Pleasure & Emotion: An Investigation of Physiological Responses Emerged by Pleasant Stimuli

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Abstract: Now that consumers expect everything they buy to be both functional and easy to use, designers need to think seriously about the pleasure their designs bring to users. The services and products with which we surround ourselves are potential sources of pleasure. They should be designed with a view to how they can provide pleasure to those who use and experience them. This study discussed the importance of pleasure for our life. It aims at investigating the critical physiological responses that are emerged by pleasant stimuli. Various physiological responses of the brain (encephaloelectrogram; EEG), autonomic nervous system (ANS), immune system and endocrine system were monitored when pleasant stimuli such as odors, emotional pictures and rakugo, a typical Japanese comical story-telling, were presented to subjects. The results revealed that (i) EEG activities of the left frontal brain region were enhanced by a pleasant odor; (ii) emotional pictures related to primitive element such as nudes and erotic couples elevated vasomotor sympathetic nervous activity; and (iii) an increase in salivary immunoglobulin A (s-IgA) and a decrease in salivary cortisol (s-cortisol) were induced by rakugo-derived linguistic pleasant emotion. Positive emotion is complicated state. However, by considering the evolutionary history of human being, it is possible to assess and evaluate positive emotion from certain physiological responses by appropriately summating various physiological parameters.

Key words: ***Emotion, Pleasant stimuli, Physiological Reactions' Measurements***

1. Introduction

In the last years, design communities have witnessed a growing interest in the role of emotions in design and in the emotional impact of the products, services and environments on users. This interest has resulted in series of conferences, workshops, projects, publications, and other activities related to emotion in design [1].

Emotion has been defined as "a subjective, internal experience correlated with a group of physiological reactions arising in response to some situation. In an experience of emotion there is a feeling, or affective, response (e.g., sadness, anger, joy), a physiological response (changes in internal bodily functioning), a cognitive response (an interpretation of the situation), and possibly also a behavioral response (an outward expression) [2].

According to the literature survey, we found that many academic researches [3-5] discussed the effects of the positive emotions on the psychological state of people during their interaction with the products and services. However the researches that study on effects of the positive emotions on the internal bodily functioning and reactions (physiological responses) are limited. The aim of the present study is to identify the critical physiological responses that are induced by pleasurable stimuli. This study will be helpful for the designers and researchers to understand the necessity of pleasure in our life.

It is well known that different systems involved in the induction of pleasant and unpleasant emotions are evoked by intracranial self-stimulation. The former is associated with the reward system (RS), while the latter is related more with the aversive system or process (AS). Anatomically the focal brain site closely related to RS is the medial forebrain bundle, while that intricately associated with the AS is the periventricular system. The amygdala complex displays intricately connected fiber networks that mutually link with the RS and AS to eventually summate the input and output of both these systems. As such, the amygdala acts as the center for integrating pleasant and unpleasant emotions.

Interestingly, the senses of vision, auditory, olfactory, taste and touch input at the amygdala. This suggests that the amygdala differentiates the 5-sense inputs and eventually discriminates the important for the living system. Therefore, designing artificial environments for the living system with special emphasis on sensory specifics may require summation of the sensory inputs from the various systems converging to the amygdala and the outputs from the medial forebrain, periventricular system and amygdala to eventually validate the relevant physical stimuli affecting the living system.

If the amygdala served as the center for integrating emotions, then the hypothalamus would play the role of expressing the emotional output. When corticotrophin-releasing hormone (CRH) is secreted from the hypothalamus, cortisol and catecholamines (medullary hormones) are then released from the adrenal glands via the pituitary gland, with the former and latter forming the hypothalamus-pituitary-adrenal (HPA) and sympathetic adrenomedullary (SAM) axes, respectively. Activities of the HPA system can be monitored by the salivary cortisol (s-cortisol) levels, while those of the SAM system can be evaluated by the cardiovascular responses. As salivary immunoglobulin (s-IgA), a parameter of immune system activity, is closely related with the HPA and SAM systems, its levels should be measured as well. As such, it is essential to investigate physiological responses upon induction of pleasant and unpleasant emotions by evaluating parameters of the autonomic nervous system [6-9], endocrine system and immune system to validate the effects of exogenous stimuli, such as sound and odor, on the living system.

In this study, the authors focused on the effects of pleasant emotion induced by olfactory, visual and culture-related linguistic (rakugo) stimuli on physiological responses. Different from other sensory stimuli, the olfactory stimulus was employed as a direct input to the amygdala, so that olfactory stimulus has been primitively thought to be a pleasant stimulus. In the evolutionary history of human beings, primitive is occurred in the processing of reproduction and maintaining the life, and Social-interacted element is induced in the processing of forming and maintaining the group for positive emotion. In other words, the visual stimulus therefore serves as an excellent input for these two perspectives. Human has developed the special skill of using an exceptionally refined and highly precise linguistic capability for communication, and positive emotion derived from linguistic inputs can be.

2. Methods

In this study, EEG, cardiac output, s-cortisol and s-IgA concentrations were monitored as physiological parameters of the brain, ANS, endocrine and immune system activities. Written informed consent was obtained from all volunteers after a detail briefing of the experimental purposes and protocol. To avoid any confounding effects of physiological responses, the subjects were asked to abstain from eating, drinking, smoking and exercise for at least 2 hr before the experiment.

2.1) EEG recording (brain activity)

Recording were made from 19 scalp sites (Fp1, Fp2, F3, F4, F7, F8, Fz, C3, C4, Cz, P3, P4, Pz, T3, T4, T5, T6, O1 and O2.) with NEC Medical EE5514 (NEC Co. Ltd.) system. Electrodes were placed using an elastic EEG electrode cap (Electro-Cap International, Inc.) according to the International 10-20 system. Signal bandpass was 0.15-32 Hz and the digital sampling frequency was 500 Hz. Referenced was to the linked earlobes (A1, A2). Resistance was below 5kΩfor all electrode sites. EEG records were visually examined for a vertical electrooculogram (EOG) artifact: epochs with deflections greater than 80μV in any scalp site were rejected. Artifact-free epochs were extracted through a Hanning window, and submitted to fast Fourier transform (FFT). Average δ (0.5 – 3.99 Hz), θ (4 – 7.99 Hz), α (8 – 12.99 Hz) and β (13 – 30 Hz) power was computed across all artifact-free epochs and EEG power was later converted to relative power (%) to normalize.

2.2) ECG and ICG recordings (Cardiac activity)

Cardiac activity was measured using electrocardiography (ECG) and impedance cardiography (ICG). The ICG was monitored using four circumferential mylar band electrodes, an impedance plethysmograph (AI-601G, Nihon Kohden Co. Ltd., Japan) and a differential microunit analysis (ED-601G, Nihon Kohden Co. Ltd., Tokyo) based on the 4-electrode method of Kubicek. Heart rate (HR), heart rate variability (HRV), CO (cardiac output), pre-ejection period (PEP) and left-ventricle ejection period (LVEP) were calculated.

2.3) Blood pressure (vasomotor activity)

Beat-to-beat blood pressure was measured non-invasively using a Finapres 2300 Continuous Monitor (Ohmeda, USA). Contiguous blood pressure was obtained via a finger cuff attached to the third finger of the dominant hand. Measurements were initiated manually, and for each measurement systolic blood pressure (SBP) and diastolic blood pressure (DBP) were recorded. Mean blood pressure (MBP) was calculated using the formula MEP = DBP + 1/3(SBP-DBP). Total peripheral resistance (TPR) was calculated using the formula TPR = MBP/CO.

2.4) s-IgA and S-cortisol concentrations (immune and endocrine responses, respectively)

Saliva was collected in a salivette (No. 51.1534, Sarstedt, Numbrecht, Germany). Collected saliva was clarified by centrifugation (3,500rpm×15min.) to eliminate buccal cells and oral microorganisms, and then was frozen at -30℃ and stored until assayed. The concentration (μg/ml) of salivary IgA was determined by ELISA (Enzymelinked immunosorbent assay) at a sample dilution of 1:1000. The secretion rate of s-IgA (μg/3min) was calculated as concentration (μg/ml)×saliva volume (ml/3min; 3min sample time). The concentration (ng/ml) of salivary cortisol was determined by ELISA kit (ELISA-cortisol®: product Np.EA65, Oxford Biochemical research, USA) at a sample dilution of 1:100.

3. Results

Based on the result of EEG responses to a pleasant odorous stimulus derived from wood-extracted odorous solution (Figure 1), beta waves were significantly ($p<0.05$) enhanced in the left frontal lobe. This result indicated that brain activity in the left frontal lobe was activated by a pleasant odorous stimulus.

Figure 2 illustrates that the pleasant visual stimuli changed systolic blood pressure (SBP), mean blood pressure (MBP), and total peripheral resistance (TPR) compared with at rest. The pleasant visual stimuli comprised the primitive element such as nudes and erotic couples, and the social-interacted element such as a happy family and cute pets. The primitive element significantly ($p<0.01$) increased SBP, MBP and TPR more than the social–interacted element.

Comparing the results for s-IgA and s-cortisol between before and after listening to the rakugo (Figure 3), the concentrations of s-IgA (left) significantly ($p<0.05$) increased and the concentrations of s-cortisol (right) significantly ($p<0.05$) decreased after listening to the rakugo.

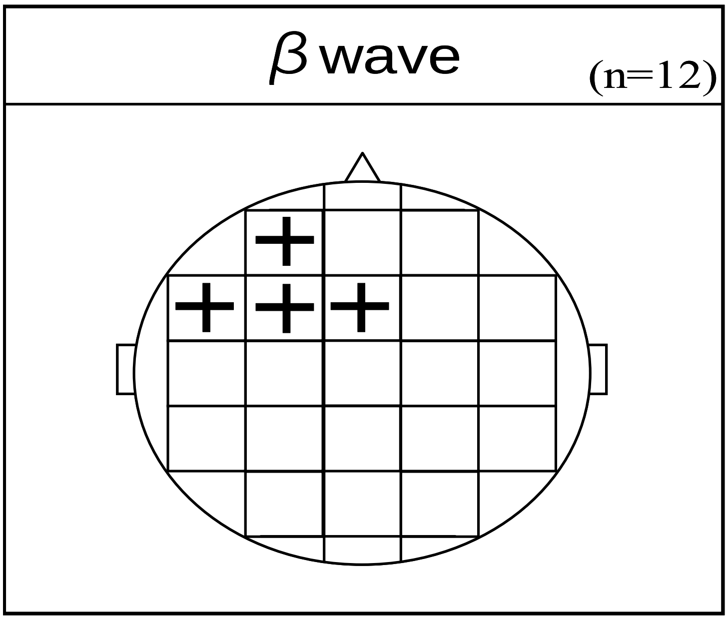

Figure. 1 Encephalographic (EEG) activities induced by pleasant odorous stimuli with significant increases (+, $p<0.05$). n=12 is the subjects' numbers.

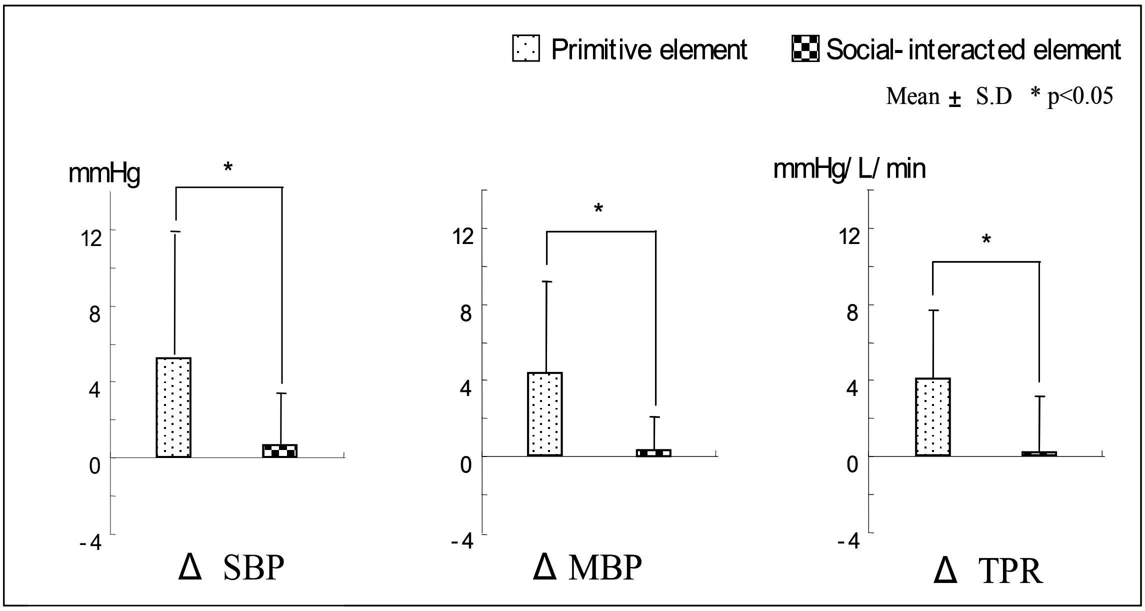

Figure. 2 Responses of autonomic nervous system (ANS) to pleasant emotion induced by visual stimuli with the primitive element (dotted) and the social-interacted element (checkered). Values are expressed as the mean ± standard deviations, and differences where p<0.05 (**) are considered statistically significant. 17 Subjects participated in this experiment.

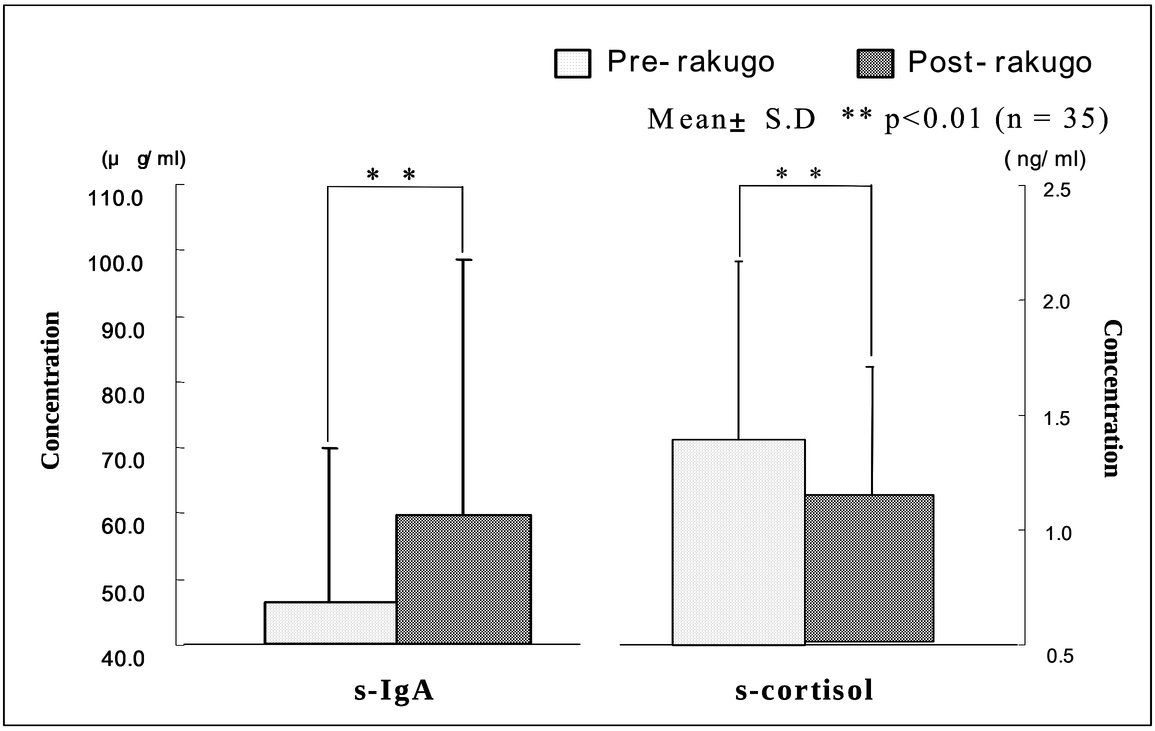

Figure. 3 The concentrations of salivary immunoglobulin A (s-IgA) and salivary cortisol (s-cortisol) between pre-rakugo (dotted) and post-rakugo (checkered). Values are expressed as the mean ± standard deviations, and differences where p<0.01 (**) are considered statistically significant. n=35 is the subjects' numbers.

4. Discussions

Pleasant emotion greatly influences our behavior. In cases relating to the designs of products and environments, the designer draws out a plan according to the individual subjective pleasant emotion. As such, this is subjective and is lacking in objectivity. In the present study, pleasant emotion was categorized into three major phases.
First one is the olfactory that is involved a direct input delivered to the amygdala, accompanied by the sending of impulses containing other sensory signals, such as visual inputs, to the amygdala via V1, V2, V4 and the medial visual cortex, implying that the said visual input were subjected to various modifications (e.g., individual experiences) before terminating at the amygdala. As such, olfactory stimuli appear to be the most appropriate exogenous inputs for the investigation of physiological responses induced by pleasant stimuli per se. The finding of enhanced brain activity in the left frontal lobe with pleasant odorous stimuli in the present study converges with the results of previous studies [10, 11]. Moreover, our results support the hypothesis that visual stimulus-induced positive emotions are related with the left cerebral hemisphere [12-14]. Furthermore, unfavorable odor-stimulated unpleasant emotion appears to incrementally excite bilateral frontal regions of humans [10, 11, 15, 16]. Taken together, the data from EEG studies render possible assessments of exogenously stimuli to be interpreted as being pleasant or unpleasant by the brain. In short, pleasant emotions were most likely to enhance EEG activities of the left frontal lobe.

Second phase is the autonomic responses of vision-induced pleasant stimuli. Odor-induced pleasant emotion is a primitively pleasant emotion. In contrast, vision-induced pleasant stimuli are subjected to certain modifications before terminating at the amygdala. In other words, the substance incorporated in pleasant emotion is indeed complex. As such, we attempted to discriminate and dissociate the differences in physiological responses between the primitive element derived from the reproduction and the social-interacted element derived from maintaining the group in pleasant emotion in this study. The results revealed certain differences in the various parameters of the cardiovascular system; significant increases in SBP, MBP and TPR were shown (Figure. 2). These findings coincide well with responses observed in the cardiovascular system when rats are subjected to central stimuli with pleasant emotion; viz., increases in blood pressure [17]. The increase of BP in the present study was probably attributable to TPR, as there was no difference in the cardiac output between the two elements. The degree of vascular contractility is dependent on the vasomotor sympathetic nervous activity. In discriminating the types and degrees of pleasant emotion, vasomotor sympathetic nervous activity is the preferred and more reliable parameter than cardiac sympathetic nervous activity.

Third phase is the s-IgA responses of a high degree of linguistic ability that enhances linguistic creativity in humans. This creativity further furnishes pleasant emotion, and rakugo is one of the methods. The pleasant emotion derived from rakugo attenuated the concentration of cortisol (a stress-hormone) and elevated the concentration of s-IgA (an index of immune activity) (Figure. 3). A persistent stressor activates the HPA system and releases cortisol [18, 19], a hormone that displays anti-inflammatory, metabolism-promoting and immuno-depressive effects. Furthermore, secretions of sex hormones and growth hormone (GH) are inhibited by activation of the HPA system. In the present investigation, rakugo-induced pleasant emotion might have depressed activation of the HPA system, suggesting that cortisol attenuation and s-IgA increase [20] could serve as plausible indexes for evaluation of the degree of linguistic-induced pleasant emotion.

Certain facets of pleasant emotions were taken up in the present study, and the physiological responses thereof were investigated. Although emotion can be complicated, a proper combination of physiological indexes may discriminate and evaluate the physiological responses of pleasant emotion when consideration from the evolutionary history of humans is taken into account.

5. Future Work

Is there a biological basis for the experience of beauty? Currently the authors are addressing this question by presenting Japanese and western arts and using a multi channel system to measure various physiological parameters of people simultaneously. Basically we attempt to identify the importance of Aesthetics pleasure.

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