 45 min. Each module concluded with an invitation for an exercise for the following week. After finishing a module including the completion of the exercise, the subsequent module was available during the subsequent week, resulting in an intervention period of 6–7 weeks.

The group receiving PMR had access to 6 audio files with spoken instructions to perform classic PMR according to Jacobson. The audio files were provided on a weekly basis via the internet and invited the participants to perform PMR every week for at least 30 min. As with the IBSM group, the intervention thus lasted 6–7 weeks. The waiting list control group received the pre-post questionnaires, but were allowed to start with the stress management program after the acute laboratory stressor test session.

2.4. Laboratory stressor – TSST for gGroups

To induce mild to moderate psychological stress, we used the Trier Social Stress Test for Groups (TSST-G; von Dawans et al., 2011v). The TSST and TSST-G resemble the gold standard of psychosocial stress induction (Allen et al., 2017) and are widely used to test for treatment effects of stress reduction methods (e.g., Engert et al., 2017; Hoge et al., 2018; Klaperski et al., 2014). In short, the TSST-G is a modified group protocol including six participants based on the original single-subject TSST (Kirschbaum et al., 1993), which comprises a short mock job interview phase (12 min) and a mental arithmetic phase (8 min) in front of an audience of two evaluators. After a familiarization period and subsequent preparation period (10 min), the participant is asked to give a short talk (2 min) in the first part of the TSST and perform serial subtractions in front of the audience in the second part (80 s). A detailed description of the procedure can be found in von Dawans et al. (2011). Over the course of the experiment, ratings on fear, bodily symptoms, avoidance, tension, controllability, stress, and anger were obtained at 6 timepoints (-10, -1, +10, +20, +30, + 40 min in reference to the beginning of the stressor) using visual analogue scales (VAS) to track the subjective response to the TSST. All TSST sessions were conducted between 16:30 h and 17:30 h to control for the circadian decline in free cortisol previously reported (Kudielka and Wüst, 2010).

2.5. Saliva sampling and cortisol analysis

Saliva samples were collected on the pre-intervention baseline day (BL) at the same time of day that the TSST-G was to be administered, and on the testing day before the TSST-G (-10 min), and at four different times following the start of the stressor (+10, +20, +40, +75 min) using the Salivette sampling device for free salivary cortisol analysis (Sarstedt, Nümbrecht-Rommelsdorf, Germany). Saliva samples were immediately frozen after the experimental sessions and stored at -20 °C. For biochemical analysis, the saliva samples were thawed and spun for 10 min at 3000 rpm. A commercially available chemiluminescence immunoassay (IBL Hamburg, Germany) was used to measure the concentration of the free fraction of cortisol with an inter- and intra-assay variability of 8.4% and 4.6%, respectively. Biochemical analyses were carried out at the Laboratory of Biological Psychology, Technical University of Dresden, Germany.

2.6. Heart rate recording and analysis

Heart rate was recorded with wearable HR wrist watches (Polar RS800, Polar Electro, Finland) connected to a chest belt. Beat-to-beat intervals were recorded and used to calculate the average heart rate over 1-minute intervals starting 5 min before the preparation period for 30 min, covering the familiarization period (5 min.), the preparation (10 min.), the stressor (20 min), and a recovery period (5 min.). Heart rate recordings were checked for artifacts and corrected using moving average filters implemented in the Polar software analysis package (Polar ProTrainer 5, Polar Electro, Finland). The average heart rate was calculated for further statistical analysis for each phase. HR data sets from eight participants were lost because their HR watches malfunctioned, leaving n = 15 (IBSM), n = 12 (PMR) and n = 14 (Control) data sets in all for further analysis. Heart rate recordings were checked for artifacts (mean = 0.622%; SD = 1.059) and corrected using moving average filters implemented in the Polar software analysis package (Polar ProTrainer 5, Polar Electro, Finland).

2.7. Questionnaires

A short questionnaire was used to assess demographic variables (age, familial situation, profession, work load, and global perceived level, body mass index). In addition, pre-training mental health status was assessed with a short version of the Brief Symptom Inventory (BSI-18; Spitzer et al., 2011) comprising the three domains: depressive, anxiety, and somatic symptoms. Finally, we measured the subjective level of stress prior to and after training with the Perceived Stress Scale (PSS; Cohen et al., 1983).

2.8. Statistical analysis

Group differences in pre-post effects regarding global stress levels were tested with a mixed between-subjects and repeated-measures ANOVA. Group differences in the endocrine and cardiovascular response to the acute stressor were tested with a repeated measures mixed ANOVA using free salivary cortisol and averaged heart rate as dependent variables. Area-under-the-curve values were calculated as an aggregated measure of the total cortisol output (AUC_G) and the output in reference to the baseline (AUC_I) over the course of the TSST (Pruessner et al., 1997). In addition, we used separate repeated measures mixed ANOVA to test for differences in psychological responding to the acute stressor using the VAS values as dependent variables. For all statistical analyses we used SPSS for Windows (Version 22). Statistical threshold was set at $p < .05$ (two-tailed) for all tests.

3. Results

3.1. Group characteristics and compliance

Descriptive data on group characteristics are illustrated in Table 1. Groups did not differ in terms of age, work load, pre-training stress levels (PSS), health status (BSI-18), and body mass index. On average, all participants reported moderate to high levels of professional work load (mean value > 40 h per week) and moderate to high stress levels (mean PSS sum score > 20). Based on login protocols, we assessed the IBSM group's compliance: all participants completed the first module, modules 2, 3, and 4 were completed by 15 participants, module 5 by 14 participants and the last module by 12 participants. Both groups reported similar subjective compliance, reflected by a nearly identical number of participants reporting that they used the program less/exactly/more than once a week: IBSM: 3:9:3; PMR: 3:10:3 ($\chi 2 = 0.02$; $p < .99$).

3.2. Subjective stress

Based on the Perceived Stress Scale, we noted an overall reduction in subjective stress levels as indicated by a significant main effect of time ($F[1,46] = 18.85$; $p < .001$; $\eta^2_{part} = .29$). Neither group nor group-by-time interaction was significant ($F[2,46] = 1.52$; $p = .229$; $F[2,46] = 1.00$; $p = .375$). However, the three groups' post-hoc pre-post

Table 1
Demographic and psychopathological characteristics of the study groups.

	IBSM n = 16		PMR n = 16		Controls n = 17		Statistics	
	mean	s.d.	mean	s.d.	mean	s.d.	F/Chi^2	p
Age	46.2	6.9	48.0	11.5	46.1	8.8	0.22	.805
Education	12.8	0.8	12.1	1.3	11.8	1.5	2.53	.091
Work load	44.5	10.0	44.8	12.0	45.1	9.1	0.07	.931
Number of children	1.3	1.0	0.9	1.0	1.6	1.2	2.00	.147
Professional status								
Employee	12		10		14		4.89	.299
Entrepreneur	4		4		1			
Other	0		2		2			
BMI	25.7	3.20	25.7	2.3	26.8	3.4	0.80	.456
Perceived Stress (PSS)	20.6	3.5	21.8	3.8	22.2	3.3	0.83	.442
Depression (BSI-18)	8.1	1.8	8.4	2.3	9.7	4.5	1.26	.293
Anxiety (BSI-18)	9.9	3.3	9.4	2.4	11.1	4.6	0.98	.385
Somatic symptoms (BSI-18)	8.7	3.0	9.3	1.7	10.1	5.4	0.60	.553

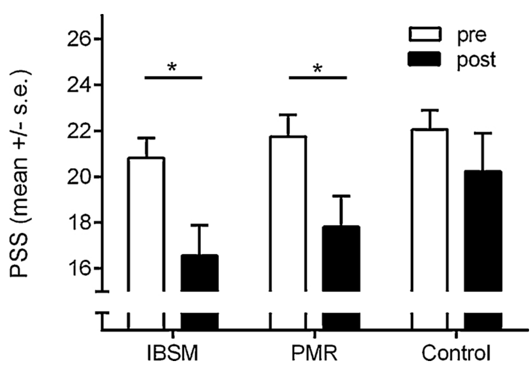

Fig. 1. Subjective stress levels assessed with the Perceived Stress Scale (PSS) before and after the 6-week Internet-based Stress Management Program (IBSM n = 16) compared to a Progressive Muscle Relaxation (PMR n = 16) group and a control (n = 17) group. Bars represent mean +/− s.e. * p < .05.

comparisons revealed significantly reduced stress in the IBSM training group (t[15] = 3.58; p = .003; Cohen's d = .93) and the PMR group (t[15] = 4.61; p < .001; Cohen's d = 1.22), but not in the control group (t[16] = 1.05; p = .308; Cohen's d = 0.27) - see Fig. 1.

Regarding the psychological reactions in response to the acute stressor, we noted significant time effects in all measures of distress (except for anger), indicating a significant psychological reaction to the stressful situation (all p < .01). There were no main effects of group and no group-by-time interactions in any of the measures, indicating similar psychological reactions to the acute stressor in all study groups (all p > .05). Detailed results of the corresponding ANOVAs can be found in Table S2, Supplementary Online Materials.

3.3. Salivary cortisol response

The groups' pre-intervention baseline cortisol levels did not differ (F[2,48] = 0.08; p = .921). The repeated-measures ANOVA comprising the baseline and five time points over the course of the TSST-G revealed a significant main effect of time (F[5,230] = 71.66; p < .001; η^2_{part} = .61) and a trend towards a significant main effect of group (F[2,46] = 2.65; p = .082; η^2_{part} = .10). No significant time-by-group interaction was apparent (F[10,230] = 1.56; p = .200; η^2_{part} = .06), indicating an overall level difference in salivary cortisol between groups rather than different courses over the TSST – see Fig. 2a. Post-hoc power analysis for the time-by-group interaction (effect size f = .26; α = 0.05) revealed a statistical power of 1-β = .86. Testing for group differences regarding the AUC_I, i.e. the increase in cortisol in reference to the baseline, we observed a significant effect in the ANOVA (F[2,46] = 3.32; p = .045 η^2_{part} = .13) driven by a significant difference

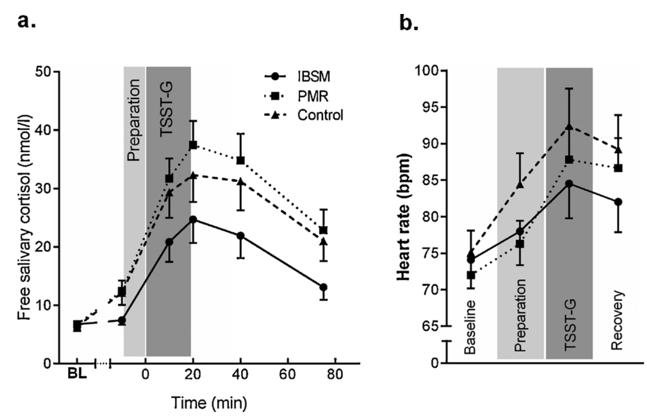

Fig. 2. (a) Free salivary cortisol levels over the course of the Trier Social Stress Test for groups (TSST-G) and (b) Heart rate averaged for baseline, preparation, stressor, and recovery phase of the Trier Social Stress Test for groups (TSST-G) for the three study groups: Internet-based Stress Management (IBSM), Progressive Muscle Relaxation (PMR) and controls. Dots and bars represent mean +/− s.e.; * p < .05.

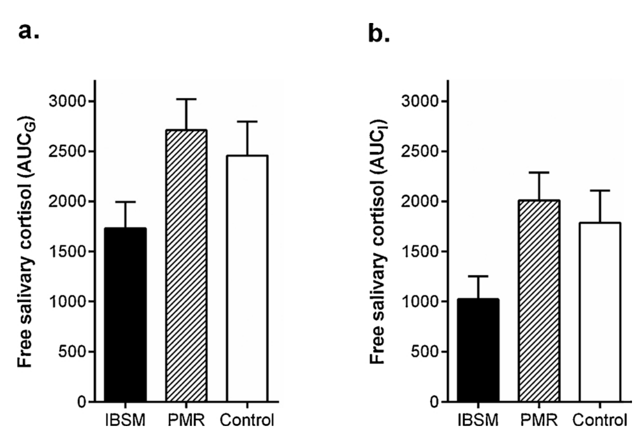

Fig. 3. (a) Area under the curve with respect to ground (AUC_G) and (b) area under the curve with respect to the increase (AUC_I) of the free cortisol response to the TSST-G compared between the three study groups. Bars represent mean +/− s.e.

between the IBSM and PMR training groups (t[30] = 2.72; p = .011; Cohen's d = 0.96), indicating a significantly lower salivary cortisol response to the TSST-G in the IBSM training group – see Fig. 3a. The AUC_G (area under the curve with respect to ground) as an index of total cortisol release showed a trend level effect of group (F[2,46] = 2.70;

$p = .078$; $\eta^2_{part} = .11$), with the IBSM group exhibiting a lower response than the PMR group ($t[30] = 2.42$; $p = .022$; Cohen's $d = 0.85$) – see Fig. 3b.

3.4. Heart rate response

For the heart rate response, we calculated a repeated-measure ANOVA to test for group differences in the cardiac response to the TSST-G's different phases (see Fig. 2b). We detected a significant main effect of phase ($F[3,114] = 50.96$; $p < .001$; $\eta^2_{part} = .57$) and a trend towards a phase-by-group interaction ($F[6,114] = 1.86$; $p = .094$; $\eta^2_{part} = .09$), reflecting the highest response in the control group and the weakest in the IBSM group. The main effect of group was not significant ($F[2,38] = 0.60$; $p = .553$).

4. Discussion

The present study compared a 6-week IBSM program to an active control group receiving audio lessons on relaxation (PMR) via the internet for 6 weeks and a waiting list control group with regard to the effectiveness in reducing psychobiological stress reactions to a standardized laboratory stressor. Participants in the IBSM training and the relaxation training reported significant reductions in perceived everyday stress over the study course. Moreover, our study revealed a reduced cortisol response in the stress management group and a trend towards lower cardiovascular reactivity to an acute psychosocial stressor. The groups did not differ in their subjective stress response to the TSST-G. Due to the fact that the acute responses of physiological and psychological stress axes do not necessarily correlate closely (Campbell and Ehlert, 2011), it might be an interesting question for future studies to reveal the mechanisms and mediating variables behind this dissociation.

The IBSM group's lower salivary cortisol output during the experiment compared to the PMR group suggests that the cognitive-behavioral intervention influenced cognitive and affective processing of the stressful situation. One could speculate that the stress management training group employed techniques successfully during the TSST-G, which they had learned and practiced during stress management training. For example, cognitive emotion regulation techniques in terms of cognitive reappraisal have been shown to dampen neural activity in the limbic system (Buhle et al., 2014) and might thus have attenuated HPA-axis activity resulting in a diminished cortisol response over the course of the TSST-G. In contrast, the relaxation techniques the relaxation group learned and practiced might not have been useful in the TSST-G setting, or they might even have raised stress responses in a setting with no feedback from the TSST-G panel. However, given that both groups reported similar reductions in perceived everyday stress, relaxation might have been a useful regenerative technique to reduce the psychological sequelae of everyday stress outside the acute stressful situation. As everyday stress and the acute stress induced by means of the TSST-G apparently differ in terms of intensity and duration, it is possible that relaxation techniques were helpful up to a certain intensity level or duration. Once a certain stress level was reached (in the TSST-G), subjects in the stress management group appear to have recruited more efficient stress-reducing strategies. However, as we did not assess the cognitive techniques the participants employed in the present experiment, our interpretation remains preliminary. Future studies could explicitly investigate whether specific cognitive strategies are more effective than others and mediate the effect of cognitive-behavioral stress management on the reactivity to acute stress.

Another possible interpretation implies a more general effect. Previous studies suggest that appraisal is associated with the physiological response to the TSST (Dickerson and Kemeny, 2004; Denson et al., 2009) and can be modified by stress management training (e.g., Gaab et al., 2003). As primary and secondary appraisal is targeted by several modules of the IBSM training (see Supplementary Table S1), participants might have perceived the entire experimental session as less threatening (primary appraisal) and/or might have perceived themselves as acting more efficiently (secondary appraisal), which could have resulted in attenuated cortisol output. This interpretation is supported by the fact that the groups' cortisol levels did not differ before the training, but revealed an overall difference during the experimental session after the intervention.

Our results regarding the IBSM group's attenuated cortisol response are in line with earlier face-to-face stress management training studies (Gaab et al., 2003; Storch et al., 2007). These studies additionally reported effects on the subjective level, suggesting that the effects might be more pronounced after a face-to-face intervention with professional guidance. It might be an interesting question for future investigators to explore the role of face-to-face contact and the additional effect of professional guidance within the same experiment.

It should be noted that we excluded women from participation in this study because of the well-known modulating effect of the menstrual cycle and oral contraceptives on the free salivary cortisol response to the TSST (Kirschbaum et al., 1999). Future studies clearly need to extend or differentiate the present findings by including women, thoroughly controlling for the menstrual cycle and use of oral contraceptives. To this end, replication with larger and representative sample sizes are needed.

In addition, as habituation to the stressor has been documented in previous studies (Schommer et al., 2003) the TSST-G was not used repeatedly. However, there is also evidence that repeated exposure over a 10-week interval does not result in substantial habituation (Petrowski et al., 2012). A repeated-measure pre-post design might have been more sensitive to capture subtle changes in stress responsiveness associated with the experimental condition. Hence, our conclusion would have differed slightly: training effects in terms of pre-post differences would have reflected differences in habituation to a previously encountered stressor rather than differences in the responsivity to a novel situation. Furthermore, future studies could employ ambulatory-assessment strategies to capture treatment effects on HPA-axis and psychological stress in every-day life.

As the present study included a session in the laboratory and thus comprised at least one personal contact with the experimenter, the present results should be generalized to other contexts with caution. Especially in conjunction with the uncontrolled dissemination of an internet-based stress management training, participants' adherence and compliance could be lower and thus psychological and physiological effects smaller. For the present study, one could assume that although the training was self-administered and not guided by a health professional, participants might have been highly motivated to finish the program, as reflected by the relatively low drop-out rate of about 18 percent during the training phase. Studies that follow realistic dissemination strategies for internet-based interventions are thus needed to replicate the present findings and be generalized to a realistic dissemination context.

Finally, the present results focus on short term effects. Although previous studies suggest that post-training attenuation of cortisol responses to a psychosocial stress remain stable over 4 months (Hammerfald et al., 2006), the stability of the effects we observed following internet-based stress management remains to be demonstrated in future studies.

In light of our small sample size and the limited statistical power the present study should be read as a pilot study, the results should be interpreted with caution and replicated with larger sample sizes. Nevertheless, the present study is the first to demonstrate that a six-week cognitive-behavioral internet-based stress management training reduces acute free salivary cortisol responses to a standardized stressor in comparison to a relaxation control group. In addition, our results suggest that both relaxation and cognitive-behavioral stress management reduce the self-reported everyday stress level in healthy working men.

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GD, TS, MH designed the study, TS conducted data collection, GD and BvD analyzed the data, all authors contributed to the interpretation of the results and writing of the manuscript. All authors have approved the final version of the article.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.psyneuen.2018.12.001.

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