Stress and Managers Performance: Age-Related Changes in Psychophysiological Reactions to Cognitive Load

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Abstract. Work ability of elderly managers may decrease probably due to decreased cognitive flexibility. Moreover, cardiovascular reactivity to changing task demands might be less efficient in elderly. Younger (36–45) and elderly (49–60) German managers had to perform a switching task when they had to switch continuously between different rules of information processing or to use the same rule. Although the performance did not differ between groups, the SBP was higher and the HRV was lower in elderly. In addition, elderly showed an increased rigidity of cardiovascular functioning against changing task demands.

1 Introduction

Managers have been confronting with complex and continuously changing tasks requiring cognitive flexibility and effort to maintain a constant level of job performance during a long time period. However, these professionally critical aspects of manager's job were not sufficiently investigated up to now. Performance of a cognitive task requires effort which can be either computational or compensatory [1]. The computational effort is directly related to task complexity in terms of resources allocating to a task under normal conditions, when there is no need to set new goals and adopt new working strategies. On the contrary, the compensatory effort becomes necessarily when an individual is acting under suboptimal conditions (i.e. stress, fatigue etc.) and trying to keep a constant performance level. Both effort types may be distinguished by cardiovascular changes that have been considered as reliable indicators of mental workload and effort [2]. The performance of a cognitive task as compared to rest is usually accompanied by an increase of heart rate (HR), blood pressure (BP) and a decrease of heart rate variability (HRV). The more complex the task (e.g. the more mental operations it requires) the greater the changes of HR, BP and HRV. Decrease of task complexity lead to opposite changes of these parameters. Such flexible adaptation of the cardiovascular system to task demands may be seen as physiological index of computational effort that typically accompanied by high and stable performance level. In case the cardiovascular parameters and performance dissociate a suboptimal regulation may be assumed when a compensatory effort comes into play to prevent performance decrement. Another index of this effort type would be a rigidity of cardiovascular functioning resulting in reduced variation of cardiovascular parameters with task complexity; e.g. when HRV remains decreased in an easy task or when a slow post-task recovery of HRV and HR is observed.

Incremental ageing of work population in Western Europe during last two decades has been resulted in a prolonged employment among managers as well. However, systematic studies of cardiovascular reactions to mental workload in elderly workers are still scarce and, to our knowledge, absent in managers. Executive control processes underlying cognitive flexibility have been found to be quite susceptible to age [3]. Additionally, the age-related dysregulation of cardiovascular functions has been usually observed [4]. Therefore, resources to perform an “executive” task are assumed to be shortened in elderly who should exert a compensatory effort to maintain performance. Keeping this in mind, one might expect the performance decrement as well as inefficient cardiovascular adaptation to changing task demands in elderly manager.

The task switching paradigm [5] belongs to a family of “executive” tasks and can be used to investigate cognitive flexibility that is critical for manager's job. During the task participants have to change the processing rules when the information context is changed. The change results usually in a lengthening of reaction time and worsening of accuracy usually defined as switching costs (SK). The global SK are computed as difference between performance in a task containing an unique processing rule (single task) and a task when the switching of rules is required (switch task). The local SK are computed within the switch task as the difference between trials when the processing rule remains the same (repeat trials) and trials when the rule has to be changed (switch trials). The task switching involves control mechanisms providing the selection of a relevant task set and the inhibition of an irrelevant ones as well as continuous updating of current task requirements in working memory. These processes are thought to be a part of executive functioning that is sub-served by the medial and dorsolateral prefrontal cortex of the brain [6]. Based on the previous data that demonstrated larger SK in elderly than younger adults [7], [8] we expected to replicate the effect in the present study. Alternatively, elderly managers might be more experienced in handling with alternating tasks and thereby may outperform their younger colleagues.

In sum, in the present study switch tasks differed in complexity were imposed and cardiovascular parameters were registered to examine the psychological and physiological adaptation of younger and elderly managers to changing task demands.

2 Method

2.1 Participants

Participants in the present study were seventeen German managers of a steel factory. They were divided by median-split (47 years) into younger (8 men, 36-45 years) and elderly (8 men, 49-60 years) groups while the participant with the median age was excluded from the analysis. Participants were right-handed, had normal hearing, normal or corrected vision and no heart diseases. The participation in the study was voluntary, as the study was presented as a part of a routine clinical examination. All participants gave their informed consent for participation.

2.2 Task

The switch task employed was modified from the alternating-run paradigm [5] participants had to alternate regularly every two trials between task A and B (i.e. AABBAABB etc.). The participants had to compare digits 2, 3, 4, 6, 7, 8 with the cue (digit “5”) either numerically (task A) or by font size (task B). If the cue appeared in white, the participants had to decide whether the following digit was numerically less or more than 5 (left response key – less than 5, right response key - more than 5). If the cue appeared in black, the comparison by font size was required (left response key - smaller than 5, right response key – larger than 5). Each trial started with a white fixation cross (15 x 15 mm) remained in the centre of the screen for 1000 ms followed by a digit “5” (8mm width x 15mm high) for 300 ms depicted in white or black and framed in green circle (diam. 25 mm). After cue off-set the cue-stimulus interval (CSI) of 500 ms was presented till an imperative stimulus appeared for 200 ms. The imperative stimuli were digits 2, 3, 4, 6, 7, 8, presented in small (7 x 10 mm) or large (12 x 18 mm) font size and equally often in each task. The distance to the screen was 70 cm. One half of the imperative stimuli were compatible and another half was incompatible with the response. On compatible trials attributes of both tasks were mapped onto the same response key, while on incompatible trials onto the different response keys. The reaction time was measured within 4000 ms from the onset of an imperative stimulus. If the correct response was made within the response window, next trial was started. The false response was followed by a delay of 200 ms and a 500 Hz tone of 100 ms duration. Omissions were indicated by a 3000 Hz tone of 100 ms duration presented immediately after the end of the response window. In addition to the switch task, the task A (numeric comparison) and task B (size comparison) were presented separately while the same timing features were used in both single tasks. The single tasks consisted of 48 trials and the switch task consisted of 192 trials (50% switch and 50% repeat trials).

2.3 Procedure

Participants were tested individually in a clinical examination room of the steel factory. The experiment began with the measure of the BD and HR via upper arm cuff followed by 3 min beat-to-beat BD registration in rest condition. Thereafter participants were presented three training tasks: task A (12 trials), task B (12 trials) and, finally, switch task (32 trials). The sequence of training tasks was equal for all participants. In the main session the task sequence was balanced across participants. The beat-to-beat BD was registered throughout experiment. Finally, the post-task beat-to-beat BD during 3 min was registered followed by rest measure of the BD and HR via upper arm cuff.

2.4 Cardiovascular Measures

At the start and the end of the experiment the BD and HR were registered via cuff from left upper arm by an electronic device Boso Medicus (Bosch+Sohn LTD, Germany). During the experiment beat-to-beat BP was registered continuously from left middle finger using a Finapres device (Ohmeda, USA). The RR interval was computed off-line as the interval between two successive BP maxima. As a HRV

measure the RMSSD index was computed. Data were processed by the trigonometric regressive spectral analysis (TRS, [9]) based on the Cosinor method and can be used to beat-to-beat recordings of cardio-vascular variables like RR interval, systolic blood pressure, stroke volume etc. The advantage of such analysis is that data can be assessed in non-equidistant steps (in contrast to Fourier transformation) and it also minimises practical problems occurring due to insufficient frequency resolution, aliasing and can assess data segments of varying length. TRS detects underlying rhythms using the following equation: $F = \sum (\text{variable}(t_i) - \text{Reg}(t_i))^2 \Rightarrow \text{Minimum}$. In this function, non-equidistant data (i.e. RR interval, systolic or diastolic blood pressure and others) is used and parameters of amplitude (a), phase shift (ϕ) and frequency (ω) are represented as a trigonometric function in which $\text{Reg}(t_i) = a \cdot \sin(\omega t_i + \phi_i)$. Using regression analysis, amplitude, frequency and phase shift can now be estimated using partial differential quotients (i.e., $\delta F / \delta a$; $\delta F / \delta \omega$; and, $\delta F / \delta \phi$).

2.5 Data Analysis

Each response was scored as correct if the appropriate key had been pressed in a time window lasting from 200 to 4000 ms after stimulus onset. The 200 ms limit was chosen to avoid counting any premature responses.

To analyse the global switch costs the error rate (% Err) and the reaction time (RT) for correct responses in switch task were compared with those in single tasks. They were subjected to an ANOVA with Task (task A, task B, switch) as a within-subject factor and Age (younger vs. elderly) as a between-subject factor. To analyse the local switch costs %Err and RT for correct responses for switch and repeat trials separately were subjected to an ANOVA with Trial (switch vs. repeat) as a within-subject factor and Age (younger vs. elderly) as a between-subject factor.

To examine how cardiovascular parameters varied with task demands SBP, DBP, HR, HRV, were subjected to ANOVAs with Condition (pre-test, task A, task B, switch task, post-test) as a within-subject factor and Age (younger vs. elderly) as a between-subject factor. Additional ANOVAs with the same within-subject factor was performed for younger and elderly group separately in order to test Condition effect within each group. The SBP and DBP measured via upper arm cuff were analyzed by ANOVA with Condition (pre-test, post-test) as a within-subject factor and Age (younger vs. elderly) as a between-subject factor.

Greenhouse-Geisser epsilon was applied to correct a possible lack of sphericity. Simple contrasts were used to clarify effects across factor levels. ANOVAs were performed by SPSS for Windows 14.0.

3 Results

3.1 Behavioural Data

Enhanced global switch cost in terms of longer RT and higher %Err were obtained in switch as compared to single tasks (Task, RT: ($F(2,28) = 15.982$, $p = .001$; Task, %Err: ($F(2,28) = 33.88$, $p < .000$). Analysis of contrasts revealed the longer RT and higher %Err in the switch task than in task A while both performance measures were

the lowest in the task B. A marginally significant effect of Age ($F(2,28) = 4.055$, $p = .064$) was due to higher %Err in elderly than younger. Post-hoc tests revealed higher %Err in elderly than in younger in switch task and in task A (numeric comparison) only. No significant effects on local switch costs in terms of RT or %Err were found.

3.2 Cardiovascular Data

A significant main effect of Condition ($F(4,56) = 8.887$, $p = .001$) indicated an enhanced HR in switch task as compared to both single tasks (Fig. 1).

Fig. 1. Heart rate (HR, beat per min) as a function of experimental condition and age: 1-pre-task rest, 2- switch task, 3-task A (numeric), 4- task B (size), 5- post-task rest

Fig. 2. Heart rate variability (HRV) as a function of experimental condition and age: 1-pre-task rest, 2- switch task, 3-task A (numeric), 4- task B (size), 5- post-task rest

In turn, the HR in single tasks was higher than in rest conditions and did not differ between single tasks. An Age by Condition interaction was non-significant. However, on the Fig.1 a tendency to increased HR in elderly in task B was clearly seen. The within-subject contrasts of switch task against task B revealed a significant Age by Condition interaction ($F(1,14) = 6.189$, $p = .014$) that was due to increase of HR in elderly in the task B only.

A significant main effect of Condition ($F(4,56) = 10.351$, $p < .000$) was attributed to a reduced HRV in the switch task as compared to both single tasks in which the HRV was lower as in rest conditions; the HRV did not differ between single tasks (Fig.2). An Age by Condition interaction ($F(1,14) = 2.25$, $p = .051$) was due to the fact that HRV varied with experimental conditions in younger group to a greater extent than in elderly one. Separate ANOVAS revealed a clear-cut Condition effect in younger (Task: $F(4,28) = 9.875$, $p = .004$) but not in elderly (Task: $F(4,28) = 1.81$, $p = .216$) group.

Fig. 3. Systolic (SBP, mmHg) and diastolic (DBP, mmHg) blood pressure and as a function of experimental condition and age: 1- pre-task rest, 2- switch task, 3- task A (numeric), 4- task B (size), 5- post-task rest

Both SPB and DBP were higher during three cognitive task than in both rest conditions while no difference among three tasks was obtained (SBP: $F(4,56) = 20.579$, $p < .000$; DBP: $F(4,56) = 20.579$, $p < .000$, Fig. 3). The SBP was generally higher in elderly (Age: $F(1,14) = 6.337$, $p = .025$).

The HR measured via upper arm cuff revealed a marginally significant Condition by Age interaction ($F(1,14) = 4.047$, $p = .064$, Fig. 4). Younger had higher HR than elderly at the start, whereas the opposite effect at the end was seen (Fig.4).

Fig. 4. Heart rate (beat per min) measured by common method as a function of experimental condition and age: 1-pre-task rest, 2-post-task rest

4 Discussion

In the present study age-related decrease of cognitive flexibility and physiological adaptation to changing task demands among managers were assumed. In the switch task we did not find age differences in reaction time, while only moderate accuracy decrement in elderly was seen. Two possible explanations may be taken into consideration. First, elderly managers are more experienced to handle with alternating tasks. If it would be true, they would show reduced physiological costs. In contrast, the physiological costs in elderly were higher than in younger suggesting that former prevented performance decrement by compensatory effort [1]. As we assumed, this effort type is related to a reduced responsivity of cardiovascular system to alternating tasks demands. In fact, elderly managers demonstrated a higher rigidity of cardiac responses to varied task complexity that was clearly seen on HRV. The HRV represents a mechanism providing allocation of physiological resources to a task in terms of changing blood supply of organs involved in task performance. Thus, the HRV should be the highest in rest condition, a somewhat reduced in an easy task, and be the lowest in a difficult task. This kind of profile was obtained in younger group indicating an efficient adaptation of their cardiovascular function to experimental conditions (Fig 2). In addition, a tendency to higher post-test than pre-test HRV in younger was seen suggesting a quick cardiac recovery in this group. On the contrary, the HRV in elderly group was insusceptible to alternating conditions. The effect is

generally in line with data has been demonstrated a reduced heart rate response to cognitive workload at older ages [4], [10]. However, some authors did not find age differences in HRV response to cognitive load [11]. As the authors used a simple reaction time task, the result is undoubtedly due to task simplicity, whereas a complex cognitive task in our study was imposed by which a clear-cut age-related HRV differences were provoked.

Several studies have shown that systolic blood pressure (SBP) increases with age [12]. We also obtained a higher SBP in elderly than in younger group (Fig. 3) that may be due to a reduced vagal control of the BP with advancing age [13] and may probably lead to hypertension in elderly. The DBP did not differ between groups suggesting that mechanisms regulating DBP is less vulnerable to age. Higher HR in the pre- than in post-test conditions observed in elderly may be interpreted as increased reaction to experimental situation (Fig. 4). In younger group the pre-test increase of HR may be attributed to initial resource mobilization, whereas the post-test decrease of HR to quick recovery of cardiac function when the experiment was finished. The decreased responsivity of cardiovascular system to task demands as well as its delayed post-test recovery in elderly may increase risks for heart diseases [14]. In turn, cardiac dysfunction (e.g. hypertension) may lead to cognitive impairments, especially in “executive” tasks [15], [16]. It has been supposed that the damage of vessels surrounding white matter of the brain may contribute to deficits in executive functions in hypertensives [17].

Finally, some limitations of the study should be mentioned. Age difference between “elderly” and “younger” participants was very small as compared with common aging studies usually investigating the contrast age groups. It may have resulted in the attenuating of age-related effects on performance and cardiac responses. Further investigations using more contrast groups are required to pinpoint aging effects and to assess possible health risks related to a decreased responsivity and delayed recovery of cardiovascular system in elderly managers.

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