stress, cortisol, music therapy,
mental workload, psychoneuroendocrinology

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EFFECT OF MUSIC ON THE SECTRETION OF SALIVARY CORTISOL AFTER THE REMOVAL OF SHORT-TERM STRESSFUL TASK

Our experience tells us the power of music on human body and mind. Moreover a series of psycho-physiological studies has revealed the positive effects of music on human autonomous nervous system such as alleviating the symptom of the hypertension. However little has been known about the effects of music on human endocrine system, which plays the dominant role for forming our life. In this study, the effect of music on the secretion of the salivary cortisol, a major glucocorticoid hormone, was investigated in a laboratory experiment. In a stream of stress psycho-physiological study, cortisol is considered as a feasible stress biomarker. In the experiment ten healthy male students were exposed to music, noise, and silence condition followed by a simple but stressful calculation task. As a result, the significant difference in the cortisol responses among the condition was observed; the salivary cortisol was decreased after the music treatment. This result plausibly demonstrated the effects of music on human hormonal secretion and might imply the power of music.

1. INTRODUCTION

1.1. EFFECTS OF MUSIC ON HUMAN BODY AND MIND

It is needless to say that music has strong positive effect on human mind. A full battery of psychological studies has repeatedly emphasized the power of music as such the relaxing music alleviates subjective anxiety, depression, and even bodily pain. Moreover many attempts have also been made for evaluating the power of music on human body. Almost all these studies employed the autonomic nervous system related indices as for the metric to evaluate the effects of music, such as blood pressure, heart rates, respiratory, etc., and reported sedative effects of music in the clinical population (e.g., [1]). The music has been proved to have strong effects on human somatic and mental states; these simple facts support the importance of music in our life. However with regard to the effects on human body, few studies attempt to evaluate the human biochemical states inside our body, which are the endocrine and immune system related indices. Because, as described later, the human secretion of biochemical substances has been recently revealed to change in responding to his/her mental state sensitively, music is also expected to have strong effects on these systems. These biochemical substances, which are the hormones and immune substances, play a quite important and substantial role for maintaining our health. Therefore it must be valuable to investigate the effects of music on human biochemical secretion toward application for music such as music therapy.

1.2. STUDIES ON BIOCHEMICAL SECRETION AND HUMAN MIND

Recent development of the molecular analysis techniques enables scientists to assess tiny amount of substances containing in the human secretory fluids, such as blood, urine, breast milk and saliva. It has been revealed that some hormones and immune substances secreted within human body change its level in responding to human mental state. For instance, salivary cortisol shows a transient increase against “acute” psychological stressors such as a job interview and cognitive task with performance pressure [2]. Thus such a biochemical substance can potentially be a practical biomarker for human mental stress. Currently numbers of such possible biomarkers have been reported in broad field of studies [3,4], and it forms a new interdisciplinary research fields called psychoneuroendocrinology (PNE) and/or psychoneuroimmunology (PNI) [5] (hereafter, we use a term PNEI to indicate for both of PNE and PNI). PNEI must be a contributory research field by which possibly establishes a “practical” criterion for objective evaluation of human mental state. However, because PNEI is rather new field of study and the dominant target of these studies is objective evaluation of human *mental stress*, on the other hand few studies have focused on the evaluation of positive state. Some studies focused on the effect of music on immune secretion but the results were still inconsistent; for example, a relaxation music peace prevents stress-induced increase of an immune substance (Immunoglobuline A: IgA) [1], meanwhile the same substance was reported to increase by music exposure [6] or musical activity [7].

On the other hand, in this study, we focused on salivary cortisol, which is known to be a feasible “acute” stress marker. We assumed that the cortisol would be a possible biomarker for the effect of music, because it is considered to reflect the different physiological stress reaction pathway from that of IgA. In the next, we briefly describe about the cortisol, its theoretical background and past studies as a stress biomarker, and the purpose of this study.

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2. SALIVARY CORTISOL

Cortisol is a major glucocorticoid secreted from adrenal cortex playing a quite important role for maintain our body, e.g., keeping blood glucose level adequately. On the other hand, when human faces a stressful situation it is known that the two mode of physiological stress reaction pathway are activated; 1) hypothalamus–pituitary–adrenal (HPA) systems and 2) sympathetic nerve – adrenal medulla (SAM) system; IgA is considered to change reflecting the activity of this system [2]. Because cortisol is released into blood stream via activation of HPA system and a significant positive correlation has been obtained between salivary and blood cortisol, salivary cortisol is assumed as a possible stress biomarker. However it should be noted that because the stress reaction of HPA system is truly complicated and potentially mediated by variety of physiological factors, the salivary cortisol cannot be taken as a direct measure of HPA system itself but as rather "indirect" measure [7].

In the past cortisol studies, a transient increase of salivary cortisol was observed by short-term stressors, such as mental arithmetic, stroop task, and oral presentation [2, 8]. Moreover it was reported that salivary cortisol also increased daily and/or chronic stressful events, such as job stress [9], job loss [10], and divorce [11]. Therefore salivary cortisol can be a possible short- and long-term stress marker.

On the other hand, the investigations on the effect of rather positive target including relaxing music with employing cortisol, or even other biomarkers, produced rather inconsistent results. However some review articles in PNEI concluded that, in the studies targeting on the relaxing factors, it is necessary to assess biomarkers under or just after stressful situation rather than merely by an exposure of such relaxing factors. It seems rational because *relaxation* can largely be context dependent as such a particular music peace would make one relax while the same music peace would disturb him/her when he/her is in busy on their business.

We then conducted a laboratory experiment, in which subjects went through relaxing music following a stressful situation, by introducing salivary cortisol as a biomarker for the effect of music.

3. METHOD

Subjects, ten healthy male university student who was from 25 to 33 in their age, were instructed to conduct 30 minutes of stressful mental workload followed by 7 minutes of exposure of music, noise, or silence (Fig. 1). The stressful mental workload was a single digit addition task repeatedly presented on the PC monitor. The procedure was very similar to so-called Kraepelin psychodiagnostic test. Subjects were instructed to conduct an addition of two succeeding numbers presented on the PC monitor from end to end with inputting each answer by keyboard. This procedure was repeated again and again with changing the initial number set. Subjects were instructed to conduct this task as fast and much as possible. This type of cognitive task has frequently been employed to the psycho-physiological studies focusing on the stress. With regard to the music, an instrumental smooth music peace, which was annotated one of the most relaxing ones by the subjects before the experiment, was selected and presented in 60dBA. White noise with also 60dBA was prepared for noise condition. When the music, noise, and silence exposure was started, subjects were instructed to stop the task immediately and site in the same position with closing eyes.

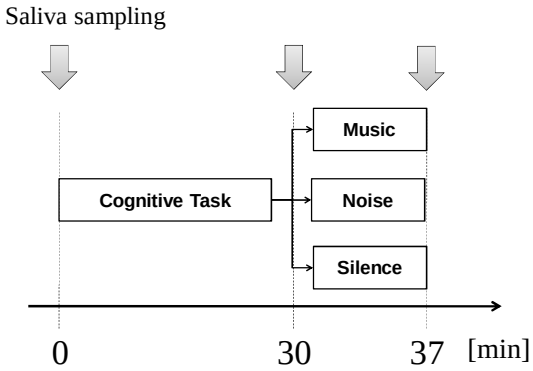

Fig. 1. Schema of the experiment

Each subject daily experienced one of the three types of experimental procedures: task-music, task-noise, and task-silence. The order of the experiments was counterbalanced. All experiments were individually conducted in a dark, soundproof room.

Saliva samples were taken by small cotton before/after the task, and after each music, noise, or silence experience. Salivary cortisol concentration was determined by enzyme-linked immunosorbent assay (ELISA) (Cortisol Elisa Kit #EA 65, Oxford Biomedical Research, Inc., USA).

4. RESULT

The average cortisol concentration of post-stress did not change significantly. The average (*SD*) cortisol concentration of pre- and post-stress was 0.78 (0.45) and 0.66 (0.39) [ng/mL]. Figure 2 shows the average change in the salivary cortisol concentration from post-stress to post-treatment of music, noise, and silence, where the error bar represents standard error. A two-way analysis of variance (*ANOVA*) on 2×3 (time × treatment) indicated the significant main effects of treatment ($p<0.01$). As for a further analysis, a post hoc Least Significant Difference test was applied and obtained significant differences between music and silence conditions ($p<0.01$) and between noise and silence conditions ($p<0.05$). On the other hand, saliva volume taken by small cotton did not change. Moreover it has no linear correlation with cortisol concentration. Therefore the change in the salivary cortisol concentration observed in this study would not attribute to the change in water contained in saliva itself.

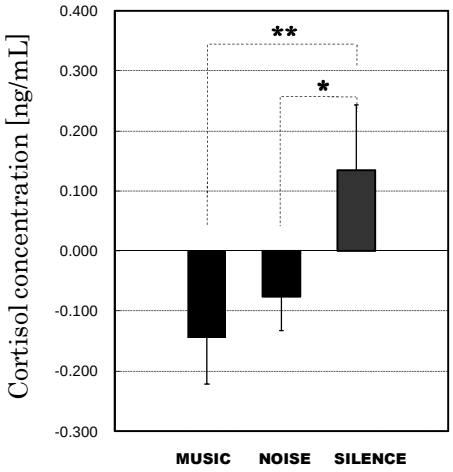

Fig. 2. The change in the salivary cortisol after the cognitive task (** $p<0.01$, * $p<0.05$)

5. DISCUSSION

By the simple cognitive task introduced in this experiment no significant change in salivary cortisol concentration was observed. However it should be noted that this does not mean the task was not stressful for subjects. Dickerson et al. reviewed more than 200 laboratory researches on cortisol and concluded that the cortisol can be feasible biomarker for the *acute* stressors, which are as typified by the cognitive task with strong threat or performance pressure (e.g., job interview and the cognitive task with psychological evaluation), meanwhile the cortisol response derived by rather *passive* stressors, e.g., strop task and mental arithmetic task without any performance pressure, showed inconsistent results and it cannot be a useful biomarker for the passive cognitive task, even though it were subjectively stressrull [8]. On the other hand these passive stressors are well known to increase salivary IgA concentration [12], while this is out of scope of this study.

The difference in the cortisol response in music, noise, and silence condition was intriguing. When one assumes the cortisol level represents human physiological stress level, the decrease of cortisol in the music condition was very consistent with past psychological studies, or the empirical fact in our daily life. However unexpectedly cortisol increased in the silence condition and by contrast decreased in the noise condition. A possible explanation can be given for this result: (1) in the silence condition, subjects might be frustrated because they cannot allow moving during 7 minutes, and (2) the magnitude of noise sound was too small to make subjects frustrate but was taken rather calm sound environment. Unfortunately we did not conducted any psychological questionnaire because we had assumed that the effect of answering time for the standardized psychological questionnaire on the secretion of cortisol would not be negligible, however the two above mentioned points was claimed by several subjects after the experiment.

We have to admit there must be uncountable potential mediators affecting the change in biomarkers, e.g., personality [14], sex and age. Also, the preference of music should be taken into account for future work. In addition, the effect of music on variety of possible biomarkers, such as IgA, cortisol, chromogranin A (CgA), amylase, dehydroepiandrosterone (DHEA), dehydroepiandrosterone sulfate (DHEA-S), and testosterone (TE) [15-18] which are considered to reflects HPA and/or SAM stress reaction pathways, must be investigated for further discussion.

6. CONCLUSION AND FUTURE WORK

We conducted a laboratory experiment focusing on the effect of music on salivary secretion of cortisol. Although some experimental limitation made it difficult to interpret the result of this study, the simple fact of which the music bring forth the decrease of salivary cortisol plausibly implies the effect of music on human hormonal secretion.

The biomarkers are not merely a measure of human psycho-physiological states, but each of them has its own biological functions. For example, IgA is one of the most important immune substances and cortisol is a steroid hormone taking part in controlling blood pressure and blood sugar. Therefore, further studies promises to bring a better understanding of the effect of "music" on the aspect not only of the mediator of psychological mood but also that of biological function.

BIBLIOGRAPHY

[1] KNIGHT W.E. and RICKARD N.S. (2001) "Relaxing Music Prevents Stress-Induced Increase in Subjective Anxiety, Systolic Blood Pressure, and Heart Rate in Healthy Males and Females," Journal of Music Therapy, vol. 38(4), pp.254-272.

[2] KIRSCHBAUM, C & HELLHAMMER, D.H. (1994) Salivary cortisol in psychoneuroendocrine research: recent developments and applications. Psychoneuroendocrinology, 19(1), 313-333.

[3] WAKIDA, S., TANAKA, Y., and NAGAI., H. (2004)High Throughput Screening for Stress Marker. Bunseki, 2004, 309-316.

[4] IZAWA, S., ShirotSuki, K., SUGAYA, N., OGAWA, N., SUZUKI, K., and NOMURA, S.(2004) The application of saliva to an assessment of stress: procedures for collecting and analyzing saliva and characteristics of salivary substances. Japanese Journal of Complementary and Alternative Medicine.4(3), 91-101.

[5] ADER, R., FELTEN, L. and CoHen, N. (Eds.) (2001) Psychoneruoimmunology. 3rd ed. Academic Press.

[6] CHARNETSKI C.J. and BENNAN Jr F.X., (1998) "Effect of Music and Auditory Stimuli on Secretory Immunoglobulin A (IgA)," Perceptual and Motor Skills, vol. 87, pp.1163-1170.

[7] KUHN, D., "The effects of active and passive participation in musical activity on the immune system as measured by salivary immunoglobulin A (SIgA)," Journal of Music Therapy, vol. 39(1), pp.30-39, 2002. Hellhammer, D.H., Wüst, S. and Kudielka, B.M. (2009) Salivary cortisol as a biomarker in stress research. Psychoneuroendocrinology, 34(2), 163-171.

[8] DICKERSON, S.S. & KEMENY, M.E. (2004) Acute Stressors and Cortisol Responses: A Theoretical Integration and Synthesis of Laboratory Research. Psychological Bulletin, 130(3), 335-391.

[9] STEPTOE. A, CROPLEY. M, GRIFFITH. J, KIRSCHBAUM, C. (2000) Job strain and anger expression predict early morning elevations in salivary cortisol. Psychosomatic Medicine, 62(2), 286-292.

[10] OCKENFELS, M.C., PORTER, L., SMYTH, J., KIRSCHBAUM, C., HELLHAMMER, D.H. and STONE, A.A. (1995) Effect of chronic stress associated with unemployment on salivary cortisol: overall cortisol levels, diurnal rhythm, and acute stress reactivity. Psychosomatic Medicine, 57(5), 460-467.

[11] POWELL, L.H., LOVALLO, W.R., MATTHEWS, K.A., MEYER, P., MIDGLEY, A.R., BAUM, A., et al. (2002) Physiologic Markers of Chronic Stress in Premenopausal, Middle-aged Women, Psychosomatic Medicine, 64(3), 502-509.

[12] BOSCH J.A., RING C., de GEUS E.J., VEERMAN E.C., and AMERONGEN A.V. (2002) "Stress and secretory immunity," International Review of Neurobiology, vol. 52, pp.213-253.

[13] VALDIMARSDOTTIR H.B. and STONE A.A. (1997) "Psychosocial factors and secretory immunoglobulin A," Critical reviews in oral biology and medicine, vol. 8(4), pp. 461-474.

[14] OHIRA H., et al. (1999) "The Type A Behavior Pattern and Immune Reactivity to Brief Stress: Change of Volume of Secretory Immunoglobulin A in Saliva," Percept. Mot. Skills., vol. 89, pp.423-430.

[15] IZAWA S., et al. (2007) "The Application of Saliva to an Assessment of Stress: Procedures for Collecting and Analyzing Saliva and Characteristics of Salivary Substances," Japanese Journal of Complementary and Alternative Medicine, vol. 4, pp.91-101.

[16] NAKANE H. (1999) "Salivary Chromogranin A as Index of Psychosomatic Stress Response," R&D Review of Toyota CRDL., vol. 34, pp.17-22.

[17] DEGUCHI M. (2006) "Evaluation of Driver Stress Using Motor-vehicle Driving Simulator," IEEJ Trans. Sensors and Micromachines, vol. 126, pp.438-444.

[18] MICHAEL A., et al. (2000) "Altered Salivary Dehydroepiandrosterone Levels in Major Depression in Adults," Biological Psychiatry, vol. 48, pp.989-995.