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ORIGINAL ARTICLE

The effects of perceived chronic stress on the fMRI correlates of attentional control in women managers

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Abstract

The aims of the current study were to examine differences in brain responses to cognitive control in stressed and non-stressed women managers. Stress complaints are highly prevalent among active workers and play an important role in women managers mental health and cognitive functioning. Psychosocial stress has been associated with differential executive functions in this population, but little is known about the neural correlates underlying such differences. We examined brain responses of a particular group of workers that has been proposed to have a different response to stress as a function of their status (i.e., managers). Stressed ($n = 19$) and non-stressed women managers ($n = 21$) were scanned using functional magnetic resonance imaging (fMRI) during the performance of a cognitively demanding task. We used the Stroop color-word task to compare neural activation associated with the suppression of a predominant response tendency (i.e., word reading) and the initiation of an appropriate behavior alternative (i.e., naming word color). Despite similar behavioral performances, stressed managers exhibited increased activation in the occipital cortex during response inhibition. No regions were more activated in the non-stressed relative to the stressed group. This finding of greater activation has been interpreted as compensatory brain response to maintain performance in front of cognitive challenge.

Keywords Stress · Women managers · Stroop task · fMRI · Attention

Introduction

Stress complaints in the job context and its impact on mental health have been extensively investigated in frontline workforce employees (Colligan and Higgins 2005; Wellens and Smith 2007). A relative less number of studies however have been focused in examining stress-related symptoms in managers or leaders. Managers have been considered a high-risk occupational group mainly because of their psychological demands and massive quantitative workloads (Brett and Stroh 2003). However, it has been proposed that the particular working conditions of the managers, including high decision latitude (i.e., they are giving power over the people) and high control over their work (e.g., the possibility to schedule their time and work duties) may compensate for their high demands (Bernin and Theorell 2001). This advantage in exerting control may confer managers a different pattern of coping with stressors (Bernin et al. 2003). Therefore, one strategy for enhancing our understanding on this possible differential psychological stress response in managers is the investigation of whether chronic stress impacts their brain function related to cognitive control functions, which plays a crucial role in dealing with stress.

So far, evidence for an unexpected physiological stress response in managers is scarce and inconclusive. One study that examined 58 male managers from Swedish companies evaluated a series of exploratory correlations between blood parameters and psychological indexes (Bernin et al. 2001). Some of the results of this study showed that good psychosocial support was associated with low LDL, and bureaucracy was associated with high LDL and low HDL levels. However, inconsistent and contradictory associations were found

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between these psychological variables and serum cortisol. Alternatively, the suggestion that workers in hierarchical higher positions have a differential stress response is corroborated by a naturalistic study showing that a sample of real leaders responsible for managing others (i.e., military officers, government officials) presented lower levels of salivary cortisol and reports of anxiety compared to a group of nonleaders (Sherman et al. 2012). Therefore, these mixed preliminary results indicate the need of further examination of the possible differential stress response in this work population.

One possible mechanism that may be implicated in a distinctive stress response in managers is their cognitive control abilities. Cognitive control, also called as executive functions, is defined as a set of cognitive processes, such as selective attention, inhibitory control, and task-shifting responsible for controlling and regulating behaviors and emotions (Miller and Cohen 2001). The constituent processes of cognitive control have been associated with the function of different portions of the prefrontal cortex, such as the dorsal anterior cingulate cortex for response inhibition, and the dorsolateral prefrontal cortex for attentional control (Peterson et al. 1999; Shields et al. 2016). The implication of these cognitive constructs and their neural substrates in coping abilities and stress regulation in neuropsychiatric disorders is well established (Lupien et al. 2007; McEwen 2007; Shields et al. 2016). However, very few studies have investigated the effects of subjectively perceived stress on the neural correlates of cognitive control processes. Among the general population, high levels of perceived occupational stress were associated with reduced brain activation in prefrontal regions during a verbal fluency task, which is an executive function task tapping attentional updating ability (Chou et al. 2016). On the other hand, another study reported that perceived stress scores were not associated with any differences in working memory and inhibition related activations (Archer et al. 2017). To the best of our knowledge, no previous study has investigated brain responses to perceived stress in the working population of managers.

To address this gap in knowledge, the current study used functional magnetic resonance imaging (fMRI) to examine differences in brain responses to cognitive control in stressed and non-stressed women managers. We used the Stroop word-color task, a widespread measure of attentional control and response inhibition, to compare neural activation associated with the suppression of a predominant response tendency (i.e., word reading) and the initiation of an appropriate behavior alternative (i.e., naming word color). Given the lack of research using fMRI to investigate subjective stress in professional leaders/managers, functional MRI hypotheses were informed by studies on perceived stress in the general population. We hypothesized that stressed managers would show increased activation on the response inhibition condition, which is consistent with a compensatory response to maintain performance.

Method

Participants

Women managers who lived in Sao Paulo city, with stress complaints aged between 25 and 60 years were recruited from a cosmetics company interested in the evaluation of their stress levels and well-being. Most of them are relationship managers and had dozens of individuals under their responsibility. All women were right-handed, had at least 15 years of education, and signed a written informed consent prior to their inclusion in the study.

Participants were screened by a physician and only individuals without serious physical or psychological health conditions were selected. They were characterized as non-stressed ($n = 19$) and stressed ($n = 21$) according to the Lipp Inventory of Stress Symptoms for Adults (Lipp 2000), in resistance ($n = 17$) and quasi exhaustion ($n = 4$) phases of stress. We excluded participants with claustrophobia, tremor, or dystonia, or who met any contraindication criteria for MRI such as heart pacemaker use, cochlear implants, and pregnancy.

The study was approved by the local ethics committee (CAAE 38662314.8.0000.0071).

Instruments

Lipp's Stress Symptoms Inventory for Adults (LSSI) Three sections refer to the four phases of stress (alert, resistance, quasi exhaustion, and exhaustion). The *alert phase* is regarded as the positive stress phase. In this phase, stress is regarded as necessary for survival and is not recognized as unhealthy. The second phase is *resistance.* In this phase, the individual tries to deal with the stressors in order to maintain homeostasis. If the stressors persist, there is a break of resistance and the individual goes into the *quasi exhaustion* phase. At this phase, the individual becomes sick and there is not stress relief even with removal of the stressors. The last phase is *exhaustion*, when serious illness like heart attack, depression, and stroke can occur (Lipp 2000).

Perceived Stress Scale The Perceived Stress Scale (PSS-10) was designed to measure the degree to which situations in one's life are appraised as stressfull (Cohen et al. 1983). The PSS has 10 questions with answer choices ranging from 0 to 4 (ranging from never to very often) (Luft et al. 2007). The questions in this scale ask about feelings and thoughts during the last month.

Mindful Attention Awareness Scale The Mindful Attention Awareness Scale (MAAS) uses a scale from 1 to 6 indicating how frequently or infrequently individuals currently have each experience. It is composed of 15 questions that measure level of attention and awareness in everyday situations.

Table 1 Characteristics of the stressed and non-stressed participants

	Stressed ($n = 21$)	Non-stressed ($n = 19$)	p value	t
Age	43 (1.93)	42 (1.92)	0.513	− 0.660
PSS	24.24 (1.40)	14.89 (1.02)	< 0.001	− 5.274
MAAS	49.48 (2.33)	57.21 (2.79)	0.039	2.143
BDI	17.67 (1.92)	7.68 (1.07)	< 0.001	− 4.412
BAI	12.90 (1.61)	4.48 (0.71)	< 0.001	− 4.623

Results are expressed as mean (standard error)

Higher scores reflect higher levels of dispositional mindfulness (Brown and Ryan 2003).

Beck Depression Inventory The Beck Depression Inventory (BDI) is a 21-item, self-report rating inventory that measures characteristic attitudes and symptoms of depression (Beck et al. 1961).

Beck Anxiety Inventory The Beck Anxiety Inventory (BDI) is a brief, criteria-referenced assessment for measuring anxiety severity in the past month (Cunha 2001).

fMRI paradigm

Participants were familiarized with the task before fMRI sessions. They were scanned with fMRI while performing the Stroop word-color task (SWCT). SWCT is a classical task used to study attention and inhibition and has been adapted for fMRI as an interesting paradigm for the understanding of cognitive control mechanisms (Peterson et al. 1999). The participants were instructed to communicate the font color (blue, red, or green) of single words presented in three conditions: congruent (color and word are the same color, e.g., the word “BLUE” in blue font); neutral (words unrelated to any color), and incongruent (color and word are different, e.g., the word “BLUE” in green font) by pressing one of three buttons on the response box in the participant’s right hand. Each word stimulus was shown for 1 s. These stimuli were interspersed by the appearance of a fixation cross for 1 s. Each condition was presented 10 times per run in blocks of 15 trials in the sequence *congruent-neutral-incongruent.*

Table 2 Comparison between groups and Stroop condition (congruent versus incongruent)

		Stressed ($n = 21$)	Non-stressed ($n = 19$)	p value
Correct answers	Congruent	9.83 (0.137)	10.22 (0.136)	0.050
	Incongruent	9.52 (0.139)	9.76 (0.219)	0.363
Reaction time (ms)	Congruent	823.71 (24.215)	863.71 (36.447)	0.358
	Incongruent	834.95 (25.237)	875.60 (37.759)	0.368
	Stroop effect	1.01 (0.010)	1.01 (0.006)	0.965

Results are expressed as mean (standard error)

Image acquisition

Image acquisition (3.0T MR System-Siemens Tim Trio, 12ch head coil), visual stimuli presentation (via projector), and subject response were synchronized (NNL systems, www.nordicneurolab.com). The fMRI acquisition was based on T2*-weighted echo planar (EPI) images for the whole brain. The acquisition parameters were EPI GRE T2–BOLD PACE: TR = 2000 ms, TE = 30 ms, 32 slices, 3 mm of slice thickness, 0.5 mm of interslice gap, FOV = 210 mm, matrix 64×64 (isotropic voxels), with 150 volumes (duration 5 min 6 s), discarding the first 4 volumes related to the signal decay, necessary for the MR signal to reach steady state. During the same scanning session, a T1-weighted sagittal high-resolution structural image (voxel size, 1 mm^3) with 192 slices was acquired for co-registration with the fMRI data and to exclude brain pathology.

Image processing

Data processing and statistical analyses were conducted using FSL (www.fmrib.ox.ac.uk/fsl/; Smith et al. 2004). The volumes were processed by movement correction (MCFLIRT), high-pass filter cutoff (50 s), spatial smoothing (FWHM = 5 mm), and spatial normalization to standard space (affine, 12 DoF). The activation maps were produced using the general linear model (GLM) using FILM routines, which is based on semi-parametric estimation of residuals autocorrelation (Woolrich et al. 2001). We determined brain regions more active in the incongruent relative to the congruent tasks in non-stressed compared with stressed women. All the statistical images were thresholded using Gaussian random field-based cluster inference with a threshold of $Z > 2.3$ at the voxel level and a corrected cluster significance threshold of $p < 0.05$.

Results

Sample characteristics

Table 1 shows participant demographic characteristics. There were no significant differences in age between groups. The stressed group presented a higher score of perceived stress, depression, and anxiety symptoms. On the other hand, the non-stressed group presented higher scores of attention and awareness.

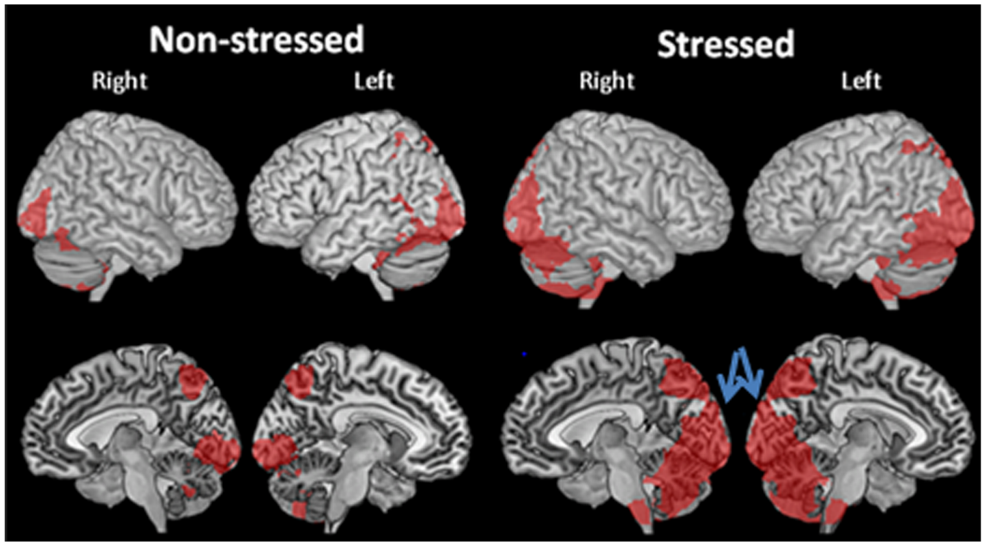

Fig. 1 Brain activation in the non-stressed and stressed group. Clusters exhibiting significant increased activation for the incongruent relative to the congruent condition in each group. The blue arrow points to cluster in which the stressed group presented significant higher activation compared to the non-stressed group (peak voxel—intracalcarine cortex)

Behavioral data

Behavioral data of the Stroop task can be found in Table 2. There were no between-group differences for number of correct responses and reaction time in both congruent (Stroop C) and incongruent task conditions (Stroop I). There were also no differences between groups in the Stroop interference effect (the requirement for conflict resolution makes the incongruent task more difficult and slower than the congruent task) (Kozasa et al. 2012).

fMRI data

Brain activation related to the Stroop task. Brain areas exhibiting increased activation for the incongruent compared to the congruent condition in the stressed and non-stressed group are described in Fig. 1. The non-stressed group showed activation in a number of regions known for their implication in cognitive control, visual processing, and conflict monitoring, including the middle frontal gyrus, inferior frontal gyrus, and precuneus and anterior cingulate gyrus (Table 3) (Laird et al. 2005). Similar activation regions were observed in the stressed group, although a more bilateral pattern of activation was observed (Table 4).

To examine differences in brain activation between groups, we compared the areas of activation that differed between the two groups. No differences were observed in prefrontal regions classically related to attentional control. The chronically stressed group showed more activation in a cluster which the peak voxel is the intracalcarine cortex (MNI coordinate $x = 26$, $y = -70$, $z = 14$; $Z = 3.48$; cluster p value corrected = 0.00758) (Fig. 1, blue arrow; Fig. 2).

Discussion

In this study, we report results from what we believe to be the first fMRI study to investigate the effects of perceived chronic stress on the neural correlates of cognitive control abilities in a sample of women working as managers. Our main aim was to compare the two groups on cerebral activation related to conflict resolution and response inhibition during a Stroop color-

Table 3 Statistical information of significant clusters during Stroop task for the incongruent relative to the congruent condition in the non-stressed group

				MNI coordinates				
Cluster	Region	Side	Z max	x	y	z	Size	Cluster p value
1	Supplementary motor cortex	L	4.54	− 10	− 6	58	8033	$p < 0.001$
	Precentral gyrus	L	4.32	− 48	− 4	48		
	Inferior frontal gyrus	L	3.73	− 46	12	22		
	Middle frontal gyrus	L	3.69	− 40	− 2	58		
2	Superior parietal lobe	L	5.4	− 30	− 50	46	21,247	$p < 0.001$
	Occipital pole	L	4.75	− 26	− 94	0		
	Cerebellum	R	4.22	16	− 56	− 52		
	Lateral occipital cortex	L	4.15	− 32	− 84	8		

Standard brains from the Montreal Neurological Institute (MNI)

Table 4 Statistical information of significant clusters during Stroop task for the incongruent relative to the congruent condition in the stressed group

				MNI coordinates				
Cluster	Region	Side	*Z* max	*x*	*y*	*z*	Size	Cluster *p* value
1	Inferior frontal gyrus	L	4.55	−40	10	26	10,073	$p < 0.001$
	Insular cortex	R	4.46	32	14	8		
	Precentral gyrus	L	4.23	−32	0	28		
	Caudate	L	3.94	−16	6	18		
	Putamen	R	3.93	26	−6	12		
2	Inferior occipital cortex	L	5.41	−28	−90	6	46,206	$p < 0.001$
	Cerebellum	L	5.13	−18	−68	−16		
	Lateral occipital cortex	L	5.09	−28	−82	12		

Standard brains from the Montreal Neurological Institute (MNI)

word task. Our hypotheses were that the stressed managers would show increased cerebral responses in regions of the cognitive control network representing compensatory activation in the presence of preserved performance in the task. This hypothesis was partially supported, as compensatory activity was not observed in anterior regions of the attentional network, such as the prefrontal and cingulate cortices, but it was in a portion of the occipital cortex.

Regarding the psychological characterization of the groups, we found that the stressed group, when compared with non-stressed, exhibited higher PSS score and presented mild symptoms of anxiety and depression, both characteristics that are known to occur alongside stress (Hammen 2005; Liu and Alloy 2010).

We first found that both groups, stressed and non-stressed, were able to recruit brain regions previously associated with the performance of the Stroop task, including the middle frontal gyrus, inferior frontal gyrus, anterior cingulate, striatum, supplementary motor cortex, and occipital cortex. These regions are well-known for their role in detection of conflict and response selection (Laird et al. 2005). Thus, it appears that perceived chronic stress in managers did not disrupt their ability to engage typical brain regions for the performance of a cognitive control task.

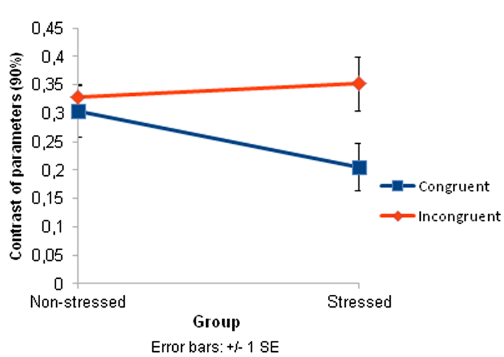

Fig. 2 Contrasts of parameters in the intracalcarine cortex. Error bars ± 1 SE (standard error)

Next, we identified that there were no group differences in the core anterior regions of the Stroop network, mainly in the prefrontal cortex. This is consistent with data from a previous study showing no correlation between perceived stress complaints and fMRI responses during a working memory task (Archer et al. 2017). However, the observed findings contrast with previous research showing differences in fMRI responses to executive control in samples of workers with burnout and stress-related exhaustion (de Andrade et al. 2016; Gavelin et al. 2017). It is possible that this inconsistency among studies may be related to the severity and duration of the stress-related symptoms, although differences in task demands and characteristics should not be ruled out.

The stressed group, however, showed increased brain activation compared to the non-stressed group in a portion of the occipital cortex and the intracalcarine cortex. The recruitment of posterior regions, in contrast to anterior regions, in Stroop tasks has been previously shown to be influenced by task-irrelevant information (Banich et al. 2000). For example, the performance of the Stroop word-color task during the incongruent condition requires the inhibition of task-inappropriate response of word reading, the selective attention to color, and the monitor of the response conflict between the possible responses of color naming and word reading (MacLeod 1991). As Stroop-related activity is thought to reflect a greater demand on cognitive control mechanisms during incongruent relative to congruent trials, a hyperactivation of this region may be thus interpreted as indicating increased compensatory cognitive control mechanisms to inhibit the word information in the stressed group.

Besides the neural correlates, repercussions such as health problems, performance decrease, and negative mood have also been reported. A previous study shows that health problems like high blood pressure, depression, and bronchitis are more frequent in the work stress group. The use of medication and visits to doctor are more common in the stressed group. And this group presents more negative mood (Smith et al. 2000).

Previous studies have already investigated the brain correlates of long-term occupational stress, although with different imaging modalities. For example, reductions in the volumes of the anterior cingulate cortex, dorsolateral prefrontal cortex, caudate, and putamen were reported in this population. These findings agree with results observed in patients with post-traumatic stress disorder (Blix et al. 2013). Although there are important differences between the samples examined by these previous studies and the one examined in our current study, one can speculate that the compensatory functional activation observed here in the stressed group may be a precursor of an anatomical volumetric reduction due to cumulative effects of chronic stress over time. Further longitudinal studies combining different imaging techniques are required to better understand the implications of our findings on the brain correlates of chronic stress in workers.

The results of our study should be interpreted in the context of some important limitations. The criteria used to classify the groups as a function of stress was performed based on cross-sectional self-reported data, and so it is not possible to completely rule out the possibility that participants belong to different subgroups at different points of a stress severity continuum. Although we did not have a complete characterization of the cortisol levels of the participants due to excessive missing data, the available results showing no differences between groups may suggest the presence of not severe stress-related conditions. The evaluation was performed outside the workplace. Finally, the obtained results cannot be generalized with confidence to the entire population of employees, since we used convenience strategies to recruit participants and they were only women and managers. Therefore, more research on this topic needs to be undertaken in order to clearly understand the effects of perceived stress on brain function of cognitive control in managers.

In summary, the results of our study show that despite similar behavioral performances, stressed managers exhibited subtle differences in brain activation of response inhibition, specifically in the occipital cortex, that may be interpreted as compensatory brain response to maintain performance in front of cognitive challenge. Future studies are required to investigate the translational significance of our results for the management of stress in the work environment.

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Compliance with ethical standards

Conflict of interests The authors declare that they have no conflicts of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethics committee approval number 38662314.8.0000.007.

Informed consent Informed consent was obtained from all individual participants included in the study.

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