PSYCHOPHYSIOLOGICAL RESPONSES TO DISTRESS AND EUSTRESS

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PhD dissertation

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2015

1 THEORETICAL BACKGROUND

Living organisms are in a constant struggle of adaptation with various external and internal challenges, known as stressors. Stress, in a broad sense, is the physiological and psychological adaptation to these factors (Lovallo and Thomas, 2000). The physiological response to stress is orchestrated by the allostatic system, and affects the whole body (McEwen, 2003). The most important components of the allostatic system are the hypothalamus-pituitary-adrenocortical (HPA) axis and the autonomous nervous system (ANS) (Chrousos, 1997). While the ANS can be measured in several ways, the most widespread method to measure HPA activity is the assessment of cortisol level.

Early research regarded the stress response generic, and dismissed the idea of response specificity (Selye, 1956). Later it was suggested that stress reaction cannot be purely reflexive, and should be mediated or moderated by the features of the stressor, and the personal experience of stress (Mason, 1968). As it was later proven, certain stressors are more likely to produce stress than others, and individuals differ in their reactivity to stressful stimuli (Dickerson and Kemeny, 2004; Meaney et al., 1993).

Most everyday stressors are psychological in nature, as they challenge our equilibrium because of their perceived potential for harm. Cognitive appraisal processes mediate between the stressors and the development of stress (Lazarus and Folkman, 1984). Evidence from several studies yielded, that the loss of control, unpredictability, and social threat are the most potent drivers of stress response in laboratory studies (Denson et al., 2009). Challenges that are perceived as controllable or do not pose threat do not increase cortisol level, despite that they elicit similar levels of physiological arousal as distressing tasks (Frankenhaeuser et al., 1980; Lovallo and Pincomb, 1990). Controllable performance tasks that caused no distress were also found to be associated with positive emotions. This positive psychological response to a stressor was identified as eustress, or positive stress (Simmons and Nelson, 2001). Although the concept of eustress has been known for decades, very few studies have attempted to explore it. Thus our understanding about eustress is very limited. We believe that by investigating the positive outcomes of stress, we could gain novel insights about stress as a whole (Nelson and Cooper, 2005).

2 OVERVIEW OF THE DISSERTATION

The dissertation is focusing on the concept of stress, and in particular the phenomenon of stress response specificity and individual response stereotypy (Stern and Sison, 1990). In other words, how different stressors can elicit different physiological responses, and how individual characteristics affect the way we respond to stressors.

The four central chapters of the dissertation contain two experimental studies, a meta-analysis, and a cross-sectional study. Despite the topics of these chapters are not being closely related to each other, they share several characteristics. All of these studies use biological stress markers and psychophysiological methods to investigate the stress response, thus mapping the interconnections between biological and psychological factors in stress. The second, third, and fourth chapters investigate stressors that differ in the way they activate the stress system, i.e. showing stress response specificity. Moreover, these studies all deal with acute stress. The third and fifth chapters both deal with individual differences in stress responses.

The first chapter provides a general introduction and theoretical background for the rest of the dissertation.

The second chapter presents how two common acute laboratory stressors – the cold pressor task and memory-search task – affect the autonomic nervous system and glandular secretion of salivary alpha-amylase. This enzyme is considered a promising candidate of sympathetic nervous system activity, and therefore receives a lot of attention in stress research nowadays.

The third chapter investigates how a challenging laboratory competition affects the autonomic nervous system, the stress system and the adrenal-pituitary-gonadal system that has a well-known role in competitive behavior. We furthermore investigated how competitive attitudes can be related to testosterone responses and performance.

The fourth chapter is a meta-analysis about acute cortisol responses to a popular eustressor, video gaming. As video gaming is sometimes regarded as stressful experience and researchers has been using them occasionally as acute stressors in studies, a meta-analysis was long overdue to clarify if video games can elicit stress responses.

The fifth chapter presents findings about how the functioning of the HPA system – as indexed by the cortisol awakening response – can be associated with recurring nightmares. This study is the most different from the others as it measures longer term effects, uses a cross-sectional design, and a non-laboratory ecological setting. Nevertheless, this study can bring a broader understanding about how the stress system can be associated with psychological processes.

The last chapter summarizes results and draws conclusions about the findings.

3 SUMMARY OF THE FINDINGS

The main objective of this dissertation was to demonstrate how different stressors can invoke dissimilar psychophysiological responses, and how individual differences can moderate these reactions. Moreover, we endeavored to explore the differences in physiological reactions between distress and eustress. To this end, we conducted four studies to investigate these topics.

The first study (Chapter 2) was a laboratory experiment that showed how the sympathetic and parasympathetic nervous system activity can be modulated differently by two common acute laboratory stressors – a cold pressor task and memory-search task in a sample of thirty-four young adults.

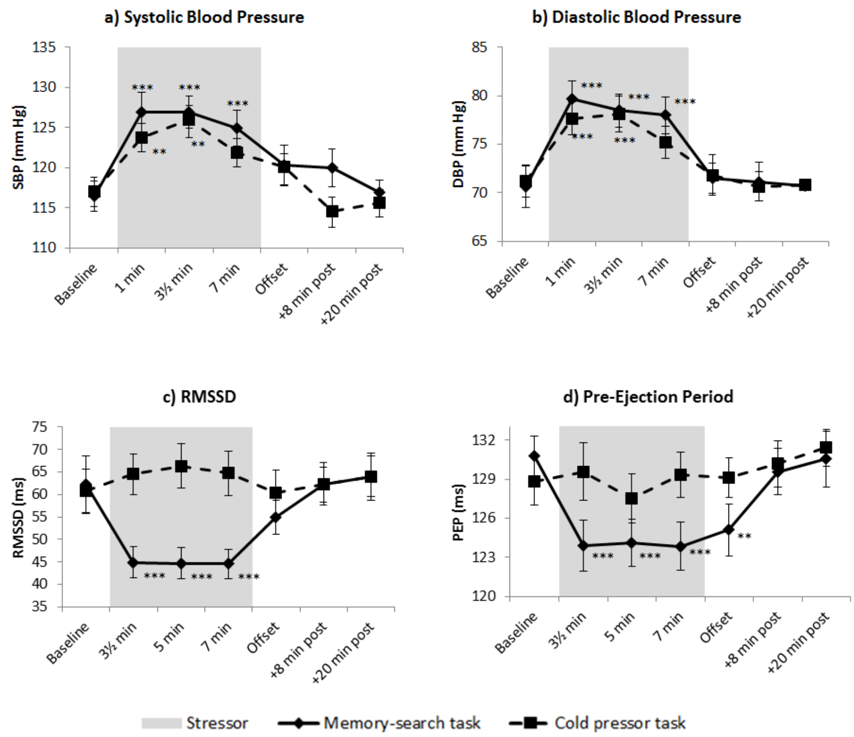

Figure 3.1: **Cardiovascular parameters (Mean ± SE) during Memory-search Task and Cold Pressor Task.** Asterisks indicate significant pair-wise differences from baseline values respectively, using Sidak correction; the timings on the x-axis indicate the end of each 2-minute ECG/ICG epoch. **p < .01, ***p < .001

We found that the two tasks increased anxiety, but the physiological responses were different. The memory-search task elicited a classic fight-or-flight response, while the cold pressor task only increased blood pressure; thus effects on both the sympathetic nervous system

(SNS) and parasympathetic nervous system (PNS) were dissimilar for the two laboratory stressors.

As it was demonstrated, the two branches of autonomic nervous system affect glandular secretion differently. While the PNS is responsible for controlling salivary flow, the SNS controls protein production. Although salivary alpha-amylase (sAA) production is supposed to reflect SNS activity, this research demonstrated that the PNS can indirectly influence sAA secretion through salivary flow. Moreover, as the SNS and PNS show asynchronous changes during acute stressors, sAA response may thus vary with sample timing. Our conclusion is that that sAA changes can be timing-dependent and stressor-specific, thus researchers should take caution when interpreting sAA responses as markers of SNS activity.

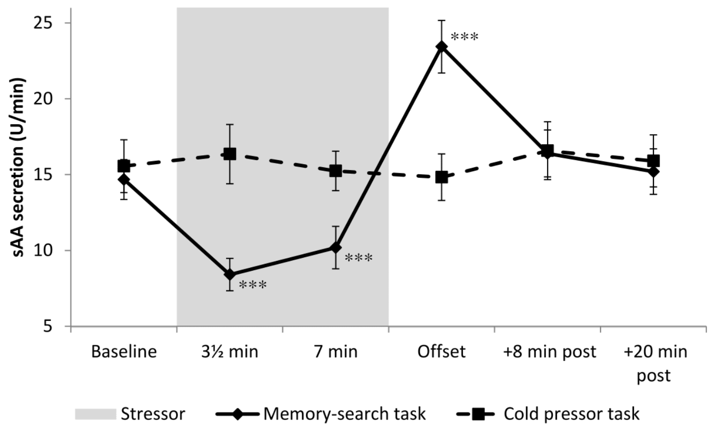

Figure 3.2: **Salivary alpha-amylase secretion (Mean ± SE) during Memory-search Task and Cold Pressor Task.** ***$p < .001$, representing Sidak corrected difference from baseline values. The timings on the x-axis indicate when each 2-minute saliva collection finished.

The second laboratory study (Chapter 3) investigated the effects of reward in a competition on the autonomic nervous system (ANS), the hypothalamus-pituitary-adrenal (HPA) and hypothalamus-pituitary-gonadal (HPG) axes in a sample of forty young males. Competition had been shown to affect all of these systems, but little is known about the psychophysiological effects of rewards. Moreover, it was also examined if the attitudes towards competition can moderate these reactions. We found that subjective and cardiac arousal was increased during competition, and participants in the unequally rewarded condition (whereby the winners gained more money than losers) were more aroused in the beginning of competition.

In the unequally rewarded group, losers showed higher cortisol (C) levels, and C was associated with competitive performance in both winners and losers. Testosterone (T) level only increased in hyper-competitive losers. Competitive performance however was correlated with both winners' and losers' T values, supporting the hypothesis that T level and the competitive performance are likely to be in a reciprocal relationship. Our findings supported the status instability hypothesis, and provided novel insights to competitive psychoendocrinology.

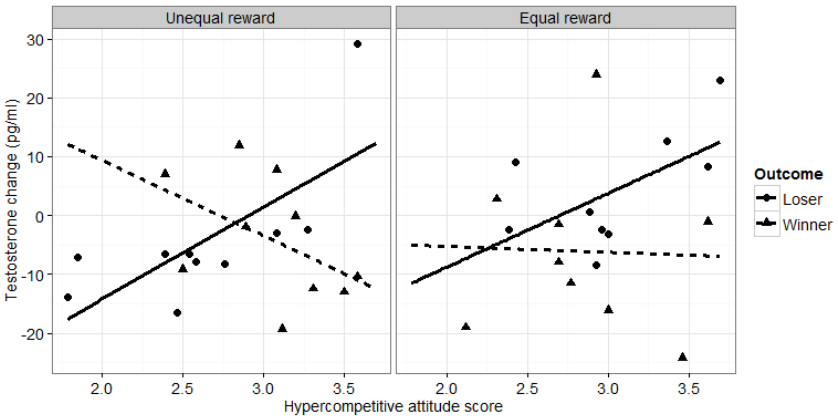

Figure 3.3: **Association between hypercompetitive attitude and testosterone change in winners and losers by reward condition.** Error bars represent standard error.

In the second study, we used a video gaming competition that elicited positive mood. Prior research had suggested that mood might influence C response, therefore we wanted to investigate if eustress exerts a different HPA reaction than distress. That is why in the third research (Chapter 4), we wanted to summarize findings about the effects of eustress on the HPA axis in a meta-analysis. However, we had to realize that there is a lack of studies regarding eustress.

Based on earlier research, we concluded that eustress can be induced in performance tasks that can optimally fit the task demands to personal skills, and elicit positive emotions. As video games are purposefully designed to attain these characteristics, we chose this activity as a model situation for eustress. We conducted a multi-level mixed-effects meta-analysis on twenty-four studies. Results yielded that during video gaming, cortisol levels decreased over time.

Individual characteristics, game attributes, violence, and competition in the game did not predict effect size. These findings suggest that video gaming did not activate the HPA axis, and cortisol level followed the normal diurnal decline. Therefore we concluded that eustress is not likely to elicit the same HPA reaction as distress.

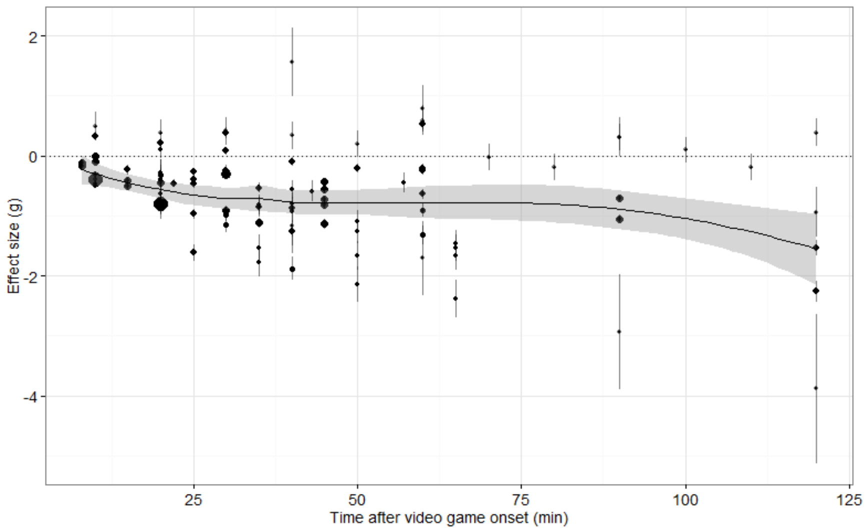

Figure 3.4: **Effect sizes against sampling times.**The solid line represents a smoothed spline function weighed by study size that predicts the average effect over time. Point size corresponds to base 10 logarithm of the sample size. Error bars represent 95% CI. Gray area represents the 95% CI of the function.

The fourth study (Chapter 5) was a cross-sectional research in an ecological setting that aimed to explore the associations of HPA functioning with emotional processes. In this study, we investigated the relationship between the cortisol awakening response (CAR) – that is used as an index of general responsiveness of the HPA system – and recurring nightmares. Nightmares are relatively common sleep complaints that seem to be associated with affective distress, but few attempts had been made to link nightmares to the biological markers of stress, and the HPA response in particular. 188 women provided seven cortisol samples over the course of a working and a leisure day. Analysis revealed that those who reported frequent nightmares ($N = 13$) showed a blunted CAR on a working day, compared to those who did not report nightmares, independent of psychiatric symptoms, demographic variables, and lifestyle.

This finding suggested that decreased HPA reactivity might be a trait-like feature of women with frequent nightmares. We believe that this study can help to bring a broader understanding about how individual differences in HPA functioning can be associated with psychological processes and emotional experiences. In the context of the dissertation, these findings suggest that individual differences in HPA functioning might be associated with alterations in emotional states. This can remind us that the correlation between emotions and stress responses can go both ways. In other words, not just emotional responses can trigger physiological responses but physiological responses can also influence affective states.

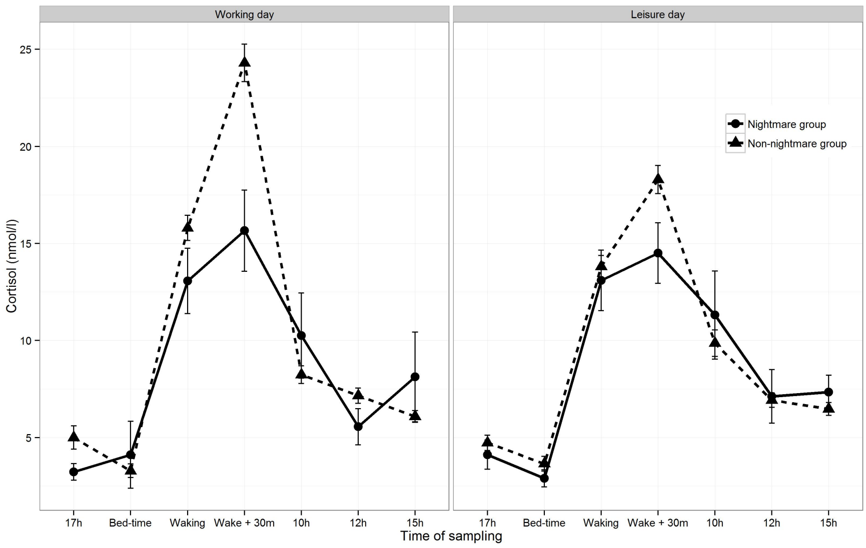

Figure 3.5: **Diurnal cortisol levels of women having frequent nightmares (N=13), and without frequent nightmares (N=175) on a working and a leisure day.** Data points represent untransformed values, error bars represent SEM.

4

IMPLICATIONS OF THE FINDINGS

In the last decade, the interest in the health consequences of positive emotions has grown rapidly (Cohen et al., 2006; Dockray and Steptoe, 2010; Seligman, 2008). Findings suggest that positive emotional states exert a protective effect on health, but the mediators are currently not well understood. Physiological, behavioral, socioeconomic, and lifestyle related factors can all be implicated in this relationship (Cohen et al., 2006; Marsland et al., 2007; Pressman and Cohen, 2005; Steptoe et al., 2005).

Stress and coping processes should also partly explain the connection between positive affect and health. It seems like stress reactions may differ in the presence of positive emotions, and this response can be independent of negative emotions (Bostock et al., 2011; Dockray and Steptoe, 2010). These findings demonstrate that the investigation of positive emotions can yield important insights for human health and longevity (Danner et al., 2001). However, currently we lack solid evidence that positive emotions are truly the causes of beneficial health outcomes, as most of the findings are based on correlational studies (Cohen et al., 2006; Marsland et al., 2007).

Clearly, more experimental research is needed, whereby emotional states are systematically manipulated to verify the effects of positive affect on health outcomes. For example it would be interesting to see how participants of different stress level can profit from the short term effects of eustress. Furthermore, identifying the key characteristics of eustress inducing activities would help us to construct more effective interventions. It would be important to establish methods for the elicitation of eustress to be able to build studies that investigate short and long term effects of positive reactions to a stressor.

In this dissertation, we hope to have provided new findings and methodologies to facilitate the research of stress, and particularly the differences in the ways we respond to distress and eustress.

BIBLIOGRAPHY

Bostock, S., Hamer, M., Wawrzyniak, A. J., Mitchell, E. S., and Steptoe, A. (2011). Positive emotional style and subjective, cardiovascular and cortisol responses to acute laboratory stress. *Psychoneuroendocrinology*, 36(8):1175–1183.

Chrousos, G. P. (1997). Integration of the Adaptive Response The 1997 Hans Selye Memorial Lecture. (301):311–335.

Cohen, S., Alper, C. M., Doyle, W. J., Treanor, J. J., and Turner, R. B. (2006). Positive emotional style predicts resistance to illness after experimental exposure to rhinovirus or influenza a virus. *Psychosomatic medicine*, 68(6):809–15.

Danner, D. D., Snowdon, D. a., and Friesen, W. V. (2001). Positive emotions in early life and longevity: findings from the nun study. *Journal of personality and social psychology*, 80(5):804–13.

Denson, T. F., Spanovic, M., and Miller, N. (2009). Cognitive appraisals and emotions predict cortisol and immune responses: a meta-analysis of acute laboratory social stressors and emotion inductions. *Psychological bulletin*, 135(6):823–53.

Dickerson, S. S. and Kemeny, M. E. (2004). Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. *Psychological bulletin*, 130(3):355–391.

Dockray, S. and Steptoe, A. (2010). Positive affect and psychobiological processes. *Neuroscience and biobehavioral reviews*, 35(1):69–75.

Frankenhaeuser, M., Lundberg, U., and Forsman, L. (1980). Dissociation between sympathetic-adrenal and pituitary-adrenal responses to an achievement situation characterized by high controllability: Comparison between type A and type B males and females. *Biological Psychology*, 10(2):79–91.

Lazarus, R. S. and Folkman, S. (1984). *Stress, appraisal, and coping*. Springer Publishing Company, New York.

Lovallo, W. R. and Pincomb, G. (1990). Heart rate reactivity as a predictor of neuroendocrine responses to aversive and appetitive challenges. *Psychosomatic medicine*, 52(1):17–26.

Lovallo, W. R. and Thomas, T. L. (2000). Stress hormones in psychophysiological research. In Cacioppo, J. T., Tassinary, L. G., and Berntson, G. G., editors, *Handbook of Psychophysiology*, pages 342–367. Cambridge University Press, 2nd ed. edition.

Marsland, A., Pressman, S., and Cohen, S. (2007). Positive affect and immune function. In *Psychoneuroimmunology*, pages 761–779. 4th editio edition.

Mason, J. W. (1968). A Review of Psychoendocrine Research on the Sympathetic-Adrenal Medullary System. *Psychosomatic Medicine*, 30:565–808.

McEwen, B. S. (2003). Interacting mediators of allostasis and allostatic load: towards an understanding of resilience in aging. *Metabolism*, 52:10–16.

Meaney, M. J., Bhatnagar, S., Larocque, S., McCormick, C., Shanks, N., Sharma, S., Smythe, J., Viau, V., and Plotsky, P. M. (1993). Individual differences in the hypothalamic-pituitary-adrenal stress response and the hypothalamic CRF system. *Annals of the New York Academy of Sciences*, 697:70–85.

Nelson, D. and Cooper, C. L. (2005). Guest editorial: Stress and health: A positive direction. *Stress and Health*, 21(2):73–75.

Pressman, S. D. and Cohen, S. (2005). Does Positive Affect Influence Health ? *Psychological Bulletin*, 131(6):925–971.

Seligman, M. E. (2008). Positive Health. *Applied Psychology*, 57(s1):3–18.

Selye, H. (1956). *The stress of life*. McGraw-Hill, Columbus.

Simmons, B. L. and Nelson, D. L. (2001). Eustress at work: the relationship between hope and health in hospital nurses. *Health care management review*, 26(4):7–18.

Steptoe, A., Wardle, J., and Marmot, M. (2005). Positive affect and health-related neuroendocrine, cardiovascular, and inflammatory processes. *Proceedings of the National Academy of Sciences of the United States of America*, 102(18):6508–12.

Stern, R. M. and Sison, C. E. (1990). Response patterning. In Cacioppo, J. T. and Tassinary, L. G., editors, *Principles of Psychophysiologyiology: Physical, social, and inferential elements*, pages 193–215. Cambridge University Press, New York.

LIST OF PUBLICATIONS RELATED TO THE DISSERTATION

CONFERENCE PAPERS AND POSTERS

Nagy, T., van Lien, R., Willemsen, G., Proctor, G., Efting, M. , Fülöp M., Bárdos, G., Veerman, E.C.I., Bosch, J.A. (2014). The role of sample timing in salivary alpha-amylase responses to acute stress. *International Journal of Behavioral Medicine*, Volume 21, Issue 1 Supplement, pp 148.

Nagy, T., Kekecs, Z., Bárdos, G., Fülöp, M. (2014). Stress without distress: meta-analysis of the physiological stress response to video gaming. *International Journal of Behavioral Medicine*, Volume 21, Issue 1 Supplement, pp 211.

Nagy, T., Kekecs, Z., Bárdos, G., Fülöp, M. (2014). Not all stressors are created equal: eustressors do not increase cortisol level. *A Magyar Pszichológiai Társaság XXIII. Országos Tudományos Nagygyűlése.* pp 270.

Nagy , T., Harmat, L., Kovács, K. J., Polyák, Á., Bárdos, Gy., Fülöp, M. (2012). Versenyhelyzetben használt jutalmazási feltételek hatása a kardiovaszkuláris és endokrin mutatókra. A Magyar *Pszichológiai Társaság XXI. Országos Tudományos Nagygyőlése*. pp 402.

Nagy , T., Harmat, L., Kovács, K. J., Polyák, Á., Bárdos, Gy., Fülöp, M. (2012). Eustresszt előidéző helyzet pszichofiziológiai és endokrinológiai vizsgálata. *A Magyar Pszichológiai Társaság XXI. Országos Tudományos Nagygyőlése.* pp 146-147.

Nagy , T., Kovács, K. J., Harmat, L., Polyák, Á., Bárdos, Gy., Fülöp, M. (2012). Élvezetes videójáték verseny csökkentette a kortizol szintjét fiatal felnőtt férfiak esetében. Kálmán Erika Doktori Konferencia, pp 18-20.

Nagy , T., Harmat, L., Kovács, K. J., Polyák, Á., Bárdos, Gy., Fülöp, M. (2012). Eustress induced by competition decreases salivary cortisol levels in healthy young males. *International Journal of Behavioral Medicine, Volume 19, Issue 1 Supplement, pp 63-64.*

Nagy T. (2012). A bioszociális versengés modelltől a kognitív komponensekig: hogyan hat a motiváció típusa a kardiovaszkuláris mutatókra versengő helyzetben? *EGYÜTTMŰKÖDÉS – VER SENGÉS – MACHIAVELLIZMUS: Kutatások az emberi kapcsolatok alaptermészetéről és kulturális sajátosságairól.*

Nagy T. (2011). Versengő helyzetek fiziológiai és pszichológiai vizsgálata a pozitív stressz kiváltására való alkalmasság szempontjából. Poszter. Hagyomány és megújulás. *A Magyar Pszichológiai Társaság Jubileumi XX. Országos Nagygyűlése.* Május 25-27, Budapest. pp. 219-220.

JOURNAL ARTICLES

Nagy, T., van Lien, R., Willemsen, G., Proctor, G., Efting, M., Fülöp, M.,Bárdos, G., Veerman, E.C.I., Bosch, J. A. (2015). A fluid response: Alpha-amylase reactions to acute laboratory stress are related to sample timing and saliva flow rate. *Biological Psychology*, 109, 111–119. doi:10.1016/ j.biopsycho.2015.04.012

Nagy , T., Kovács, K. J., Polyák, Á., Harmat, L., Bárdos, G., Fülöp, F. (2015). A versengés jutalmazásának hatása a nyáltesztoszteronszintre és a teljesítményre fiatal felnőtt férfiakban: A hiperversengés szerepe [The effect of reward on salivary testosterone level and performance in young adult males during competition: the role of hypercompetitiveness]. *Magyar Pszichológiai Szemle*, 70(1), 121–141. doi:10.1556/0016.2015.70.1.8

Nagy, T., Kekecs, Z. (under preparation). The pursuit of eustress: Meta-analysis of the effects of video gaming on cortisol level.

Nagy, T., Salavecz, G., Simor, P., Purebl, G., Bódizs, R., Dockray, S., & Steptoe, A. (2015). Frequent nightmares are associated with blunted cortisol awakening response in women. *Physiology & Behavior*, 147, 233–237. doi:10.1016/j.physbeh.2015.05.001

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