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Is heart rate variability (HRV) an adequate tool for evaluating human emotions? – A focus on the use of the International Affective Picture System (IAPS)

Kwang-Ho Choi, Junbeom Kim, O. Sang Kwon, Min Ji Kim, Yeon Hee Ryu, Ji-Eun Park*

Korea Institute of Oriental Medicine, Daejeon, Republic of Korea

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ABSTRACT

Because human emotion varies greatly among individuals and is a qualitative factor, measuring it with any degree of accuracy is very difficult. Heart rate variability (HRV), which is used in evaluations of the autonomic nervous system (ANS), is used to evaluate human emotions. This study examines the validity of HRV as a tool to evaluate emotions using the International Affective Picture System (IAPS). For experimentation, five photos were selected for each of the categories of "happy," "unhappy", and "neutral" from among the images provided by the IAPS. The subjects were required to complete the Self-Assessment Manikin (SAM) after being shown each picture. We extracted the R-R interval (RRI) value of each photo from the PPG, as well as the valence, arousal, and dominance value of each photo from the SAM to analyze their correlation. As results, there was significant positive correlation with valence and significant negative correlation with dominance in the photo simulation associated with the "unhappy" emotion, only when the arousal value exceeded a critical value. Therefore, the findings of this study suggest that it is possible to use an HRV-based evaluation only when a high level of emotion is induced by visual stimulation.

1. Introduction

Recently, many studies assessing human psychological and mental states and measuring emotional changes have been conducted in various fields, including psychology, psychiatry, and neurophysiology (Cernea and Kerren, 2015; Coelho et al., 2010; Sheppes et al., 2015). However, emotion is very difficult to measure quantitatively because it comprises moods that arouse various sentiments that depend on the individual. Caicedo et al. reported that emotional response is typically divided into three components: physiological arousal, motor expression, and subjective feeling. Emotional response can be assessed using physiological arousal with methods that include measurements of changes in factors such as blood pressure, heart rate, and brain waves. Emotional response can also be measured using motor expression through facial expression, voice, and gesture, and using subjective feeling through self-report questionnaires (Caicedo and van Beuzekom, 2006).

Because of convenience and the possibility of assessing mixed emotions, assessments of subjective feeling have commonly been used in studies of emotion. As one of those tools, Lang et al. developed the Self-Assessment Manikin (SAM) scale (Bradley and Lang, 1994). SAM comprises three domains: valence, arousal, and dominance. SAM has been validated by several studies as a useful instrument for assessing personal response to an affective stimulus (Backs et al., 2005; Bestgen et al., 2015), and it has been used in many studies (Betella and Verschure, 2016; Imbir, 2016). However, because of the limitation of SAM as subjective tool, several studies suggested the need of objective measurement tool (Desmet, 2003).

Thus, many researcher suggested HRV to complement the limitation of the SAM because HRV reflect the state of autonomic nerve system. Valenza et al. suggested that heart rate variability (HRV) could be an objective tool to assess emotional responses Valenza et al. (2012) and Lane et al. reported a correlation between a subject's emotional state and HRV (Lane et al., 2009). Yu et al. built an algorithm to identify the emotional state based on Electrocardiogram (ECG) (Sung-Nien and Shu-Feng, 2015). For the expansion of measuring emotions, HRV has also used to measure the social cognition ability (Okruszek et al., 2016; Quintana et al., 2012) or the changes in emotional state after meditation (Tang et al., 2009). In diagnostic area, the quantitative measurement for stability of panic disordered patients (Yeragani et al., 1993), and mood in bipolar patients (Valenza et al., 2014) has used HRV.

* Correspondence to: 1672 Yuseong-daero, Yuseong-Gu, Daejeon 30675, Republic of Korea.
E-mail address: jepark@kiom.re.kr (J.-E. Park).

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Although HRV is currently used sporadically in experiments that are designed to assess human emotional states, no research has yet verified its validity as a tool for assessing human emotion. This study aimed to assess the validity of HRV as a tool for evaluating emotions by comparing changes in HRV and SAM scores upon visual stimulation.

2. Methods

2.1. Subjects

The experiment was conducted in subjects who were 19–35 years old and did not have abnormal blood pressure or photoplethysmogram (PPG) responses. Potential participants were excluded if they had nervous system disorders, systemic diseases, chronic diseases, such as hypertension or diabetes, skin diseases, injuries in parts of the body that were necessary for study observation, an inability to undergo acupuncture stimuli, or inadequate writing skills for full study participation.

2.2. Setting

The subjects were recruited in Daejeon, Republic of Korea from September to November 2015. The study was approved by the institutional review board of Oriental Medicine Hospital of Daejeon University and was registered in the Clinical Research Information Service (registration number: KCT0001721). The consent of all the subjects was obtained after providing them with an explanation of the experiment. All subjects were prohibited from consuming alcoholic drinks, smoking, and ingesting caffeine for 24 h before the experiment. The subjects participated in the experiment after they had a sufficient amount of sleep. To induce an identical mental state among all subjects, the experiment was begun after their rest period without subjecting them to any stimuli while in dark illumination for 30 min.

2.3. Selection of the IAPS photographs

The tool used for emotion stimulation in this study was IAPS, which is currently used in diverse research areas including the assessment of human emotions and the assignment of experimental tasks (Britton et al., 2006). IAPS, which was developed by Professor Lang, currently includes approximately 900 visual stimuli (photographs) that can be jointly used by emotion researchers. IAPS presents three-dimensional values (arousal, dominance, and valence) of subjects' emotional responses, which are assessed through SAM for each photograph (Bradley and Lang, 1994).

A total of 15 IAPS photographs (5 photographs for each group) were selected based on the following valence values in each group: unhappy (4 points or less); happy (6.3 points or more); and neutral 4.5–5.1 points). Table 1 shows the valence, arousal, and dominance data of the IAPS photographs that were presented (Table 1). Fig. 1 shows the selected photographs (Fig. 1).

2.4. Self-Assessment Manikin (SAM)

SAM is a system used to assess the emotional response to a photograph with drawings provided by the IAPS. The drawings are divided into three parts (valence, arousal, and dominance). With five drawings per part, the drawings were produced to enable assessment on a scale of 1–9 points, including steps between the drawings. The points increase from right to left (Bradley and Lang, 1994). The valence part assesses the subject's emotions over a range from pleasant to unpleasant, the arousal part assesses emotions ranging from calm to excited, and the dominance part assesses emotions ranging from controlled to uncontrolled states (Fig. 2).

Table 1
Data of each photograph presented from IAPS.
Source: International Affective Picture System (IAPS) (Lang, 1999) (http://csea.phhp.ufl.-edu/media/iapsmessage.html)

Type of emotion	Number of photograph	Valence	Arousal	Dominance
Unhappy photograph group	1931	4.00 ± 2.28	6.80 ± 2.02	6.80 ± 2.02
	9410	1.51 ± 1.15	7.07 ± 2.06	2.81 ± 1.99
	3000	1.45 ± 1.20	7.26 ± 2.10	2.99 ± 2.10
	6350	1.45 ± 1.20	7.26 ± 2.10	2.99 ± 2.10
	3170	1.46 ± 1.01	7.21 ± 1.99	2.70 ± 1.89
	Total	1.97 ± 1.37	7.12 ± 2.05	3.66 ± 2.02
Happy photograph group	1931	6.48 ± 2.18	6.99 ± 2.35	4.73 ± 2.68
	9410	6.36 ± 1.70	2.51 ± 2.01	5.72 ± 2.03
	3000	6.44 ± 2.22	7.07 ± 1.78	5.51 ± 2.11
	6350	7.33 ± 1.76	7.35 ± 2.02	4.70 ± 2.66
	3170	7.57 ± 1.52	7.27 ± 2.08	5.47 ± 2.42
	Total	6.84 ± 1.88	6.24 ± 2.05	5.23 ± 2.38
Neutral photograph group	1931	4.83 ± 1.28	2.41 ± 1.80	5.92 ± 2.01
	9410	5.00 ± 0.84	2.42 ± 1.79	6.14 ± 2.14
	3000	4.49 ± 1.03	2.63 ± 1.70	5.97 ± 1.89
	6350	4.87 ± 1.00	1.72 ± 1.26	6.47 ± 2.04
	3170	5.07 ± 1.02	2.30 ± 1.75	6.10 ± 2.04
	Total	4.85 ± 1.03	2.30 ± 1.66	6.12 ± 2.04

All values are given as the mean ± standard deviation.

2.5. Procedure

For emotional stimulation, the International Affective Picture System (IAPS) was used. Selected IAPS photographs were shown to participants for 6 s for each photograph after an interval of 20 s. To assess objective feeling, SAM was used. While the participants completed the SAM scale, HRV was measured during emotional stimulation. The photos were arranged randomly (Fig. 3).

The experiment was conducted after the subjects rested for 30 min. The experiment was conducted in a dark, quiet room with an average temperature of 23 °C and an average humidity of 40%.

2.6. HRV measurement

In this study, HRV was assessed using PPG. After a 30-min rest, a PPG sensor (PolyG-A, LAXTHA, Daejeon, Republic of Korea) was applied to the subject's left index finger. While the photographs were shown to the subject, HRV was measured by the mounted PPG sensor.

2.7. Data analysis

The R-R intervals (RRI) for each photograph were derived from the PPG data after the photographs were shown. In the SAM assessment, the valence score (VS), arousal score (AS), and dominance score (DS) were analyzed for each photo and for each category. In this study, an integrated index was calculated by subtracting 5 from VS and multiplying it by AS. For an unhappy group of photographs, −5 was applied to the valence value to divide the valence values into negative (unhappy) and positive (happy) numbers with 5 as the baseline value. This procedure attempted to more comprehensively assess the SAM values. Moreover, the RRI correlation was evaluated after the arousal value scale was increased by multiplying it by an arousal value that reflected the degree of change in happy and unhappy emotions.

The results of the SAM assessment and RRI were compared using Pearson's correlation for statistical analysis to analyze the validity of HRV. For the statistical analysis, R program (version 3.2.3) was used.

2.8. Subgroups based on arousal

To evaluate differences in correlations between RRI and high/low