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Evaluation and Validation of Emotional Expression Mimicry Tasks for Highly Sensitive Person Assessment

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ABSTRACT

In recent years, Highly Sensitive Persons (HSP) have gained increasing attention. HSP refers to individuals with heightened sensory sensitivity, making them more sensitive to stimuli and frequently more empathetic. In this study, we focused on HSPs' high empathy and their ability to detect subtle cues from facial expressions. We hypothesized that individuals with HSP tendencies are more likely to perceive and express minor changes in facial expressions. To test this hypothesis, we created deliberate facial expressions representing nine emotional states, i.e., happiness (four levels), neutrality (one level), and sadness (four levels). We measured mouth corner movements using the MediaPipe system, which is a webcam-based motion capture system. The subjects imitated 10 facial expressions, ranging from neutral to happy and sad, each with five levels of intensity. We then examined the correlations between the subjects' facial expressions and psychological measures, including the Highly Sensitive Person Scale (HSPS) and the Japanese version of the Interpersonal Reactivity Index. The result exhibited correlations in specific intervals. First, there was a strong correlation in the five-level range from neutral to happy ($r = 0.67$). Second, there was a correlation in the interval from minor expression change from neutral to the second level of happiness ($r = 0.50$). Third, a correlation was observed in the interval from the second to the fourth level of happiness ($r = 0.61$). These results suggest that individuals with higher HSPS scores (indicating HSP tendencies) exhibit greater changes in facial expressions when experiencing happiness, which suggests that those with HSP tendencies are more receptive to subtle changes in intentional facial expression mimicking stimuli, particularly happiness.

Keywords: Exemplary paper, Human systems integration, Systems engineering, Systems modeling language

INTRODUCTION

The Highly Sensitive Person (HSP) concept has gained attention since approximately 2020, primarily through social network systems and public disclosures by celebrities. HSPs are individual with a genetically - based trait characterized by heightened sensitivity to various stimuli, including a lower sensory threshold and stronger emotional reactions, in addition to heightened aesthetic sensitivity (Aron et al., 1997). However, HSPs are not designated in the Diagnostic and Statistical Manual of Mental Disorders, unlike various other conditions, e.g., depression or Attention Deficit/Hyperactivity Disorder (ADHD). Instead, HSP is considered an inborn personality trait.

Subjects with HSP exhibit several specific traits, e.g., deep thinking and processing, heightened sensitivity to excessive stimuli, overall strong emotional reactions (especially high empathy), and the ability to perceive subtle cues (Yano et al., 2018). Due to these characteristics, it is believed that individuals with HSP tendencies are more prone to experiencing depression. The growing awareness of HSP has led to an increase in clinics where individuals can seek assessment regarding their HSP tendencies. Typically, these clinics utilize psychological questionnaires for evaluation; however, such questionnaires can require the subject to have a certain level of language proficiency and may be susceptible to intentional bias or self-deception (Psycho Psycho., 2022).

To the best of our knowledge, no previous study has attempted to evaluate HSP using physiological method; however, there have been studies on emotional contagion, defined by Hatfield et al. as the phenomenon where emotions arise through the automatic imitation or synchronization of others' facial expressions, speech, posture, and actions (Hatfield et al., 1992, 1994). In addition, there have been studies on mirror system activity, which involves the activation of motor-related brain regions when observing the same actions in others or during one's own action execution. These studies could provide clues related to HSP. Notably, previous research has suggested that subjects with HSP, known for their high empathy, are more susceptible to emotional contagion (Kushizaki, M., 2020). Additionally, studies examining the relationship between emotional contagion and mirror system activity have demonstrated that variations in μ-waves (in the α-wave frequency range) recorded in specific brain regions, including the left central, central, and right central regions, reflect mirror system activity. These studies have indicated that subjects that are more prone to emotional contagion tend to exhibit higher mirror system activity (Ikeda et al., 2016).

In addition, previous research conducted by our team has demonstrated that measuring emotional contagion and mirror system activity can help identify subjects with a propensity for HSP (Figures 1 and 2) (Ishikami et al., 2022). Based on these findings, we hypothesized a correlation between Event-Related Desynchronization (ERD), α-wave power values, and HSP. Further, by considering HSP's traits, e.g., sensitivity to subtle cues and strong overall emotional reactions, we referred to the action units from Ekman's Facial Action Coding System (FACS), specifically "AU12: Raising Both Lip Corners" and "AU15: Lowering Both Lip Corners." We theorized that subjects with HSP tendencies would exhibit an upward movement of the corners of the lips when mimicking expressions of happiness and a downward movement when mimicking expressions of sadness.

Thus, in the current study, we attempted to elucidate the characteristics of subjects with HSP by having subjects mimic expressions of happiness, neutrality, and sadness from nine levels of facial expressions. We measured these changes using MediaPipe, which is a tool that enables facial motion capture using a webcam. We categorized the acquired data into five levels for transitioning from neutrality to happiness and five levels for transitioning from neutrality to sadness. In addition, we included two intermediate levels for transitions from happiness and sadness, respectively, to further evaluate minimal changes. We compared the results of these expression changes to the scores from the Highly Sensitive Person Scale (HSPS) and the Japanese version of the Interpersonal Reactivity Index (IRI-J) to gain insights into HSP traits.

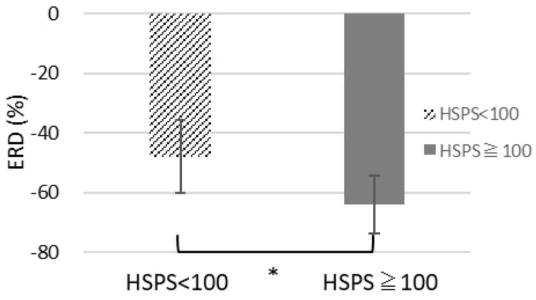

Figure 1: HSPS cutoff value of 100 and ERD change rate (Ishikami et al., 2022).

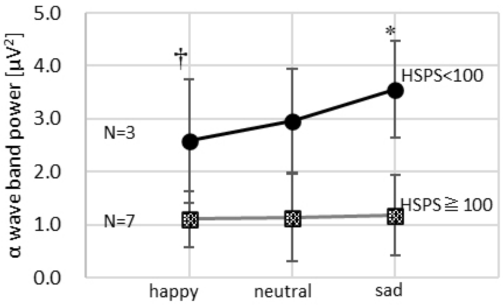

Figure 2: HSPS cutoff value of 100 and α-wave band power values for three emotions (Ishikami et al., 2022).

METHOD

Highly Sensitive Person Scale

Aron et al. conducted a series of investigations to validate the concept of Sensory Processing Sensitivity (SPS) as distinct from personality traits, e.g., introversion and neuroticism. They conducted qualitative face-to-face interviews (n = 39), random telephone surveys (n = 299), and five quantitative questionnaire surveys targeting university students from various regions in the United States. The scale for measuring sensory processing sensitivity developed as a result of these studies is known as the Highly Sensitive Person Scale (HSPS). The HSPS comprises three factors, i.e., ease of excitation, low sensory threshold, and aesthetic sensitivity, totaling 27 items. In this study, the subjects were asked to respond to each item using a seven-point Likert scale.

Interpersonal Reactivity Index

The IRI scale was designed to measure the trait of empathy comprehensively (Himichi et al., 2017). It comprises 28 items and assesses empathy through four dimensions, i.e., empathic concern (EC), Perspective Taking (PT), Personal Distress (PD), and 'Fantasy Scale (FS). Here, EC measures the propensity to be emotionally moved by others' emotional experiences, PT gauges the degree to which an individual consider others' feelings from their perspective, PD evaluates the extent to which an individual becomes anxious or fearful due to observing others' suffering, and FS examines an individual's inclination to imagine being in the place of fictional characters in narratives.

EC and PD are considered to reflect the emotional aspects, and PT and FS represent the cognitive aspects of empathy. Among these dimensions, EC and PT are considered central concepts within their respective domains. In this study, the subjects were asked to respond to the IRI-J questionnaire using a five-point Likert scale.

Measuring Mouth Corner Expressions Using MediaPipe

In this study, MediaPipe's Iris Tracking was employed to measure facial changes, specifically capturing changes when intentionally mimicking expressions. MediaPipe is a cross-platform and customizable machine learning tool provided by Google that is designed for live and streaming media applications (MediaPipe, 2023). MediaPipe offers various functionalities, including Face Mesh, Iris Tracking, Pose Tracking, and Holistic.

Within MediaPipe's Iris Tracking, facial coordinates are tracked relative to 478 points. From these, the angles between the upper lip and the corners of the mouth (corresponding to points 164, 78, and 308) were calculated using Equation (1) (Figure 3).

$$\theta = \cos^{-1} \frac{{mouth_{right}}^2 + {mouth_{left}}^2 - {mouth_{center}}^2}{2 \times mouth_{right} \times mouth_{left}} \tag{1}$$

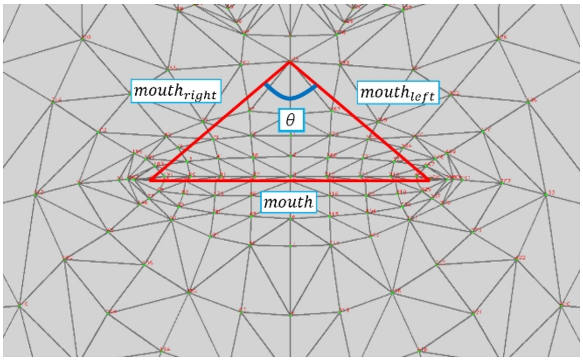

Figure 3: Diagram to calculate the angle between the nose and both corners of the mouth.

EXPERIMENT

Experimental Content

In this experiment, the subjects were tasked with imitating the expressions of happiness, neutrality, and sadness from images with varying intensities. This allowed us to investigate whether individuals with higher HSPS scores are more capable of detecting subtle changes in stimulus images and recognizing the emotions conveyed by those images. As a result, they could raise or lower the corners of their mouths, potentially experiencing emotional contagion. In addition, to assess whether individuals exhibited HSP tendencies, we also used the IRI-J as a measure to explore the subjects' level of empathy, which is acharacteristic associated with HSP.

Environment and Subjects

The subjects were seated in a chair, and a camera (iPhone 13 Pro) was positioned at a sufficient distance to clearly capture the subjects' faces. To ensure that there were no disruptions during the MediaPipe measurements, care was taken to avoid any unwanted background interference behind the subjects. Here the study included a total of seven subjects (six males and one female, all in their twenties).

Experimental Apparatus and Procedure

We ensured that nothing was visible behind the subjects, and we captured their faces at a distance that clearly displayed their facial expressions. In this experiment, the subjects were shown prerecorded facial photographs representing four levels of happiness, neutrality, and four levels of sadness. The subjects were asked to mimic these expressions, and we captured their mimicked expressions.

We measured the facial coordinates using the MediaPipe software and calculated the changes in facial expressions by determining the angles of both corners of the mouth relative to the nose base (MediaPipe Landmark: 78th, 164th, and 308th points), which corresponds to "AU12: Raising both lip corners" and "AU15: Lowering both lip corners" as defined in Ekman's Facial Action Coding System (FACS) (Ekman et al., 2002). We compared the changes in mouth corner angles at each level with the results of the previously administered HSPS and the IRI-J.

Note that this experiment was conducted according to the guidelines outlined in "Psychophysiological Measurement for New Interface Development 2021-A-29".

RESULTS AND DISCUSSION

Facial Expression Mimicry

When the subjects were asked to mimic the expressions of happiness, we observed that the angle formed between the upper lip and both corners of the mouth increased significantly for all subjects as the intensity of happiness increased (Figure 4). In contrast, when the subjects were asked to mimic the expressions of sadness, there was variation among the subjects. For example, some subjects showed an increase in the angle as the intensity of sadness increased, others exhibited a reduction in the angle, and some subjects exhibited little change (Figure 5).

In addition, as shown in Figures 4 and 5, it was apparent that, for expressions of happiness, subjects with higher scores on psychological indicators

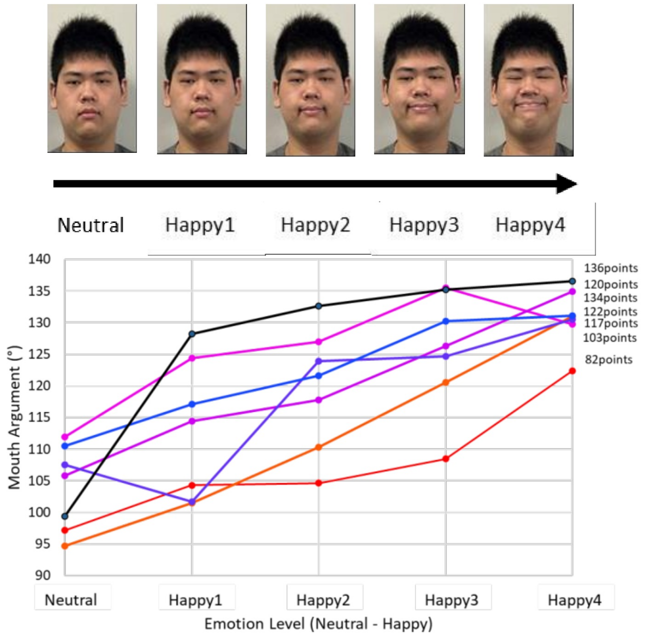

Figure 4: Angle changes based on intensity when mimicking happy expression.

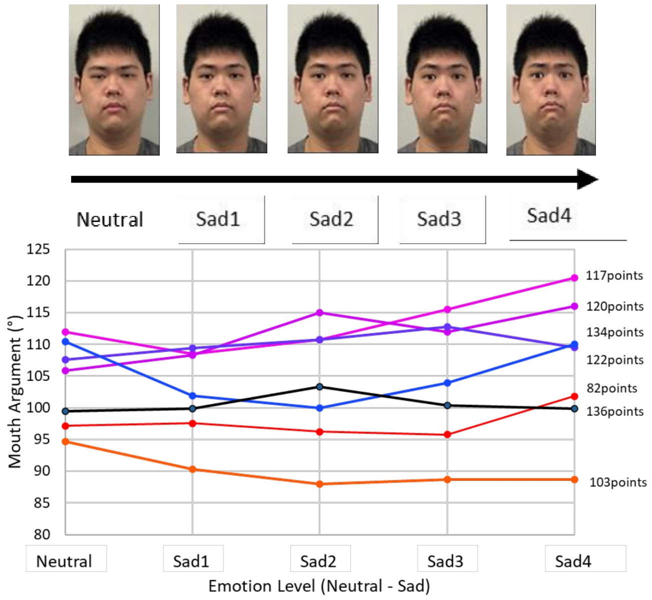

Figure 5: Angle changes based on intensity when mimicking sad expression.

followed a logarithmic curve $y = a \log x + b$, and those with lower scores followed an exponential curve $y = e^{ax}$. In contrast, for the expressions of sadness, no clear trend was observed between the scores on the psychological indicators and the angle changes. This may be attributed to the inherent difficulty in expressing sadness compared to other emotions (Kagamihara, 2017).

Relationship Between Facial Expression Mimicry and Psychological Indicators

We compared the changes in facial expression with the HSPS and IRI-J scores. Here, we calculated the coefficient a (where a > 0) for the approximation curves, which was then used to represent the change in mouth corner angle (hereinafter referred to as 'Mouth Changes'). We analyzed the changes in mouth corner angles for five levels of happiness intensity beginning from neutrality, five levels of sadness intensity beginning from neutrality, and more specific intervals, including from neutrality to the second level of happiness, neutrality to the second level of sadness, from the second level of happiness to the fourth level of happiness, and from the second level of sadness to the fourth level of sadness. We then compared these with the HSPS scores.

First, we compared the mouth changes for the five levels of happiness intensity and five levels of sadness intensity with the HSPS and IRI-J scores. The results demonstrated that, for the mouth changes, individuals with higher HSPS scores exhibited larger changes when imitating the expressions of happiness (Figure 7) ($r = 0.67$). However, no significant difference was observed when imitating the expressions of sadness. In addition, when we examined specific intervals, e.g., neutrality to the second level of happiness and from the second level of happiness to the fourth level of happiness, individuals with higher HSPS scores exhibited greater changes in the mouth corner angle (Figure 8 and Figure 9) ($r = 0.50$ (Neutral – Happy2), $r = 0.61$ (Happy2 – Happy4)).

We also compared the mouth changes with the IRI-J scores; however, no significant differences were observed for the expressions of both happiness and sadness.

From these findings, it was evident that individuals with higher HSPS scores were better at mimicking subtle changes in facial expression. The lack of significant differences in the mouth changes when mimicking the expressions of sad may be attributed to the inherent difficulty in expressing sadness compared to other emotions.

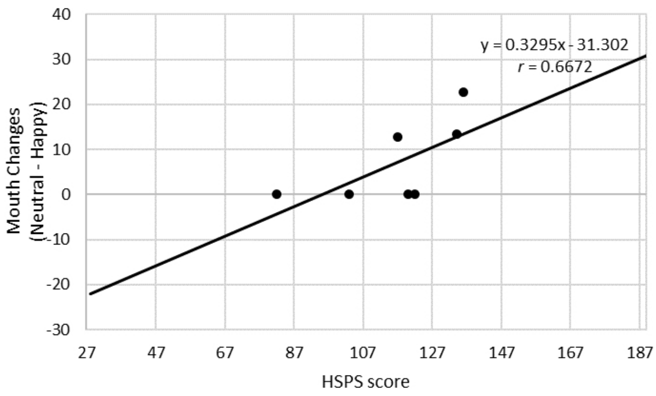

Figure 6: Correlation between HSPS scores and mouth changes (Neutral - Happy).

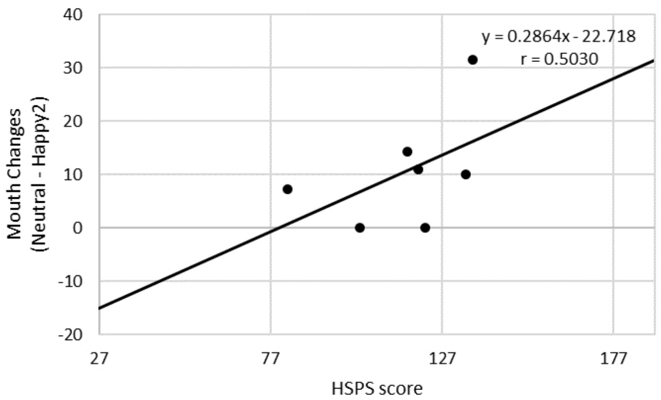

Figure 7: Correlation between HSPS scores and mouth changes (Neutral - Happy2).

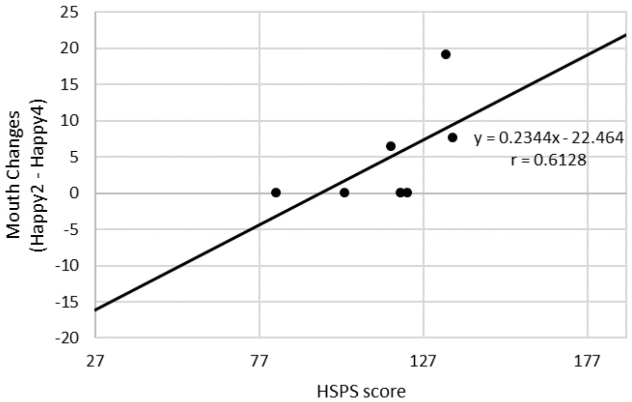

Figure 8: Correlation between HSPS scores and mouth changes (Happy2 - Happy4).

CONCLUSION

In this study, we focused on HSP characteristics, particularly their heightened empathy and ability to detect subtle cues. We hypothesized that individuals with HSP tendencies would be more receptive to subtle changes in facial expressions when intentionally mimicking those expressions, which could be expressed as their own facial expressions. To evaluate HSP objectively, we compared the changes in facial expressions when subjects intentionally mimicked the expressions of happiness (four levels), neutrality, and sadness (four levels) with their HSPS and IRI-J scores.

An experiment was conducted, where the subjects were tasked with mimicking the expressions of happiness, neutrality, and sadness. Then, we categorized the changes in expressions into five levels of intensity for both happiness and sadness beginning from neutrality. We compared these results with the subjects' HSPS and IRI-J scores. The findings demonstrated that individuals with higher HSPS scores exhibited larger changes in facial expression intensity when mimicking the expressions of happiness; however, no significant difference was observed for the expressions of sadness.

In addition, we evaluated the changes in facial expressions when the subjects mimicked subtle facial expressions by narrowing down the intervals of the expression intensity. Here, we found that individuals with higher HSPS scores exhibited larger changes in intensity in the intervals from neutrality to the second level of happiness and from the second level of happiness to the fourth level of happiness. However, for the expressions of sadness, no significant differences were observed in the mouth changes concerning the psychological indicators.

From these findings, we infer that individuals with higher HSPS and IRI-J scores, thereby indicating HSP tendencies, are more capable of perceiving and expressing subtle changes in facial expressions when intentionally mimicking such expressions.

In future research, we plan to revisit the calculation method used to measure changes in facial expressions, especially for the challenging area of sadness expressions, and investigate their correlation with the HSPS results. In addition, by increasing the number of subjects, we plan to conduct a more detailed exploration of the relationship between HSP and the changes in facial expressions during intentional mimicry to further assess HSP through intentional expression mimicry.

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