Int Marit Health
2013; 64, 2: 54–60
www.intmarhealth.pl

ISSN 1641–9251

VIA MEDICA

ORIGINAL PAPER

Relationship between Neuroticism, threat of shock and heart rate variability reactivity

Anita L. Hansen[1, 2], Bjørn Helge Johnsen[1]

[1]Department of Psychosocial Science, University of Bergen, Bergen, Norway
[2]Centre for Research and Education in Forensic Psychiatry, Haukeland University Hospital, Bergen, Norway

ABSTRACT

The aim of the present study was to investigate the relationship between Neuroticism, non-executive functioning and heart rate variability (HRV) in both threat and non-threat situations. Sixty-five male sailors from the Royal Norwegian Navy participated in the study. Participants were randomly assigned into non-threat and threat groups. Neuroticism was measured by the NEO-PI-R and, based on the median-split of Neuroticism, groups were divided into 2 additional groups. A Visual Search Task was used to measure non-executive functioning. HRV reactivity was measured during baseline-, test- and recovery-conditions. Overall, the results revealed that there were no differences between any of the groups in terms of the performance on the Visual Search Task: this was true for both accuracy data and mean reaction time. However, the results showed that the High Neuroticism Threat Group had a significant increase in HRV from test-condition to recovery. This may indicate that the High Neuroticism Threat Group found the whole task condition more stressful due to the threat situation.

(Int Marit Health 2013; 64, 2: 54–60)

Key words: Neuroticism, threat of shock, heart rate variability, non-executive function

INTRODUCTION

Navigation onboard vessel requires high demands on attentional and memory processes and complex interaction of both executive and non-executive functions in different kinds of situations. Detections of critical signals, like lanterns and navigational lights have to be attended to and understood during conditions such as fatigue, high stress or threat situations. Previously, studies from our research group has focused on these cognitive mechanisms in relation to onboard environment in different kinds of situations (e.g. during normal circumstances and threat situations) [1–3] and it has been found that executive functioning in particular, is associated with other underlying mechanisms such as heart rate variability (HRV), but also Situation Awareness and personality [4].

Thus, studies from our and other research labs, have put emphasize on individual differences in executive functioning. In the study of Saus et al. [4] it was reported that higher Situation Awareness in navigation simulators for naval cadets was characterised by a resilient personality type. This personality type consists of high scores on Extraversion and Conscientiousness as well as low scores on Neuroticism. Another recent study identified several traits and state correlates of individual differences in the functioning of attentional network [5]. Mathews and Zeidner [5] confirmed that state task engagement and the traits of Extraversion and Conscientiousness were all associated with superior executive functioning. Path analyses suggested that Extraversion might have a direct effect on executive control, and Conscientiousness an indirect effect, mediated by task engagement. However, Neuroticism did not affect executive functions.

Neuroticism gives a picture of anxiety, hostility, self-consciousness, impulsivity, and vulnerability. The 5-factor model of personality was originally developed in order to describe the basic traits comprising the normal population (NEO-PI — Neuroticism, Extraversion, Agreeableness, Openness, Conscientiousness) [6]. However, Costa and Widiger [7]

Anita L. Hansen, Department of Psychosocial Science, University of Bergen, Christiesgt. 12, Bergen, Norway, tel: +47 55 58 31 85/+47 91623181, fax: +47 55 58 98 79, e-mail: anita.hansen@psysp.uib.no

argued that this model is useful in describing personality disorders and psychopathology as well as normal variations in trait dispositions.

Studies have exhibited a relationship between personality and HRV. HRV is a measure of the continuous interplay between sympathetic and parasympathetic influences on heart rate [8]. Sollers et al. [9] found that subjects with high score on Neuroticism also showed a decreased HRV compared to subjects who scored low on Neuroticism. Previous studies from our lab have shown that subjects characterised by high HRV during normal circumstances had better performance on tasks that required executive functioning compared to individual with low HRV. On the other hand no differences between high and low HRV have been found on tasks taxing non-executive functioning (e.g. [1, 2, 10]). Thus, the findings related to Neuroticism and executive functioning in Mathews and Zeidner's [5] study seem to be contradictory.

However, in the study performed by Hansen et al. [2] it was found that during a situation where subjects were exposed to an adverse and harmful event (threat of shock), participants with low HRV performed as good as participants with high HRV on an executive function task (accuracy data). Moreover it was found that a low HRV threat group had faster mean reaction time compared to the high HRV threat group on a non-executive (simple reaction time) task. Thus, it was speculated that fear, induced by threat of shock, had motivational effect on participants with low HRV and that they increased their attention to the task as they strove to improve their performance and avoid the punishment. Considering the relationship between Neuroticism and low HRV [9], as well as Eysenck's [11] suggestion that individual variations in personality dimensions reflects differences in neurophysiological functioning it will be of importance to investigate reactivity related to Neuroticism during different test-conditions and in different situation such as threat and non-threat situations.

Executive functions are needed when task demands are non-routine and they are responsible for human planning, reasoning, problem solving, decision-making, and acting [12]. Thayer and Lane [13] developed a network model that integrates functionally psychological processes with physiological underlying structures. In this model they emphasized HRV as an index of self-regulation and executive functioning. Moreover, Porges and Raskin [14] demonstrated that HRV was significantly reduced during sustained attention tasks. This was supported by Hansen et al. [1]. However, in this study there was a significant increase in HRV from baseline and test-conditions to the recovery phase. Before exposure to an experimental test procedure the participants may be characterised by performance anxiety. Thus, HRV reactivity measured after attention termination or an experimental test procedure may be regarded as a better index of resting HRV since there is no anticipation effect confounded in the recording of resting HRV [1]. Thus, HRV recovery may add some significant information with regard to the physiological effort spent during a demanding situation.

In an operational setting non-executive attentional processes are equally important as the executive functioning. In contrast to executive function tasks, non-executive function tasks are based on processes driven automatically or reflexively by stimulation. This occurs even when the person is instructed to be passive toward the event. In accordance to Cowan [15, 16] it could be argued that simple reaction time and choice reaction time tasks are non-executive tasks since they do not require short-term memory in addition to controlled and focused attention, or manipulation of new information. Another variant of these non-executive function tasks is the Visual Search Tasks which could be described as a kind of pop-out attention task [17] where the subjects have to respond when a discrepancy from the background display is presented on the screen. The main difference between the executive and the non-executive tasks is that the executive tasks require active attention, while non-executive tasks only require a passive attention toward the event [17].

Several studies have shown that non-executive functions are not affected by individual characteristics or environmental changes or demands (e.g. [1–3, 10]). Based on the evidence that during threat of shock low HRV individuals performed as good as high HRV individuals on executive function tasks, together with the fact that high Neuroticism is associated with lower HRV [9] and higher physiological arousal in general [11], there is reason to believe that these individuals will experience exhaustion after some time, especially in a threatening situation. However, less is known about the physiological effort during a threatening condition in subjects scoring high on Neuroticism. Since non-executive functioning is extremely important in operational settings, physiological effort during different task conditions (cf. baseline, test and recovery) in different environmental demands has to be investigated. More knowledge about this may have important implications with regard to selection, prevention of accidents and development of intervention programs in order to improve personal competence.

Thus, the aim of this study was to investigate the relationship between levels of Neuroticism and performance on non-executive functioning in both non-threat and threat situations. Based on earlier findings [1, 2, 10] related to non-executive functioning, we did not expect to find any differences between any of the groups on performance on a Visual Search Task. Furthermore, we wanted to explore whether high Neuroticism was associated with increased physiological effort during exposure to an experimental test procedure during threat of shock.

MATERIAL AND METHODS

PARTICIPANTS

Sixty-five male sailors, with a mean age of 23.1 years, (range from 18 to 36 years); from the Royal Norwegian Naval Academy participated in this study.

APPARATUS AND STIMULI

Neuroticism was assessed by the NEO-PI-R [18].

A Visual Search Test was used as a pop-out attention task in order to measure non-executive function. The test was presented using the Micro Experimental Laboratory (version 2) [19] installed on a Fujitsu Life Book with 10 × × 7.5 inch screen. The task required an active scan for the letters I, F, L, or S among a background of the E. All letters were presented on the screen.

Cardiac activity was measured by using an Ambulatory Monitoring System [20]. The cardiac responses were measured with 8 mm Ag/AgC1 ECG electrodes (Cleartrode, Disposable Pregelled Electrodes, 150, Standard Silver). One electrode was placed over the jugular notch of the sternum, between the collarbones, another was placed 4 cm under the left breast between the ribs, and the third electrode was placed at the right lateral side between the 2 lower ribs.

Shock was administered to the participants by a pulsating (18 Hz) adjustable DC shock generator. The electric shock was delivered through the fourth and fifth fingers, on the non-dominant hand.

PROCEDURE

In order to recruit the participants, we contacted one of the chief officers in the operational unit in the Royal Norwegian Navy and informed him about the purpose of the study. The participants were recruited by both written and verbal information about the study. All participants were tested individually at the same time of day (9.00 a.m.–12.00 a.m.). Before the start of the experiment the participants read and signed an informed consent statement. They were informed about their rights to leave the experiment at any time. No participants withdrew from the experiment.

HRV was registered during 5 min of rest (baseline condition), during exposure to the experimental task (test condition) and then during 5 min of rest again (recovery condition). The participants were randomly assigned into non-threat and threat groups. The intensity of the electrical shocks was set individually to the threat group after baseline psychophysiological recordings, but before presentation of the cognitive task. The procedure for setting the shock intensity followed standard procedure. The instructions to the subjects were that the shock should be unpleasant but not painful, and they were exposed to gradually increasing intensities [21, 22]. They were also told that they had to respond as soon as possible to the target stimuli on the cognitive tasks. If not, they would get an electric shock. Furthermore, they were informed that the criterion for responding varied randomly in order to prevent the participants from guessing the criterion. In spite of the instruction, no shocks were to be administered during the experiment [23].

Before presenting the Visual Search Task the participants were instructed to focus on the computer screen and respond as soon as possible to the target stimuli that were I, F, L, S or only E's. Thus, the participants were instructed to press the corresponding button (I, F, L, or S) on the keyboard if they could detect any deviations from the background that consisted of E's. If only the background that consisted of only E's was presented they were instructed to press the corresponding button "E" on the keyboard. Accuracy data was measured by frequency of correct responses to target stimuli. The responses were recorded in milliseconds from the stimulus onset to the manual reaction by the participants. The reaction times indicate the average speed with which the individual was able to respond to target stimuli. This was done using the internal clock of the computer.

HRV was measured as the root mean of the squared successive differences (rMSSD), and also averaged over task period. Each R- to R-wave inter-beat interval in the selected period was used to calculate the average HR and the rMSSD. rMSSD is an index of vagally mediated cardiac control that correlates highly (about 0.90) with spectrally derived measures of vagally-mediated HRV [24, 25]. In addition, this measure acts as a high pass filter and thus removes the slower, blood pressure mediated variability from the signal. HR was measured as beats per minutes, based on the inter-beat intervals averaged over 30 s periods.

In addition to the randomly assigned non-threat (31 participants), and threat (34 participants) groups, the participants were further assigned into two groups; High Neuroticism and Low Neuroticism based on the median split of the Neuroticism (raw score > 75 = High Neuroticism). There were 32 participants in the High Neuroticism group and 33 participants in the Low Neuroticism group. All together there were 4 groups: High Neuroticism Non-Threat (19 participants; Neuroticism: M = 92.68/SD = 11.76); High Neuroticism Threat (13 participants; Neuroticism: M = 92.43/ /SD = 9.85); Low Neuroticism Non-Threat (13 participants; Neuroticism: M = 62.29/SD = 9.20) and Low Neuroticism Threat (20 participants; Neuroticism: M = 63.92/SD = 9.75).

The project was sanctioned by the Regional Committees for Medical Research Ethics, Western Norway (REK-West).

DESIGN AND STATISTICS

Differences between the four groups on the measures of test performance on the Visual Search Task and HRV were investigated by repeated measures of ANOVA. Groups

Table 1. Means and standard deviations (SD) for performance on the Visual Search Task (VST, mean reaction time [mRT] and number of correct responses) and heart rate variability (HRV) reactivity to the different conditions

	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
mRT	**E**		**F**		**I**		**L**		**S**	
LNNT	2003.28	374.03	1356.49	251.63	745.44	245.65	817.57	108.43	1038.41	308.56
LNT	1887.72	320.87	1389.51	286.145	772.34	284.56	793.46	287.84	941.73	265.00
HNNT	1776.27	419.46	1173.53	507.48	832.05	578.55	698.32	461.09	788.35	409.45
HNT	1968.35	323.44	1432.92	142.46	685.31	344.20	890.48	411.64	1049.96	616.91
# Correct	**E**		**F**		**I**		**L**		**S**	
LNNT	55.08	20.05	13.62	4.57	15.46	5.97	15.62	5.55	15.46	5.77
LNT	51.60	16.15	11.90	4.08	14.05	4.84	14.05	4.85	13.85	4.64
HNNT	43.69	23.94	10.56	5.51	11.69	6.87	11.31	6.87	11.63	6.81
HNT	51.20	16.45	12.00	4.06	13.70	4.90	14.10	4.36	13.80	4.66
HRV	**Baseline**		**VST**		**Recovery**					
LNNT	66.29	41.43	54.49	39.88	60.82	43.87				
LNT	70.11	50.73	66.18	48.11	75.85	47.79				
HNNT	73.46	46.73	61.82	37.58	65.11	34.32				
HNT	75.13	54.13	66.19	38.11	99.66	77.83				

LNNT — Low Neuroticism Non-Threat; LNT — Low Neuroticism Threat; HNNT — High Neuroticism Non-Threat; HNT — High Neuroticism Threat

were treated as independent variables, whereas conditions on Visual Search Task (I, F, L, S and E) and HRV reactivity to baseline, test-condition and recovery were treated as dependent variables. The results were followed up by Bonferroni test. According to Wilcox [26], as well as Rosnow and Rosenthal [27], multiple comparison procedures should also be used regardless of whether omnibus tests are significant. Thus, based on our expectations related to the performance for the different groups on the non-executive functioning task also non-significant interactions were followed up and Bonferroni corrected. The magnitudes of the significant differences between the independent means were calculated as effect sizes using Cohen's d [28].

RESULTS

DESCRIPTIVE STATISTICS

Means and standard deviations for performance on the Visual Search Task and HRV reactivity are presented in Table 1.

PERFORMANCE ON VISUAL SEARCH TASK

Accuracy data. The results revealed no effect of groups (F [3,55] = 1.08, $p < 0.36$). However, there was a significant effect of conditions (F [4,220] = 359.93, $p < 0.001$) with a higher score on the E condition compared to the other conditions (F, I, L, S; Table 2). Moreover, there was no significant interaction between groups and conditions (F [12,224] = 0.76, $p < 0.70$). Follow up this non-significant interaction the Bonferroni test showed that there were no significant differences between the groups on non-executive performance (all p-values < 0.51).

Mean response time. No effect of groups were found (F [3,56] = 1.58, $p < 0.20$). There was a significant effect of conditions (F [4,224] = 116.21, $p < 0.001$) showing a significant longer reaction time for the E condition compared to the other conditions (all p-values < 0.001). Additionally the response time for F was significant longer than for the I, L, and S conditions (all p-values < 0.001; Table 2). The interaction between groups and conditions was not significant. No significant differences between any of the groups were found by the Bonferroni follow up test (all p-values < 1.00).

REACTIVITY TO TEST PROCEDURE

Looking at HRV during the different conditions there was no effect of groups (F [3,61] = 0.71, $p < 0.71$). However, there was a significant effect of conditions (F [2,122] = 7.12, $p < 0.001$). Follow up test indicated a significant decrease in HRV from baseline to test-condition ($p < 0.01$), and a significant increase form test-condition to recovery-condition ($p < 0.001$). Interestingly, there was a significant interaction between groups and conditions (F [6,122] = 2.54, $p < 0.02$). Bonferroni test showed that for the High Neuroticism Threat group there was a significant increase in HRV from test-condition to recovery-condition ($p < 0.003$, $d = 0.55$; Fig. 1). No other significant results were found.

Table 2. The significant effect of conditions, means and standard deviations (SD) for all groups pooled together

	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
mRT	**E**		**F**		**I**		**L**		**S**	
	1897.82[1]	362.62[2]	1332.72	343.69	766.48	245.14	791.1	340.84	941.62	399.66
# Correct	**E**		**F**		**I**		**L**		**S**	
	50.15[3]	19.41	11.93	4.62	13.66	5.72	13.66	5.63	13.59	5.58

[1]E significant higher than F, I, L, and S; [2]F significant higher than I, L, and S; [3]E significant higher than F, I, L, and S; mRT — mean reaction time

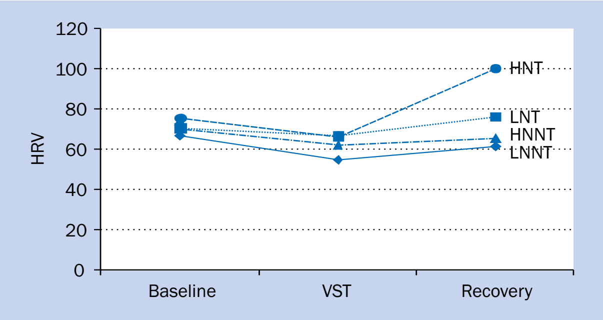

Figure 1. Heart rate variability (HRV) reactivity to the different experimental conditions (baseline, Visual Search Task [VST] and recovery) for the Low Neuroticism Non-Threat group (LNNT), Low Neuroticism Threat group (LNT), High Neuroticism Non-Threat group (HNNT), and the High Neuroticism Threat group (HNT)

DISCUSSION

Overall, the results revealed that there were no differences between any of the groups looking at the performance on the non-executive performance task. This was true for both accuracy data and mean reaction time. However, the results showed that the High Neuroticism Threat group had a significant increase in HRV from task-condition to recovery. This may indicate that the High Neuroticism Threat group found the whole task condition more stressful due to the threat of shock.

As expected, there were no differences between any of the groups in terms of performance on the Visual Search Task. The results are in line with earlier findings [1]. However, the Hansen et al. [2] study reported that the low HRV threat group showed significantly faster mean reaction time than the high HRV threat group. This was found only on a non-executive function tasks that measured simple reaction time, which is a task where the subjects were asked to press a key as soon as possible in response to target stimuli. This simple reaction time task provides only a basal measure of reaction time. Moreover, in a pre-post design it has also been found that subjects who showed a reduction in HRV due to physical exercise cessation (after exposure to a training program for 8 weeks) improved their mean reaction time from pre- to post-test on a simple non -executive function task. Participants without reduction in HRV (due to continued exercise program) only showed improved performance on the executive function tasks [10].

It has been argued that performance can be related to level of arousal and that this relationship can be expressed as an inverted U-curve [29]. The cortical functions are most efficient at moderate levels of arousal, when the person is alert and wakeful, but not highly excited or agitated. Both low and high arousal produce inefficiency, and performance is best at an intermediate level of arousal. This is in line with Broadbent [30] who argued that the optimal level of arousal for performance is inversely related to task difficulty. Thus, based on these arguments one could also expect that both personal characteristic, in this case high Neuroticism, or threat condition would have influenced the performance accuracy and mean reaction time on the task. However, looking at the performance data on the non-executive functioning task neither accuracy nor mean reaction time were associated with personal or situational characteristics.

However, looking at the performance for all the groups pooled together, differences in conditions was found for both accuracy and reaction time data. Longest reaction time was found for the E condition and F condition. This is in line with Posner and Raichle [17] who argued that visual search where no deviances from the background are most time consuming followed by the target stimuli which shares most common feature with the background. The letter F has 3 of 4 common elements with the background. Thus this letter would be difficult to detect among a background of the letter E.

The second aim of this study was to investigate the reactivity to the different task conditions during threat and non-threat conditions in relation to levels of Neuroticism. Interestingly the results revealed that the High Neuroticism Threat group showed a significant increase in HRV from test-condition to recovery. Also this is in line with the results from Hansen et al. [1]. In the paper of Hansen et al. [1] it was argued that worry related to the performance at the beginning of the test-procedure could have influenced the reactivity at baseline. Due to the instruction before the presentation of the experimental procedure in the current study (they were told that they had to respond as soon as possible to the target stimuli on the cognitive tasks, if not, they would get an electric shock), worry may also be a plausible explanation of the increased HRV from test-condition to recover. This suggestion is further supported by the fact the instruction was given to the participants after the baseline measure. Thus, one could expect that the lack of a significant decrease in HRV from baseline to test-conditions (cf. [14]) was due to performance anxiety, but the significant increase in HRV form test-condition to recovery was related to the fear generated by the threat of electrical shock. The suggestion that recovery could be viewed as a better measure of resting cardiac activity [1] is supported and this change in recovery may add some significant information which may have important implications with regard to a deeper understanding of what is going on in the individual during a demanding situation.

According to Porges [31], usually a rapid or fast recovery indicates a positive and adaptive response and has often been associated with personal characteristics such as low anxiety and low levels of depression. However, in this case this significant increase in HRV reactivity from test- to recovery-condition may also indicate a feeling of coping and control in high Neurotic individuals due to the fact that they did not get any electrical shock. Thus, one could speculate whether the increased HRV from test-condition to recovery in the present study was an expression of perception of safety [32] at the end of the experimental procedure. However, the whole threat situation in this study only lasted for 30 min. An open question would be how they would manage to recover if the situation had been for much longer time?

Frankenhaeuser et al. [33] compared the performance of high-arousal subjects and low-arousal subjects during understimulation and overstimulation tasks. Performance during understimulation was better in the high aroused subjects, and during overstimulation in low aroused subjects [33]. Furthermore, Broadbent [30] has shown that exposing subjects to a loud noise or stress (> 95 dB) improved reaction time on well-rehearsed or simple tasks, but impaired performance on more complex tasks. This was especially true when the subjects experienced themselves to have no control over the stressor. Furthermore, Broadbent [34] also suggested that effects of environmental stress can often give superior performance at the beginning of the work period. The effects of stress may indeed produce a greater decrement compared to normal condition, but often produce greater decrement at the end of the work period.

CONCLUSIONS

In summary, there were no differences between high and low Neuroticism groups in non-executive functioning. However, looking at the reactivity to the different conditions, the threat condition may have affected the participants with high Neuroticism in one way or another. The present findings, together with earlier knowledge [30, 32], may have important implications with regard to selection, prevention of accidents, and development of intervention programs. Neuroticism is associated with anxiety, hostility, self-consciousness, impulsivity, and vulnerability [6]. Thus, emotional stability may be a very important personality trait for personnel working in high stress-environment. Moreover, there is a relationship between Neuroticism and HRV, an important index of flexibility and adaptation [31]. Thus, manipulation of this underlying mechanism (cf. [10]) may also have beneficial effect on personality traits such as Neuroticism. However, this issue needs further investigation. Additionally, more research on HRV reactivity and recovery after work-related stress for a longer period of time than 30 min is of importance in order to draw any conclusion.

REFERENCES

1. Hansen AL, Johnsen BH, Thayer JF. Vagal influence on working memory and attention. Int J Psychophysiol 2003; 48: 263–274.
2. Hansen AL, Johnsen BH, Thayer JF. Relationship between heart rate variability and cognitive function during threat of shock. Anxiety Stress Copin 2009; 22: 1–12.
3. Saus ER, Johnsen BH, Eid J, Riisem PK, Andersen R Thayer JF. The Effect of brief situational awareness training in a police shooting simulator: an experimental study. Mil Psychol 2006; 18: S3–S21.
4. Saus ER, Johnsen BH, Eid J, Thayer JF. Who benefits from simulator training: Personality and heart rate variability in relation to situation awareness during navigation training. Computers Human Behav 2012; 28: 1262–1268.
5. Mathews G, Zeidner M. Individual differences in attentional networks: trait and state correlates of the ANT. Pers Indiv Differ 2012; 53: 574–579.
6. Costa PT, McCrae RR. Normal personality assessment in clinical practice: the NEO personality inventory. Psychol Assessment 1992; 4: 5–13.
7. Costa PT, Widiger TA. Personality disorders and the five-factor model of personality. American Psychological Association, Washington, DC 1994.
8. Thayer JF, Lane RD. The role of vagal function in the risk for cardiovascular disease and mortality. Biol Psychol 2007; 74: 224–242.
9. Sollers JJ, Thayer JF, Pearson MA, Faith ML, Costa PT Jr. Personality correlates of autonomic activity and mood rest. Psychophysiology 1999; 36 (suppl. 1): 60.
10. Hansen AL, Johnsen BH, Sollers JJ, Stenvik K, Thayer JF. Heart rate variability and its relation to prefrontal cognitive function: the effects of training and detraining. Eur J Applied Physiol 2004; 93: 263–272.
11. Eysenck HJ. Biological dimensions of personality. In: Pervin LA (eds.). Handbook of personality: theory and research. Guilford Press, New York 1990: 244–276.
12. Shimamura AP. The role of the prefrontal cortex in dynamic filtering. Psychophysiology 2000; 28: 207–218.
13. Thayer JF, Lane RD. A model of neurovisceral integration in emotion regulation and dysregulation. J Affect Disorders 2000; 61: 201–216.
14. Porges SW, Raskin DC. Respiratory and heart rate components of attention. J Exp Psychol 1969; 81: 497–503.
15. Cowan N. Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information processing system. Psychol Bull 1988; 104: 163–191.
16. Cowan N. Attention and memory: an integrated framework. Oxford University Press, Oxford, England 1995.

17. Posner MJ, Raichle ME. Images of mind. Scientific American Library, New York 1999.
18. Costa PT, McCrae RR. Revised NEO Personality Inventory manual. Psychological Assessment Resources, Inc. Odessa, FL 1992.
19. Schneider W. Micro experimental laboratory: an integrated system for IBM PC compatibles. Behav Res Met and Comp 1988; 20: 643–661.
20. Klaver CHAM, de Geus EJC, de Vries J. Ambulatory monitoring system. In: Maarse FJ (ed.). Computers in psychology 5, applications, methods and instrumentation. Swets & Zeitlinger, Lisse 1994.
21. Öhman A., Soares JJF. Emotional conditioning to masked stimuli: expectancies for aversive outcomes following nonrecognized fear-relevant stimuli. J Exp Psychol 1998; 127: 69–82.
22. Johnsen BH, Hugdahl K. Hemispheric asymmetry in conditioning to facialemotional expressions, Psychophysiology 1991; 28: 154–162.
23. Friedman BH, Thayer JF, Tyrrell RA. Spectral characteristics of heart periodvariability during cold face stress and shock avoidance. Clin Auton Res 1996; 6: 147–152.
24. Thayer JF, Friedman BH, Borkovec TD, Johnsen BH, Molina S. Phasic heart period to cued threat and non-threat stimuli in generalized anxiety disorder. Psychophysiology 2000; 37: 361–368.
25. Friedman BH, Allen MT, Christe IC, Santucci AK. Validity concerns of common heart-rate variability indices: addressing quantification issues in time- and frequency- domain measures of HRV. IEEE Eng Med Biol 2002; 21: 35–40.
26. Wilcox RR. New designs in analysis of variance. Annu Rev Psychol 1987; 38: 29–60.
27. Rosnow RL, Rosenthal R. Effect sizes. Why, when, and how to use them. J Psychol 2009; 217: 6–14.
28. Cohen J. A power primer. Psychol Bull 1992; 112: 155–159.
29. Malmö RB. Activation: a neurophysiological dimension. Psychol Rev 1959; 66: 367–386.
30. Broadbent DE. Decision and stress. Academic Press, London 1971.
31. Porges S. Vagal tone: a physiological marker of stress vulnerability. Pediatrics 1992; 90: 498–504.
32. Porges, SW. Social engagement and attachment. A Phylogenetic perspective. Ann NY Acad Sci 2003; 1008: 31–47.
33. Frankenhaeuser M, Nordheden B, Myrsten AL, Post B. Psychophysiological reactions to understimulation and overstimulation. Acta Psychol 1971; 35: 298–308.
34. Broadbent DE. The role of the auditory localization in attention and memory span. J Exp Psychol 1954; 47: 191–196.