Activitas Nervosa Superior Rediviva Volume 58 No. 4 2016

ORIGINAL ARTICLE

Pupil dilation changes, cognitive performance, anxiety and allergy

Daniela Turonova, Petra Solarikova, Igor Brezina

Department of Psychology, Faculty of Arts, Comenius University, Bratislava, Slovakia.

Correspondence to: Daniela Turonova, Department of Psychology, Faculty of Arts, Comenius University, Gondova Street Nr. 2, SK-814 99 Bratislava, Slovakia, e-mail: daniela.moskalova@uniba.sk

Submitted: 2016-10-25 *Accepted: 2016-12-05* *Published online: 2016-12-28*

Key words: **HANS reactivity; cognitive performance; anxiety; allergy; pupil dilation**

Act Nerv Super Rediviva 2016; **58**(4): 105–109 ANSR580416A02

Abstract

INTRODUCTION: This study is focused on the reactivity of Autonomic Nervous System (ANS), cognitive performance, presence of an allergy and anxiety. We were testing an assumption that anxiety connected to the ANS hyperactivity would be leading to reduced processing efficiency and, at the same time, it would have no effect on the performance effectiveness of an anti-saccadic task. The scope of our testing was an assumption that allergy connected to the sympathetic hypoactivity will also be connected to the processing efficiency, but at the same time it will have no effect on the performance effectiveness of this task.

METHOD: 67 participants at the age of 18–35 (M = 22,3 years old, SD = 3,1) took part in the research. Subjects were divided into 4 groups: individuals suffering from an allergy with a high level of anxiety, individuals without allergy showing a high level of anxiety, individuals suffering from an allergy with a low level of anxiety and a control group. For evaluation of the trait anxiety, the Speilberger State-Trait Anxiety Inventory was used. Within the cognitive performance we were testing the ability to inhibit reflexive responses in antisaccadic task. The autonomic activation was evaluated through pupil dilation changes. Participants were tested in The Psychophysiology Laboratory (Department of Psychology, Faculty of Art, Comenius University in Bratislava)

FINDINGS: We observed significant interaction effect between pupil dilation and allergy. The autonomic activation was higher in the group of individuals with an allergy than in the group of individuals who did not suffer from any allergy. In contrast to the allergy, the effect of anxiety was not significant. High and low anxiety groups were showing a very similar tendency of changes in the pupil dilation during task. Allergy and anxiety were not in a direct connection to the performance effectiveness but, there was a statistically significant difference between groups in processing efficiency. The autonomic activation had no influence on processing efficiency or performance effectiveness.

INTRODUCTION

The Autonomic Nervous System (ANS) activation and the personality are significant factors of the cognitive performance. The influence of the ANS activation and the level of arousal (in general) on the cognitive performance shall be a field that is subject to an intensive analyses since the Twentieth Century, when the influence of arousal on performance and the level of arousal dependence on the type and complexity of the task were described by Yerkes and Dodson (1908). Since that time, evaluation of the arousal and especially the ANS activation was subject to substantial changes, in particular, in the field of availability of its scanning and evaluation methods.

Pupillometry is one of the relatively new methods. Evaluation of the pupil dilation as the arousal index is based on an assumption, that it is controlled by a sympathetic as well as by a parasympathetic ANS branch. According to this assumption, the sole pupil dilation is being activated by the sympathetic activity which stimulates the radial dilator muscles of the pupil as well as by the inhibition of the parasympathetic system which controls the sphincter muscles of the iris (Bradley *et al.* 2008).

The level of the ANS activation as a characteristics underlying inter individual differences may also be used in relation to the personality. To the significant extent, this assumption is based on the Eysenck´s Theory of Personality (Eysenck 1967). In his theory, Eyesenck anticipated that the biological basis of interindividual differences in anxiety is based on the increased ANS reactivity. Individuals rated with a high level of ANS reactivity in this respect were identified as emotionally unstable. This perception of anxiety is though over-simplified and despite the fact that the increased ANS reactivity may be considered as one of the signs of anxiety (Steimer 2002; Takahashi *et al.* 2005), there is a probability that in different forms of anxiety disorders the reactivity, or the ANS activity, is expressed in a different way (Friedman & Thayer 1988). The increased ANS reactivity is also directly connected to constructs that are related to the anxiety, including but not limited to neuroticism (Eysenck 1967, Noriis *et al.* 2007; Di Simplicio *et al.* 2012), or Type A behaviour pattern (Pérez-Garcia & Sanjuán 1996).

Changes in the ANS activity, even if conditioned by the sympathetic hypoactivity and parasympathetic hyperactivity (contrary to the anxiety or neuroticism), are connected to allergic diseases (Solarikova *et al.* 2016; Rajcani *et al.* 2016; de Assis *et al.* 2015; Ozsutcu *et al.* 2013; Mirotti *et al.* 2010). Although the nature of this connection is not entirely clear. Emin *et al.* (2012) describes changes in the functions of the autonomic nervous system, related to allergy rhinitis, but he associated this changes with dysfunction of the parasympathetic nervous system rather than a sympathetic hypoactivity. In contrast, Ozsutcu *et al.* (2013) observed an increase of vagal activity through pupillometry in children with allergic rhinitis which he associated with parasympathetic hyperactivity.

The ANS reactivity as characteristics underlying interindividual differences may though be considered also in relation to the cognitive performance as it depends directly on the level of the arousal (including autonomic arousal). Cognitive performance is also influenced by personality and especially anxiety (Eysenck *et al.* 2007; Crowe *et al.* 2007; Derakshan & Eysenck 2009; Pacheco-Unguetti *et al.* 2010). One of the cognitive functions that should be directly affected by anxiety (in relation to its typical hyperactivity of a sympathetic), is also the inhibition.

Inhibition, as a mechanism which reduces or softens neural, mental or behavioural activities, thus an ability to reject information that is irrelevant in the particular situation, may be considered as one of the primary executive functions (Norman & Shallice 1986). In respect of the anxiety, the inhibition is one of the two functions of the central executive which should be directly influenced by the anxiety according to the Theory of the Attention Control (Eysenck *et al.* 2007). Pursuant to the cited theory, the anxiety should be primarily linked to the reduced processing efficiency. In the context of these starting points, our thesis is focused on the analyses of the relationship between the anxiety and cognitive performance in the field of executive processes. Our assumption was that the individuals participating in the high trait anxiety will be allocating a higher level of reactivity of a sympathetic NS that will be related to longer reaction times of correct anti-saccadic responses (reduction of the processing efficiency). We assumed that there would be no influence on their performance captured as correctness of the anti-saccadic responses (performance effectiveness). In relation to the assumed hyperactivity of a parasympathetic, our interest was aimed to discover whether this particularity of an allergy would also be shown in the cognitive performance, either via the processing efficiency or performance effectiveness.

METHOD

67 participants at the age of 18–35 (M = 22,3 years old, SD = 3,1) took part in the research. 31 men and 36 women were selected. Based on the questionnaire score (STAI) 27 were classified into a high trait anxiety group and 40 into a low trait anxiety group. Allergy group (34 participants) was defined by allergy diagnosed by allergologist. Within the group 14 participants were classified as high trait anxious. 19 participants were classified into a control group. None of the allergy group shown acute allergic symptoms and have not taken corticosteroid medication for at least a month nor antihistaminic medication for at least a week.

For evaluation of the trait anxiety, the Speilberger State-Trait Anxiety Inventory (Slovak version: Müllner *et al.* 1980) was used. Administered part STAI X-2 is made of questions to which the participant responses as he or she naturally feels. The estimated rate of anxiety is expressed as a summary score and it is assumed that the higher score the participants receives, the higher is his or her level of anxiety as a personal feature.

Within the executive functions we were testing the ability to inhibit reflexive responses. For testing of these functions, an anti-saccadic task was administered. Task, which requires the top-down inhibition of a reflexive, autonomic saccades (Munoz & Everling 2004).

Under the anti-saccadic task, the task of a participant was to look at the other direction as was the direction where the target stimulus was located as soon as possible after the fixing interval faded away; and to look back at the middle part of the screen to the fixing point following its presentation. The fixing point was being presented during 800ms or 1000ms. Alternatives to the length of the fixing point presentation were randomised. The fixing point was followed by an anti-saccadic stimulus, which was presented as a black point random on the right side or on the left side of the screen in two alternative positions. Anti-saccadic stimulus was presented in the fixed length 1500ms. A response, where the first saccade was leading to the mirror side of the presented stimulus was evaluated as correct. Participants were instructed to repress their reflexive reactions on the presented stimulus.

The autonomic activation was evaluated through pupil dilation changes. The pupil dilation and the saccadic response were being scanned during the process of solving of the cognitive task. The pupil dilation was scanned by a 50 Hz monocular camera (EAS Monocular, NYAN software). To avoid the pupillary light reflex on the dilation and the constriction of the pupil, the stimulus computer monitor was the only source of illumination. Eye blink artefacts were automatically removed by the eye tracking software. The estimated changes in autonomic activation were compared in three time windows. Each time window was corresponding approximately to the same number of presented stimulus.

Participants were tested in Laboratory of psychophysiology, Faculty of Art, Comenius University in Bratislava. An adaptation phase in the duration of 15 minutes was preceding the testing. Administration of the saccadic task, which was serving as a training, was preceding the anti-saccadic task.

RESULTS

Changes in autonomic activation

In the context of changes in the ANS activation, we were testing our assumption that allergy and anxiety would be in a relationship to the changes of the ANS reactivity. For assessment of within subject effect of antisaccadic task on autonomic activation and between subject effect of anxiety and allergy on autonomic activation we used repeated measures ANOVA.

We observed statistically significant effect of time (inhibition task) on changes in autonomic activation $F(1.466, 96.72) = 40.555$, $p > 0.005$, $\eta_p^2 = 0.38$ (*Figure 1*). In the first place, these changes were related to the presence of an allergy. We observed significant interaction effect between pupil dilation and allergy $F(1.516, 98.56) = 6{,}642$, $p < 0.005$, $\eta_p^2 = 0.093$.

In all three stages, the autonomic activation, or pupil dilation average was higher in the group of individuals with an allergy than in the group of individuals who did not suffer from any allergy. The tendency of changes was though comparable in both groups (*Figure 2*).

More significant distinction in the tendency was noticed during the evaluation of the second and the third time window. Individuals who were suffering from an allergy were keeping almost the same level of autonomic activation at this stage, where in the group of individuals with no allergy the level of autonomic activation was lowered substantially.

In contrast to the allergy, the effect of anxiety was not significant $F(1.464, 95.19) = .071$, $p > 0.005$, $\eta_p^2 = 0.001$. Both groups were showing a very similar tendency of changes in the pupil dilation *Figure 3*. In the course of the whole task, a little higher activation was noticed at anxious participants.

Cognitive Performance

In the context of the cognitive performance, an assumption was tested that the anxiety has an effect on the processing efficiency, but it has no influence on the performance effectiveness. We assumed that this influence would be conditioned by the level of the autonomic activation. For the purposes of this analysis, the participants were divided into 4 groups: individuals suffering from an allergy with a high level of anxiety, individuals without allergy showing a high level of anxiety, individuals suffering from an allergy with a low level of anxiety and a control group.

As is indicated by our results, allergy and anxiety were not in a direct connection to the performance effectiveness $F(3.63) = .528$, $p = 0.091$. Having no regard on their membership to any group, the participants were showing very similar outcomes. Even though the group with allergy and high trait anxiety achieved the lowest score (67%). Control group achieved 81%. Neither the autonomic activation level ($r = 0.074$, $p > 0.005$) had influence on the performance effectiveness.

But, there was a statistically significant difference between groups in processing efficiency as determining by one-way ANOVA ($F(3, 36) = 2.898$, $p = 0.042$). A Turkey post hoc test revealed that the processing efficiency was lower in group with allergy ($M = 0.3634$, $SD = 0.15$, $p = 0.032$) and high trait anxiety compared to the control group ($M = 0.228$, $SD = 0.095$). The autonomic activation had no influence on processing efficiency ($r = 0.011$, $p > 0.005$).

DISCUSSION

It is obvious from the results, that allergy was connected to significant changes in the autonomic activation. Higher levels of pupil dilation were observed at all stages in the group of individuals suffering from allergy. Even if the pupil dilation is controlled by the sympathetic as well as by a parasympathetic ANS branch (Bradley *et al.* 2008), the sympathicus should have the dominant effect. In this direction, our results are in conflict with the assumed hypoactivity of the sympathicus and hyperactivity of the parasympathicus in case of patients suffering from allergy.

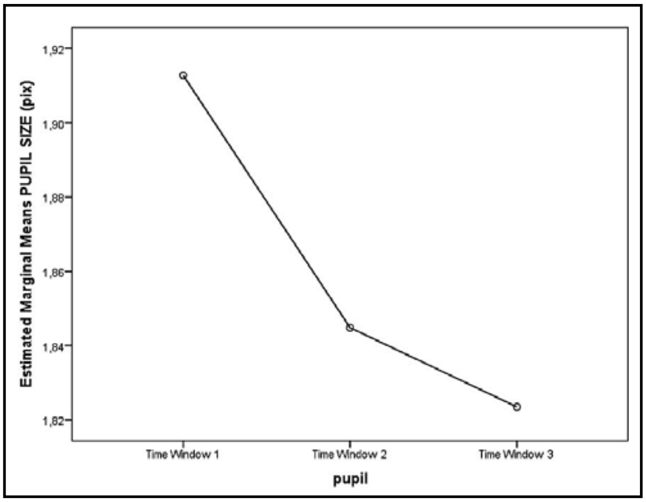

Fig. 1. Changes in pupil dilation during inhibition task.

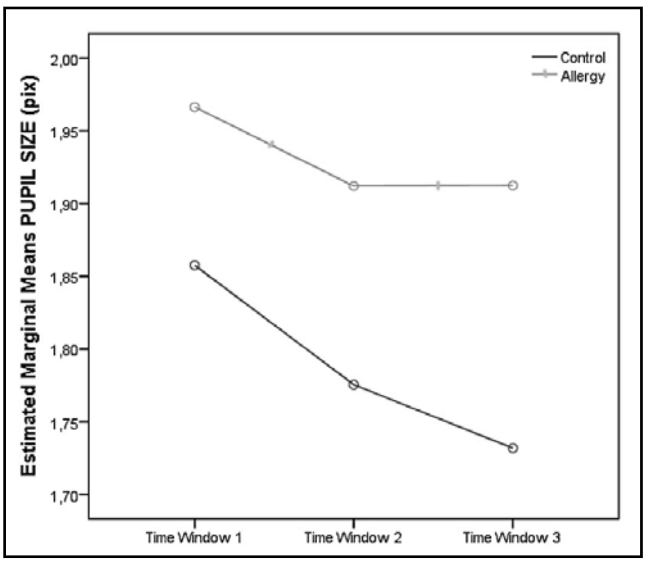

Fig. 2. Changes in pupil dilation during inhibition task. Effect of allergy.

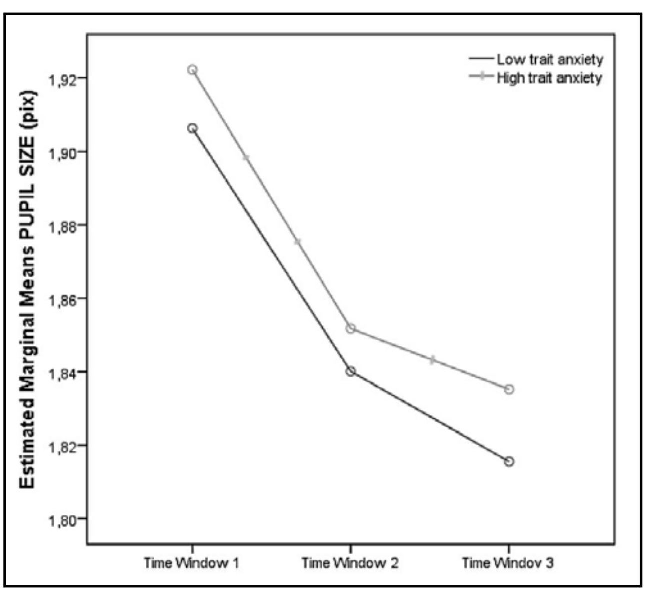

Fig. 3. Changes in pupil dilation during inhibition task. Effect of anxiety.

This conflict may be clarified by various factors. The results may be affected by a selected method of the autonomic activation evaluation. Pupil size represents a sensitive index of arousal mainly in resting period; phasic changes are used mainly to index cognitive processes and are less sensitive to arousal state. From the view of the contradictory experiment outcomes, the phase element, on which we were focusing, seems to be the problematic one. In this respect, it will be therefore necessary to verify the results, for example by a parallel EDA evaluation, as a sympathicus index, or HRV for the evaluation of the sympathicus and parasympathicus balance.

Despite our starting point – the sympathicus hypoactivity and the parasympathicus hyperactivity – our results are in line with various analyses, including, but not limited to Buske-Kirschbaum *et al.* (2010), in which sympathicus hyperactivity was shown by individuals suffering from allergy under stressing situations. That is why we may take into consideration that the ANS deregulation in cases of individuals suffering from allergy does not have to be expressed only by the sympathicus hypoactivity or by parasympathicus hyperactivity, and that this connection also depends on the situation factors.

In our selection, the anxiety had no statistically significant effect on the changes in the autonomic activation. The tendency of changes was though corresponding to the expectations and theoretical starting points. These results could have been affected by a high proportional rate of individuals suffering from allergy in our selection. The results may also be interpreted in the context of the processing effort and the processing load (Kahneman *et al.* 1968). In this respect, the pupil dilation is connected with the requirements of a task. Kahneman states that a complexity of the task or advanced requirements of the task are connected with an increase of the pupil dilation. Based on this assumption and on the assumed sympathicus hyperactivity of participants showing a high level of anxiety, a stressing situation did not have to be created by an anti-saccadic task for this group, which would be requiring allocation of additional caution resources. This effect could have an influence even on the results of individuals suffering from allergy. In respect of the assumed hypoactivity of the sympathicus, allocation of additional cognitive resources was required for successful performance of the task, which could have caused the monitored effect.

In the field of anxiety, our findings are in line with the Attention Control Theory (Eysenck 2007, 2010). According to this theory, it is necessary to distinguish between the processing efficiency and the performance effectiveness when evaluating the influence of the distress and anxiety on the cognitive performance.

In this area we noticed a very similar effect of the allergy and anxiety. Both, the allergy and the anxiety were connected to a lower performance. Membership to the group of individuals suffering from allergy and high level of anxiety was also connected with longer response times of the anti-saccadic task.

CONLUSION

This study was focused on evaluation of the relationship between allergy, anxiety and cognitive performance. The level of autonomic activation was considered as a mediator of this relationship. Our starting point was the assumption of the sympathicus hypoactivity shown in cases of individuals suffering from allergy and the sympathicus hyperactivity observed in cases of anxious participants. It is indicated by our results, that some aspects of the cognitive performance, in particular the processing efficiency, are affected by allergy and anxiety but not necessarily by the level of autonomic activation.

Acknowledgements

This paper was supported by grant APVV-0496-12.

REFERENCES

1 Bradley MM, Miccoli L, Escriq MA, Lang PJ (2008). The pupil as a measure of emotional arousal and autonomic activation. Psychophysiology. **45**(4): 602–607.
2 Buske-Kirschbaum A, Ebrecht M, Hellhammer DH (2010). Blunted HPA axis responsiveness to stress in atopic patients is associated with the acuity and severeness of allergic inflamma¬tion. Brain Behav Immun. **24**(8): 1347–1353.
3 Crowe SF, Matthews C, Walkenhorst E (2007). Relationship between worry, anxiety, and thought suppression and the components of working memory in a nonclinical sample. Aust Psych. **42**: 170–177.
4 De Assis EV, De Andreade Isidório U, et al. (2015). Autonomic Nervous System and Allergic Diseases: Integrative Literature Review. Int Arch Med. 8(112).
5 Derakshan N & Eysenck MW (2009). Anxiety, processing efficiency, and cognitive performance. New developments from attentional control theory. Eur Psychol. **14**(2): 168–176.
6 Di Simplicio M, Costoloni G, Western D, Hanson B, Taggart P, Harmer CJ (2012). Decreased heart rate variability during emotion regulation in subjects at risk for psychopathology. Psychol Med. **42**(8): 1775–1783.
7 Emin O, Esra G, Aysegul D, Ufuk E, Ayhan S, Rusen DM (2012). Autonomic nervous system dysfunction and their relationship with diseaseseverity in children with atopic asthma. Respir Physiol Neurobiol. **183**(3): 206–210.
8 Eysenck HJ (1967). The biological basis of personality. Springfield: Thomas.
9 Eysenck, MW, Derakshan N, Santos R, Calvo MG (2007). Anxiety and cognitive performance: Attentional control theory. Emotion. **7**(2): 336–353.
10 Eysenck MW (2010). Attentional Control Theory of Anxiety: Recent Developments. In: Gruszka A, Matthews G, Szymura B, editors. Handbook of Individual Differences in Cognition. New York: Springer, p. 195–204.
11 Friedman BH & Thayer JF (1998). Anxiety and autonomic flexibility: a cardiovascular approach. Biol Psychol. **49**(3): 303–323.
12 Kahneman D, Onuska L, Wolman R (1968). Effects of grouping on the pupillary response in a shortterm memory task. Q. J Exp Psychol. **20**: 309–311.
13 Mirotti L, Castro J, Costa-Pinto FA, Neural M (2010). Pathways in allergic inflammation. J Allergy. 2010: 491928.
14 Munoz DP & Everling S (2004). Look away: the anti-saccade task and the voluntary control of eye movement. Nat Rev Neurosci. **5**: 218–228.
15 Müllner J, Ruisel I, Farkaš G (1980). Príručka pre administráciu, interpretáciu a vyhodnocovanie dotazníka na meranie úzkosti a úzkostlivosti [(Manual for administration, interpretation and evaluation of a questionnaire to measure anxiety and scrupulosity) in Slovak}. Bratislava: Psychodiagnostické a didaktické testy. 93.
16 Norris CJ, Larsen JT, Cacioppo JT (2007). Neuroticism is associated with larger and more prolonged electrodermal responses to emotionally evocative pictures. Psychophysiology. **44**(5): 823–826.
17 Norman W & Shallice T (1986). Attention to action. In: Davidson RJ, Schwartz G, Shapiro D, editors. Consciousness and selt regulations: Advances in Research and Theory, New York: Plenum, vol. 4, pp. 1–18.
18 Ozsutcu M, Ozkaya E, Demir A, Erenberk U, Sogut A, Dundaroz, R (2013). Pupillometric assessment of autonomic nervous system in children with allergic rhinitis. Med Princ Pract. **22**: 444–448.
19 Pacheco-Unguetti AP, Acosta, A, Calleja A, Lupiáñez J (2010) Attention and anxiety: different attentional functioning under state and trait anxiety. Psychol Sci. **21**(2): 298–304.
20 Pérez-Garcia AM & Sanjuán P (1996). Type-A Behaviour Pattern's (global and main components) attentional performance, cardiovascular reactivity, and causal attributions in the presence of different levels of interference. Pers Individ Diff. **20**(1): 81–93.
21 Rajcani J, Solarikova P, Turonova D, Brezina I (2016) Heart rate variability in psychosocial stress: Comparison between laboratory and real-life setting. Act Nerv Super Rediviva. **58**(3): 77–82.
22 Solarikova P, Brezina I, Turonova D, Rajcani J (2016). Anxiety and sympathetic response to stress in allergic patients. Act Nerv Super Rediviva. **58**(3): 88–94.
23 Steimer T (2002). The biology of fear-and anxiety-related behaviors. Dialogues Clin Neurosci. **4**(3): 231–249.
24 Takahashi T, Ikeda K, Ishikawa M, Kitamura N, Tsukasaki T, Nakama D, Kameda T (2005). Anxiety, reactivity, and social stress-induced cortisol elevation in humans. Neuro Endocrinol Lett. **26**(4): 351–354.
25 Yerkes RM & Dodson JD (1908). The relation of strength of stimulus to rapidity of habit-formation. J Comp Neurol. **18**: 459–482.