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Effect of rain sound on mental arithmetic, mood, autonomic nervous activity, and salivary cortisol

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ABSTRACT

Effects of rain sound on mental arithmetic, mood, autonomic nervous activity and salivary cortisol was evaluated, by examining characteristics of autonomic and endocrine system responses to a psychological stressor (Mental arithmetic), along with associated mood change and mental arithmetic performance under rain sound condition and control one, in 24 female college students (18 to 23 years old). We employed profile of mood states and visual analogue scale to assess mood, and employed heart rate variability, systolic and diastolic blood pressure to assess autonomic nervous activity, and salivary cortisol response to mental arithmetic to assess hypothalamo-pituitary adrenal axis reactivity. Repeated measures ANOVA revealed decrease of basal anger-hostility, and decrease of salivary cortisol secretion response to mental arithmetic, along with increased accuracy of mental arithmetic, and with some tendency of sympathetic predominance, under rain sound condition. These results suggest that rain sound would raise arousal level with coolness, and may increase accuracy of mental arithmetic.

Keywords: rain sound; mental arithmetic; profile of mood states; heart rate variability; salivary cortisol

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1. Introduction

Music is reported to improve parasympathetic reactivation and promote a prompt recovery after exercise (Jia, Ogawa, Miura, Ito, & Kohzuki, 2016). It is also reported that natural environments, such as forests and coastlines, can promote stress reduction and assist in mental recovery after acute stress (Depledge, Stone, & Bird, 2011). Proverbio and colleagues (2015) found background auditory processing could affect other perceptual and cognitive processes depending on the emotional value. They also found beneficial effects of rain sound on mental arithmetic performance, and speculated that the effects would be provided by enhanced cerebral alertness induced by the sound (Proverbio, De Benedetto, Ferrari, & Ferrarini, 2018). Ulrich and colleagues (1991) described that natural environment would induce wakeful relaxation and sustain attention. Viewing a nature scene and/or listening to nature sound is a safe, inexpensive method, and is considered to alleviate pain during invasive procedures, such as pain during bone marrow aspiration and biopsy, or postoperative pain (Lechtzin et all, 2010; Bauer et al., 2011). Nature sounds are suggested to facilitate recovery from sympathetic activation after a psychological stressor (Alvarsson, Wiens, & Nilsson, 2010). Gould van Praag and colleagues demonstrated that naturalistic sounds would shift autonomic balance towards parasympathetic activation which reflects restorative effect of the sounds, through the analyses of heart rate variability and fMRI scan (Gould van Praag et al., 2017). Then, background nature sound may be effective to reduce stress or pain and to provide relaxation, and may have some beneficial effects on a cognitive process. Rain sound can easily be provided anywhere as a background sound, and is sometimes used as a tool for relaxation in various scenes (Richards, 1994; Ambient Mixer Home, 2016; Hadhazy, 2016).

Profile of mood states (POMS) is designed to measure a person's affective states, with scores of six subscales, and is thought to be a useful tool for estimating moods repeatedly and has been a popular research tool among psychologists (Yokoyama & Araki, 1994). A visual analogue scale (VAS) is also an effective tool to assess subjective momentary feeling, which varies continuously and cannot easily be directly measured (McCormack, Horne, & Sheather, 1988; Wewers & Lowe, 1990; Gould, Kelly, Goldstone, & Gammon, 2001).

Numerous studies have indicated that a spectral analysis of heart rate variability (HRV) is a powerful tool for evaluating autonomic nervous functions non-invasively (Akselrod et al., 1985; Pomeranz et al., 1985; Pagani et al., 1986; Pagani et al., 1991; Langewitz et al., 1991; Montano et al., 1994; Berger, Saul, & Cohen, 1989). Blood pressure is also considered to be related with autonomic nervous function or mental state (Conway, Boon, Jones, & Sleight, 1983; Steptoe & Sawada, 1989).

Salivary cortisol measurement is a useful tool to evaluate hypothalamus–pituitary– adrenal axis (HPA axis) activity noninvasively (Giles, Mahoney, Brunyé, Taylor, & Kanarek, 2014; Qi, Gao, Guan, Liu, & Yang, 2016).

Then, we studied effects of rain sound on mood and autonomic nervous system in female college students using POMS, and VAS for mood estimation, and HRV, systolic and diastolic blood pressure (BP) for an evaluation of autonomic nervous system, and salivary cortisol for an estimation of HPA axis status, along with mental arithmetic performance for a cognitive process assessment. Numerous studies have demonstrated that autonomic nervous function is modulated by various factors such as a physical stimulus (Yamamoto, Hughson, & Peterson, 1991; Sun, Eiken, & Mekjavic, 1993), and a mental load (Pagani et al., 1991; Langewitz et al., 1991). Therefore, we analyzed responses of autonomic, endocrine and mood to acute psychological stimulus (mental arithmetic), along with basal states under two conditions (rain sound or control).

2. Method

2.1 Participants

The study was approved by The Ethics Committee of our university beforehand, and was performed according to the Declaration of Helsinki. 24 female college students agreed and participated in this study after providing written informed consents. The age of the participants ranged from 18 to 23 years old (*M*±*SD* = 20.58±1.56). They were asked to abstain from eating, drinking and smoking for at least three hours before experiments, and to sleep for 6 hours or more on the previous day. Strenuous exercise and heavy drink on the previous day were also prohibited.

2.2 Procedure

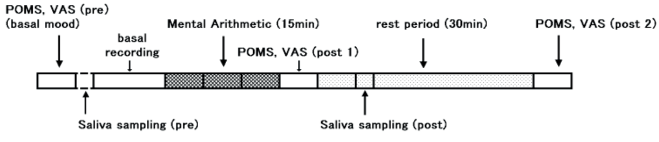

Figure 1. Sequence of experimental procedure

The experimental procedure is shown in Figure 1. Each subject underwent both experiments, an experiment under rain sound condition and that under control one, planned on separate days. The procedure was the same except for sound condition. The order of an experiment under rain sound condition and that under control one was counterbalanced across subjects to minimize habituation effects. The day and time of the two experiments (rain sound and control) was equally planned since mood and autonomic nervous activity could change depending on the day of the week and the time zone (Malliani, Pagani, Lombardi, & Cerutti, 1991). The sound source of rain sound was downloaded from the Website (URL = http://taira-komori.jpn.org/nature01.html). The sound pressure level of rain sound condition was matched to that of previously measured room noise level by adjusting the level of rain sound, to minimize the influences of intensity of the sounds, and level of the intensity was measured on every experiment. Actually measured levels of the intensity were 43.304 ± 1.43 dB under rain sound condition and 43.043 ± 1.331 dB under control one. The experiments were carried out in their follicular phase after the third day of the menses, to minimize the influences of a menstrual cycle which could affect mood and autonomic nervous activity. The experimental room and the around was kept quiet and the room temperature was kept at 22 ± 2 degree Celsius. The subjects were not told about current experimental condition (rain sound condition or control one), to minimize so-called placebo effects. They entered the room already set to either condition and were asked to fill out POMS questionnaires and to write down VAS for an evaluation of their basal mood state. Each subject sat upright on a chair, while disc electrodes were attached for chest electrocardiograms (ECG) with CM5 leads, and a thermistor for detecting respiration was also attached just under one nostril.

Blood pressure was also measured every 5 minutes throughout the experiments with a sphygmomanometer (BP-203X, Colin Japan). Mental arithmetic was addition of 2 two-digit integers from 10 to 99, such as: 87 + 24, which were generated by multiplication of random variable (0 to 1) by 90, accompanied by addition of 10, and rounded down into integer. The addition problems printed on sheets of A4 paper, were continuously provided for 15 minutes, and the subjects were instructed to calculate as fast and accurate as possible, and to mark the point they just finished at 5 minutes and 10 minutes after the start of mental arithmetic period for later analysis. ECG and respiration curves were recorded throughout the experiment. Data were stored on a personal computer equipped with a 12-bit analog-digital converter (ADTM-98, Canopus, Kobe, Japan) for subsequent offline analysis.

Each experiment consisted of six parts: a pre POMS and VAS period of about 5 minutes (pre) followed by basal saliva sampling; basal recording of 10 minutes; mental arithmetic (MA) period of 15 minutes; 1st post POMS and VAS period of 5 minutes (post 1) for an evaluation of whatever mood states were induced by the MA; post-MA rest period of 30 minutes which were interrupted by post MA saliva sampling 10 minutes after MA, and 2nd post POMS and VAS period of 5 minutes (post 2) for an evaluation of current mood states.

Subjects were asked to keep their eyes open and to keep quiet, and not to fall asleep, avoiding any disruptive movements of their heads or hands throughout the experiments

2.3 Measures

Profile of mood states (POMS). — Comprehensive mood was assessed by the POMS which was designed to measure a person's mood states, and includes six subscales: Tension-anxiety; T-A, Depression-dejection; D, Anger-hostility; A-H, Vigor; V, Fatigue; F, and Confusion; C. Subjects are given a score for each trait according to their responses to certain statements which include key words such as unhappy, tense, careless, and cheerful. For each statement, subjects state how they feel at that moment, or how they felt over the previous day, few days, or week, by choosing one of the following responses: not at all; a little; moderately; quite a lot; extremely. Internal consistency for the Profile of Mood States was reported at 0.74, 0.81, 0.85, 0.89, 0.90, 0.73 Cronbach alpha rating for T-A, D, A-H, V, F, C, respectively (Kitaoka-Higashiguchi, Tanimoto, Morikawa, Nakagawa, 2005). Score for each scale was converted into T-score for parametric statistical analysis (Yokoyama & Araki, 1994).

Visual analogue scale (VAS). — Subjective momentary feelings were evaluated by the VAS which was a horizontal line, 100 mm in length, anchored by word descriptions at each end, and a participant marks on the line the point that they feel represents their current feeling state (McCormack, Horne, & Sheather, 1988; Wewers & Lowe, 1990; Gould, Kelly, Goldstone, & Gammon, 2001). Each score was determined by measuring the distance from the left end to the point they marked. The VAS was used for the assessment of concentration and relaxation. Higher ratings on each scale indicated more concentrated and more relaxed.

Heart rate variability (HRV). — Heart rate varies according to respiration and blood pressure variation, and the extent of variation of heart rate is usually dependent on the autonomic nervous activity. HRV can be divided into two main components by spectral analysis, i.e., a high-frequency component (HF) which corresponds to respiratory sinus arrhythmia and reflects parasympathetic nerve activity, and a low-frequency component (LF) which corresponds to Mayer wave related sinus arrhythmia and relates to both sympathetic and parasympathetic nerve activities (Akselrod et al., 1985; Pomeranz et al., 1985; Pagani et al., 1986; Montano et al., 1994; Berger, Saul & Cohen, 1989). Therefore, we can know the level of autonomic nervous activity to some extent by the spectral analysis of HRV.

Blood pressure (BP). — Blood pressure is determined by cardiac output × total peripheral resistance, which are mainly regulated by endocrine system and autonomic nervous system. Short-term control of BP is mainly achieved by sympathetic and parasympathetic activity which will affect diameters of veins and arteries, heart rate and force of cardiac contraction, to adjust blood supply and distribution in the body. Then, systolic and diastolic BP may be influenced by local circulation change, possibly made by vasoconstriction or vasodilatation, along with the change of autonomic nervous activity.

Salivary cortisol (Cortisol). — Salivary cortisol is known to increase after a stressful event and frequently used to monitor stressed level (Giles et al., 2014; Qi et al., 2016). Salivary samples were collected by each subject through a cotton swab (Salivettes®: Sarstedt, Germany) keeping under her tongue for 2 minutes, thereafter, centrifuged at 1500g for 2minutes and frozen at -20 degree Celsius until later analysis. Free cortisol levels were assayed in duplicate, employing Salimetrics® Cortisol Enzyme Immunoassay Kit (Salimetrics, Germany), and determined by a 4 parametric logistic regression analysis according to the manual provided by the Salimetrics®. Those samples whose intra-assay coefficient were over 30% (possibly caused by technical difficulties), were excluded from the analysis.

2.4 Data Analysis

POMS data were summed to generate six sub-scales: T-A, D, A-H, V, F and C. These summed raw scores were converted into T-scores for parametric statistical analysis according to the POMS manual (Yokoyama & Araki, 1994).

ECG data were digitized at a sampling frequency of 1 kHz on a personal computer. After detecting every R-wave peak, consecutive R-R intervals on the ECG were calculated, excluding ectopic beats and abrupt discharges in R-R intervals. Spectral analysis was applied to the time series data of R-R intervals for each 5 min block, using the maximum-entropy method (MemCalc Version 2.5, Suwa Trust) (Ohtomo, Terachi, Tanaka, Tokiwano, & Kaneko, 1994). After calculating the power-spectral density, the magnitude of the power for HRV was obtained by measuring areas under the spectral density curves. The values were divided into two major bands, a low-frequency component (LF; 0.04-0.15 Hz) and a high-frequency component (HF; 0.15-0.5 Hz). Thereafter, the amplitude of each frequency band was calculated as twice the power magnitude and the square root thereof. We considered HF amplitude (HF) as an index of parasympathetic nervous function and LF/HF amplitude (LF/HF) as a marker of relative sympathetic activity (Pagani et al., 1986; Malliani et al., 1991). Systolic

BP and diastolic BP were measured for every 5 min.

Five-minute data just prior to the MA period were used to establish pre-MA basal activity (basal). Fifteen-minute data for the MA period were divided into 3 five-minute blocks, and represented as MA 1, 2, 3. Thirty-minute data for the post-MA period were also divided into 6 five-minute blocks, and represented as post 1, 2, 3, 4, 5 and 6.

2.5 Statistical Analysis

To clarify the effects of rain sound on mood and autonomic nervous function, interactions between condition (rain sound and control: within-subjects variable) and time course (before and after the MA: within-subjects variable) were examined by repeated measures analysis of variance (repeated measures ANOVA). A repeated measures ANOVA is referred to as a within-subjects ANOVA and is suitable to investigate changes in values over time from the same participants, and can examine the difference of trend of values taken under different conditions. Furthermore, paired *t*-test was carried out to know whether the scores changed significantly from pre to post, when repeated measures ANOVA revealed significant interaction. Paired *t*-test was also carried out to know whether the values were different between both conditions at each time point. Effect size (Cohen's d for student's *t*-test, and partial η^2 for repeated measures ANOVA) was also calculated to help readers better understand the importance of the findings in this study (Cohen, 1988; Faul, Erdfelder, Lang, & Buchner, 2007; Mizumoto & Takeuchi, 2008). Statistical analysis was performed on a personal computer using Statview Ver. 5.0 (HULINKS), and differences with a probability value of less than 0.05 were considered significant.

3. RESULTS

3.1 Performance of Mental arithmetic

Figure 2 shows results of MA under rain sound condition and control one. Data from one subject was excluded from the analysis because she fell asleep for a few minutes during MA period. Repeated measures ANOVA revealed no significant interaction of condition (rain sound or control) × change (from 1st- to 3rd-MA session) in number of answers, nor percent of correct answers, but revealed significant main effect of condition in percent of correct answers ($F(1, 22) = 6.63$, $p = 0.0173$, partial $\eta^2 = 0.2314$), that is, percent of correct answers were slightly but significantly higher under rain sound condition.

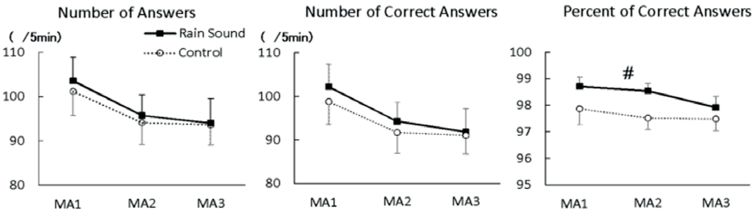

Figure 2. Number of answers, number of correct answers, and percent of correct answers in mental arithmetic period, divided into three 5-minutes epochs. All values are represented as M +/– SE. A hashtag (#) denotes Significant main effect of condition (p<0.05) revealed by repeated measures ANOVA

3.2 Effects of rain sound on mood

Figure 3 shows T-scores of 6 subscales of POMS before and after MA under rain sound condition and control one. Repeated measures ANOVA revealed significant interaction of condition (rain sound or control) × change (from pre- to post-MA period) in A-H subscale ($F(2,46) = 5.873$, $p = 0.0053$, partial $\eta^2 = 0.19$), that is, basal A-H score before MA period under rain sound condition was lower compared to that under control one, and decreased less after MA than control condition. Paired *t*-test revealed marginally significant lower basal A-H score (pre MA) under rain sound condition ($p = 0.052$). Repeated measures ANOVA revealed no significant interaction of condition × change in the other subscales (T-A, D, A-H, F, C), but revealed significant main effect of condition in F subscale ($F(1,23) = 4.33$, $p = 0.049$, partial $\eta^2 = 0.16$), that is, F score throughout the experiment under rain sound condition was slightly higher compared to that under control one. Repeated measures ANOVA revealed no significant interaction of condition × change in VASs (concentration, and relax).

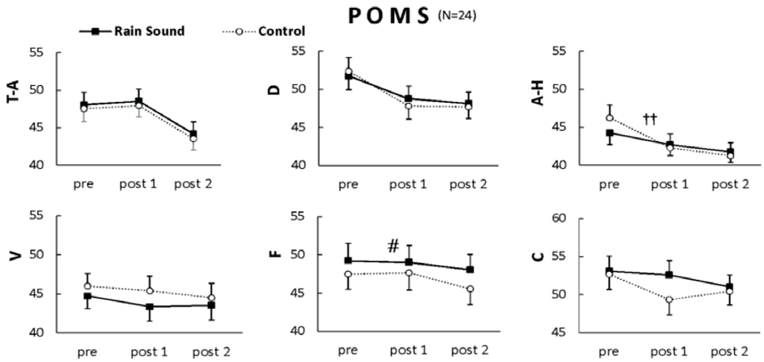

Figure 3. Changes in T-scores of six subscales of POMS in both conditions. Closed square: scores under rain sound condition (Rain Sound), open circle: scores under control condition (Control). All values are represented as M +/– SE. Daggers († †) denotes significant condition × time course interaction (p<0.01) revealed by repeated measures ANOVA. A hashtag (#) denotes significant main effect of condition (p<0.05) revealed by repeated measures ANOVA

3.3 Autonomic nervous response

Autonomic nervous activity was assessed by HF amplitude and LF/HF amplitude of HRV, and its reactivity was evaluated applying 15 minutes of mental arithmetic to the subjects. ECG data from one subject were excluded from the analysis because a part of the data were not obtained due to mechanical trouble. ECG data from the other subject, whose respiratory frequency sometimes decreased below 9/min (corresponds to 0.15 Hz), were also excluded from the analysis, since it allows respiratory sinus arrhythmia (HF: 0.15 to 0.5Hz) contaminate into low frequency band (0.04 to 0.15Hz). Figure 4 shows trends of HRV indices throughout the experiments. There was no significant interaction of condition (rain sound or control) × trend (from basal through MA period to post-MA period) in HF amplitude and LF/HF amplitude, while significant main effect of condition was observed in HF amplitude ($F(1,21) = 4.92$, $p = 0.038$, partial $\eta^2 = 0.19$), that is, mean HF amplitudes under rain sound condition were lower than those under control condition at all time-point. Paired *t*-test revealed significant difference between both conditions at post 2, and 5 in HF amplitude. Most mean LF/HF amplitude within 5-minute epoch were higher under rain sound condition, though main effect of condition did not reach the significant level ($F(1,21) = 3.412$, $p = 0.079$). Paired *t*-test revealed significant difference between both conditions at pre-stimulus basal value, post 2 and 3 in LF/HF amplitude.

Figure 5 shows trends of blood pressure (BP) and heart rate (HR) throughout the experiments. Repeated measures ANOVA revealed no significant interaction of condition (rain sound or control) ×trend (from pre- to post-MA period), nor main effect in systolic BP, diastolic BP, and HR. Most mean systolic and diastolic BPs, and HRs seem higher under rain sound condition, despite main effects of condition were not significant.

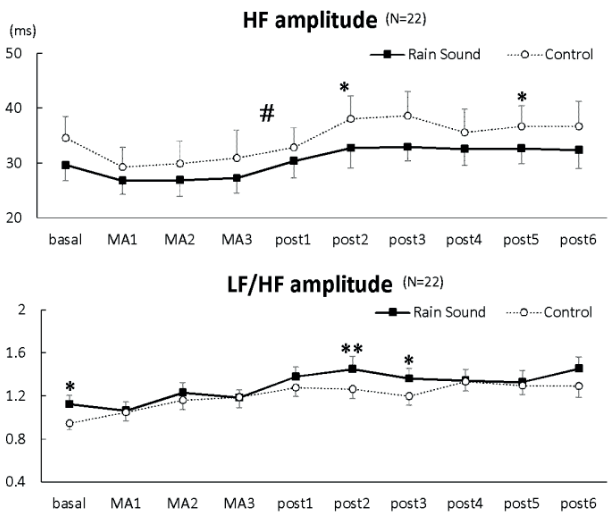

Figure 4. Time courses of HF amplitude and LF/HF amplitude under both conditions. Closed square: values under rain sound condition (Rain Sound), open circle: values under control condition (Control). All values are represented as M +/– SE. A hashtag (#) denotes significant main effect of condition (p<0.05) revealed by repeated measures ANOVA. An asterisk (*) and asterisks (**) denote significant differences between both conditions revealed by paired t-test, at level of p<0.05 and p<0.01, respectively

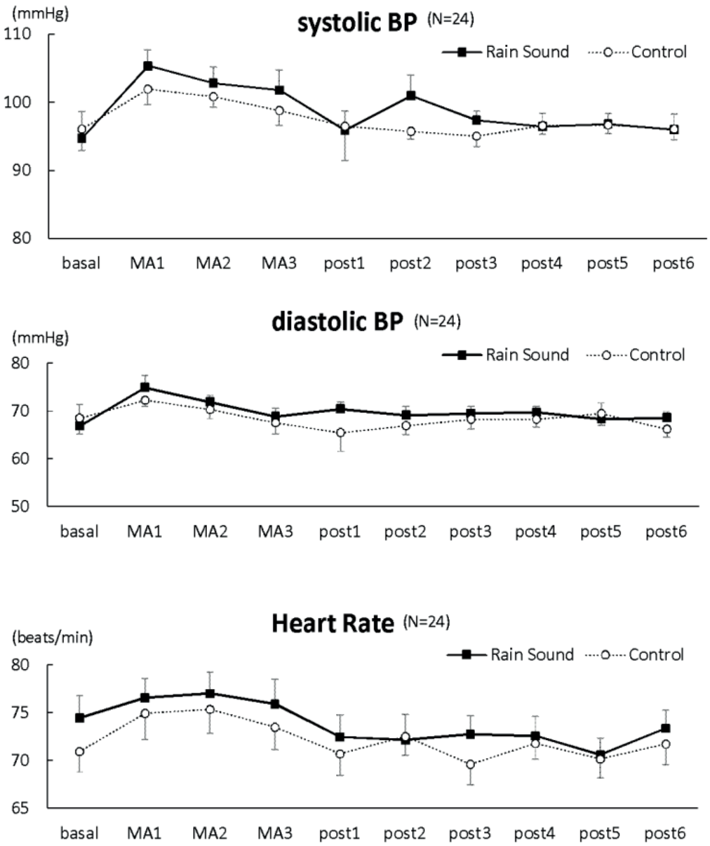

Figure 5. Time courses of systolic BP, diastolic BP and heart rate under both conditions. Closed square: values under rain sound condition (Rain Sound), open circle: values under control condition (Control). All values are represented as M +/– SE

3.4 Hypothalamo-pituitary adrenal axis activity

Hypothalamo-pituitary adrenal axis activity was evaluated by salivary cortisol concentration. Samples whose intra-assay coefficient of variance more than

30percent were excluded from the analysis to improve the reliability of the assay, and data from subjects with 4 available samples (pre- and post-MA under both conditions) were analyzed. Finally, overall intra-assay coefficient of variance was 9.83 percent, and data from 16 subjects were analyzed. Repeated measures ANOVA revealed significant interaction of condition (rain sound or control) × change (from pre- to post-MA period), that is, salivary cortisol decreased after MA under rain sound condition, while slightly increased after MA under control condition ($F(1, 15) = 6.174$, $p = 0.0253$, partial $\eta^2 = 0.29$)(Fig. 6).

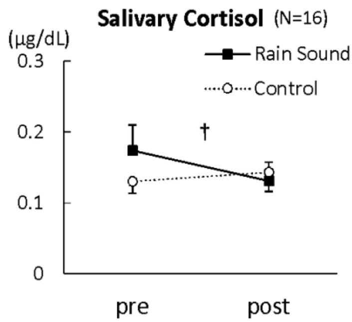

Figure 6. Changes in salivary cortisol level assessed by ELIA under both conditions. Closed square: values under rain sound condition (Rain Sound), open circle: values under control condition (Control). All values are represented as M +/– SE. A daggers (†) denotes significant condition × time course interaction (p<0.05) revealed by repeated measures ANOVA

3.5 Relation among performance of mental arithmetic, autonomic activity and cortisol

Since there might be some correlations among performance of mental arithmetic, autonomic activity and salivary cortisol level, Pearson's correlation coefficients among these values were calculated, and some significant correlations were found. Basal HF amplitude had significant negative correlation with percent of correct answers in 1st MA session ($r = -0.42$, $p < 0.01$), and that in total MA session ($r = -0.36$, $p < 0.05$). Basal LF/HF amplitude had significant positive correlation with percent of correct answers in 1st MA session ($r = 0.39$, $p < 0.05$), that in 2nd MA session ($r = 0.33$, $p <$

0.05), and that in total MA session (r = 0.35, p < 0.05). Concentration of salivary cortisol taken 10 minutes after the end of mental arithmetic had significant negative correlation with percent of correct answers in 1st MA session (r = -0.55, p < 0.01), that in 3rd MA session (r = -0.51, p < 0.01), and total session (r = -0.55, p < 0.01).

4. Discussion

Rate of correct answers in mental arithmetic under rain sound condition was slightly but significantly higher under rain sound condition. The fact that HF amplitudes under rain sound condition were lower than those under control condition, and mean LF/HF amplitude were higher in most 5-minute epochs under rain sound condition, would indicate sympathetic predominance under rain sound condition. There were also significant correlation between percent correct answers in MA and basal autonomic activity, that is, autonomic status just before MA session may contribute to the accuracy of the performance.

Ulrich and colleagues (1991) suggested that viewing natural environment would be effective in sustaining arousal/attention. Proverbio and colleagues (2018) described that rain sound condition brought better accuracy and faster reaction time in difficult arithmetic performance than silent condition and suggested that the benefit would be due to an enhanced cerebral alertness induced by the sound. Sustaining attention, or cerebral alertness enhancement would possibly require some sympathetic activation. Taken together, the rain sound may enhance cerebral alertness, and sustain attention, which would consequently improve mental arithmetic performance with appropriate sympathetic activation. Cassidy and Macdonald (2007) reported that music with high arousal potential and noise had worse effects than music with low arousal potential on cognitive task performance. Music with high arousal potential and noise would be more distractive than that with low arousal. Therefore, adequate intensity and some regular rhythm might be important factors of sound to induce cerebral alertness and mental concentration.

Monotonous rhythm of rain sound with moderate intensity may have some effects on increasing caution level and calmness. One possible explanation is that a person might have to concentrate on listening cautiously to a sound in the neighborhood to protect himself or his family against unknown enemy or risk while raining, which would consequently result in calm mind with moderate arousal with adequate sympathetic predominance. On the other hand, Gould van Praag and colleagues (2017) suggested naturalistic sounds would increase parasympathetic activity through heart rate variability analysis, which is inconsistent with the results in the present study. The inconsistency may be due to the difference of the base on which they conclude, since they found an increase in the peak frequency in the naturalistic condition, and interpreted it as parasympathetic activation, though they found no significant difference in high frequency power. High frequency component of HRV is usually called respiratory sinus arrhythmia, and its peak frequency would generally correspond respiratory frequency, and parasympathetic activity is generally evaluated by HF power or amplitude of HRV, as in the present study (Akselrod et al., 1985, Malliani et al., 1991). Ulrich and colleagues (1991) also mentioned that average heart rate was higher while viewing nature scenes and interpreted as the scenes were more effective in sustaining arousal/attention. Nature sounds or scenes would certainly induce relaxation and moderate arousal, which in turn may modulate autonomic nervous activity adequately to sustain these states, and autonomic balance would vary depending on individual basal autonomic state.

Basal A-H subscale in POMS under rain sound condition were possibly lower and would result in less decrease after MA, compared to that under control condition, while the time courses of the other subscales were not significantly different. Rain sound or such monotonous rhythm may have some alleviation effects on anger and hostility, though the mechanism was not clearly understood. The possibility that basal mood before entering the experimental room might have been different for some reasons cannot be denied, however, the fact that the time course of only A-H subscale was significantly influenced by rain sound, may possibly indicate some effects of rain sound on anger-hostility. Ulrich and colleagues (1991) suggested that nature viewing would induce wakeful relaxation. According to the study of Gould van Praag and colleagues (2017), nature sounds have restorative effect through altering the connections in the brain and reducing fight and flight instinct. These descriptions may be supportive of reduction effect of rain sound on anger-hostility feeling. F subscales in POMS under rain sound condition at each time point were higher, compared to those under control condition, while the main effect of condition were not significant in the other subscales. The degree of fatigue may have increased due to slightly increased caution level and concentration with sympathetic predominance under rain sound condition.

Salivary cortisol level decreased after MA under rain sound condition, while slightly increased after MA under control condition. Salivary cortisol level is known to change 10 to 15 minutes after stimulus application (Giles et al., 2014; Qi et al., 2016). Cortisol awakening response and fluctuation with circadian rhythm are also known (Edwards, Evans, Hucklebridge, & Clow, 2001; Schmidt-Reinwald et al., 1999). The fact that pre-MA basal level of salivary cortisol did not significantly differ, may indicate rain sound itself does not affect cortisol secretion. The rate of correct answers were significantly correlated with pre-MA basal level of parasympathetic withdrawal and sympathetic activation, that is, sympathetic predominant situation seems to have contributed to the MA performance. On the other hand, better performance of MA may have reduced the psychosocial stress level, which would have consequently resulted in the lowered post-MA salivary cortisol level after MA under rain sound condition. The fact that concentration of salivary cortisol taken after MA had significant negative correlation with percent of correct answers, would also support the idea mentioned above. In other words, sympathetic predominance would be induced to prepare upcoming performance, and HPA axis activation would be affected by the results of the performance. Or restorative effect of rain sound might reduce stress level caused by mental arithmetic, which would consequently result in less secretion of cortisol after MA. The restorative effect may relate to both increase in percent of correct answers and decrease in stress level while performing MA, which would bring about negative correlation between percent of correct answers and concentration of salivary cortisol taken after MA.

There are some limitations to consider in this study. Our sample size was small, and several salivary samples were not available due to large intra-assay coefficient of variance. Larger sample size with detailed analysis may have more consistent and clear results. We also cannot completely exclude the placebo effects since there might be some subjects who know whether the experimental situation was rain sound condition or control one, though we never told them previously about the experimental sound condition. We employed only female college students as subjects in this study. Then, there may be some differences by age or gender, and may not be generalized to persons in wide age range.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of our university held on 19th August, 2016. After receiving an explanation of the study, all participants gave written informed consent for participation before taking part in this study.

Consent for publication

Not applicable

Availability of data and material

The datasets during and/or analysed during the current study available from the corresponding author on reasonable request

Funding

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Competing interests

The author declares that there is no competing interests regarding the publication of this paper.

Authors' contributions

SS designed the experiments, analyzed data and drafted the manuscript. The author read and approved the final approval.

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Abbreviations

POMS: profile of mood states; BP: blood pressure; ANOVA: Analysis of variance; VAS: visual analogue scale; HRV: heart rate variability; HPA axis: hypothalamo-pituitary adrenal axis; MA: mental arithmetic; T-A: Tension-anxiety; D: Depression-dejection; A-H: Anger-hostility; V: Vigor; F: Fatigue; C: Confusion; HF: high-frequency component; LF: low-frequency component

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