Judgment of perceived exertion by static and dynamic facial expression

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Unlike facial expressions of emotion, the effect of static and dynamic facial information on the perception of physical exertion have not been discussed in much depth. The purpose of this study is to examine whether the observer could perceive exertion by others based only on static or dynamic facial expression. And to examine which conditions (static and dynamic exertion face) could be better perceived by observers. Fifteen male and 15 female observers were recruited to observe both static and dynamic exertional faces to estimate the perceived exertion by facial pictorial RPE scale. The results of this study suggested that observers could perceive exertion by others only based on static or dynamic facial expression. The dynamic characteristic of our facial display is an important factor in the perception of the low intensity of exertional expressions. The static exertional face of a male is better than the dynamic exertional faces for perceiving incense facial expression.

Practitioner Summary: This study demonstrated that observers could use the facial pictorial RPE scale to assess both static and dynamic facial expression of effort. The effect of static and dynamic display could be used by ergonomist for observational assessment of forceful exertion.

Keywords: Facial expression of effort, perceived exertion, dynamic and static stimuli

1. Introduction

The rating of perceived exertion (RPE) scale has been widely used for workers to measure their own exertion. This method is commonly used for subjectively evaluating work tasks and determining acceptable loads in order to understand the task demands and prevents injuries. Besides exertion assessment by workers themselves, level of forceful exertions can also be estimated through observations by others. Observational methods offer an advantage in that they do not interfere with the task, thereby minimizing disruption. As Robertson et al. (2006) suggested that exertional observation is unobtrusive, inexpensive, and has a low participant burden making it suited for use in physical activity surveys, exercise prescription, and fitness-tracking involving children and adolescents. Some studies have demonstrated that observers could use RPE scales to assess someone else’s exertion. For examples, Ljunggren (1986) examined concurrent validity of a observational method to estimate Borg RPE of subjects performing randomly presented cycle ergometer power outputs. Drury et al. (2006) observed subjects who performed different postures for weight holding task to estimate Borg RPE. Robertson et al. (2006) showed the direct kinematic observation procedure to estimate OMNI Scale RPE for female and male children performing treadmill exercise. These studies have shown that observer-estimated RPE was strongly correlated with the subject’s RPE.

Usually exertion observation needs some visual cues for measuring forceful exertion in terms of detecting differences in exertion intensity. Facial expression is believed to be an important observation key in the observational assessment of forceful exertion that could provide a perceptual estimate of exertion intensity (Huang and Chiu, 2013; Huang et al., 2014; de Morree and Marcora, 2010). The face of effort is a type of facial expression that reflects how hard people are working during physical tasks and exercise. Previous studies have been shown that facial muscle activity correlated with RPE during weightlifting and cycling (de Morree and Marcora, 2010; Huang et al., 2014). Facial expression not only can convey emotion but also express physical effort; grimacing and squinting are examples of non-verbal behavior used to judge effort.

Most research on the facial expressions of emotion has been conducted using static faces as stimuli. However, the importance of dynamic properties of facial expression has recently been emphasized in some psychological literature. Some studies have shown a particular sensitivity for dynamic facial movements such
as, recognizing emotional expressions (Kamachi et al., 2001; Ambadar et al., 2005), in the perceived intensity of basic emotional expressions (Biele and Grabowska, 2006), recognizing mental states and even in the perceived intensity of of pain expression (Simon et al., 2008). Nevertheless, some studies also indicated that there was no difference between static and dynamic facial perception. Recio et al. (2011) showed that no significant differences in error rates of recognizing were observed between static and dynamic stimuli within neutral and anger facial expression. Rhodes et al. (2011) revealed that facial attractiveness ratings from video-clips and static Images tell the same story. Even though the videos contained a lot more information than the photographs, which could potentially affect perceptions of attractiveness. However, either static or dynamic faces on facial expression of effort have not been discussed in much depth, and an effect of static and dynamic facial information on perceived of physical exertion remains to be determined. Accordingly, the purpose of this study is to examine whether observer could perceive exertion by others based only on static or dynamic facial expression. And to examine which conditions (static and dynamic exertion face) could be better perceived by observers.

2. Method

2.1 Experimental design

A cross-sectional, perceptual estimation design was used to assess exertional perceptions during a load-incremented cycle ergometer protocol that terminated at peak task intensity. Each participant performed continuous incremental workload cycling exercise on an electromagnetically braked cycle ergometer (Corival 906900, Lode BV, Groningen, The Netherlands). The exercise included a 5-minute warm up at 0 watts (W), the initial power output was 50 W for women and 75 W for men. Power outputs were incremented in continuous 3-min test stages by 25 W and 50 W, respectively, for women and men. Participants were instructed to maintain a cycling cadence between 60–70 rpm throughout the exercise test. When a participant experienced volitional exhaustion or an inability to sustain a cadence greater than 55 rpm for a period of 5 seconds, the exercise test was terminated.

A Sony digital video camcorder (HDV 1080i- HV20) was used, at a fixed distance of 60 cm from the subject's face, at eye level. The final videos were edited to 10 seconds and muted, using iMovie 4.0 from each stage.

During the final 30 seconds of each stage (3 minutes) of the cycle ergometer exercise, the participants were asked to report their feelings of exertion according to the facial pictorial RPE scale (Huang and Chiou, 2013). An undifferentiated rating was estimated for the overall body. The facial pictorial RPE scale has a category rating format that contains both pictorial and verbal descriptors positioned along a comparatively narrow numerical response range, namely 0–10. The facial pictorial RPE scale was chosen because of the visual information on the pictorial faces was the primary cues emphasizing the scale instructions and this scale has been evidence supported by the use of this facial pictorial RPE scale by adult females and males for estimating RPE.

HR was monitored continuously using a wireless chest strap telemetry system (Polar WearLink System and Polar FT4 HR monitor, Polar Electro Oy, Kempele, Finland) during the task. Throughout the test the corrugator supercilii (CS) muscle activities were continuously recorded using EMG during exercise. For details about the recording method, please see our previous publication on facial EMG (Huang et al., 2014).

Five of the 22 male and 4 of the 18 females subjects were selected to analyze their video clips because of they were able to complete at least five stages of exercise. Dynamic stimulus were created by editing the videos to 6-s clips at the final 30 s of each stage and saving them in Quicktime format at 30 frames per second. Static stimuli were created by taking from each video a frame in which the frame was expressly exposed and the face maintained an actual state of exertion, looking toward the camera, and without purposely offering extra emotional expression. All faces were displayed for rating on an iMac 27 inch PC and viewed from 57 cm. Written informed consent was obtained from all participants.

2.2 Observation procedure

Thirty observers were recruited including 15 male and 15 female. Each observer observed both static and dynamic exertional faces to estimate perceived exertion by facial pictorial RPE scale. Randomize the display order of each subject's faces into 5 groups. Observers randomly selected one group to observe. The first
face displayed was selected from the warm up stage where no effort was made in order to show the baseline condition of each subject. After a baseline face was observed, the faces from each stimulation stage were assessed. The printed facial pictorial RPE scale was for observers to estimate the RPE when the faces were shown.

2.3 Data analysis

Subject’s self-report RPE was categorized into three levels. Subject’s RPE from 0 to 3 was low RPE level, 4-6 was medium RPE level, and 7-10 was high RPE level. Descriptive analysis of physiology and RPE data were shown as means±sd. Statistical analyses was performed using a two-way ANOVA to examine the difference between RPE levels and using two-tailed student’s t-test to examine the difference of estimated error between static and dynamics display conditions. The correlations between RPE estimated by the observer and RPE estimated by the subject were examined using a Pearson product–moment correlation coefficient. Statistic method Significance was set at a P value of 0.05 (two-sided) for all analyses. All analyses were conducted using the Statistical Package for Social Sciences Version 20 (SPSS Inc., Chicago, IL)

3. Result

Table 1 presents the average and standard deviation of physiology and RPE data of three RPE levels. Physiology data, HR and facial muscle activity of subjects for both gender were all significantly different between RPE levels except facial activity of female. Facial muscle activity of females did not change significantly through the task. All RPEs showed significant difference between RPE levels for both genders. Both static and dynamic observer RPEs were under estimated. Overall, the estimated error of observing female faces was significantly higher than male faces for both display conditions.

Table 2 shows that for both genders, static and dynamic RPE estimated by observers were all significantly correlated with subject’s self report RPE. Otherwise, all the RPEs were significantly correlated with HR. Comparisons between two observers RPEs, dynamic RPE show higher correlation between subject’s RPE and HR than static RPE.

<table>
<thead>
<tr>
<th>Subject gender</th>
<th>RPE level of subject</th>
<th>HR ± sd</th>
<th>CS muscle activity ± sd</th>
<th>Subject’s RPE</th>
<th>Static RPE ± sd</th>
<th>Dynamic RPE ± sd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Low (Easy)</td>
<td>112.0±20.0</td>
<td>4.95%±2.1%</td>
<td>2.25±0.4</td>
<td>2.87±1.5</td>
<td>1.88±1.4</td>
</tr>
<tr>
<td></td>
<td>Medium (somewhat hard)</td>
<td>130.1±25.5</td>
<td>12.78%±5.3%</td>
<td>5.11±0.7</td>
<td>4.12±1.8</td>
<td>3.00±1.8</td>
</tr>
<tr>
<td></td>
<td>High (Hard)</td>
<td>164.5±16.0</td>
<td>29.47%±16.9%</td>
<td>8.25±1.0</td>
<td>7.41±1.8</td>
<td>6.90±2.1</td>
</tr>
<tr>
<td>Female</td>
<td>Low (Easy)</td>
<td>110.5±12.9</td>
<td>11.80%±10.0%</td>
<td>2.75±0.4</td>
<td>2.16±1.8</td>
<td>1.91±1.1</td>
</tr>
<tr>
<td></td>
<td>Medium (somewhat hard)</td>
<td>142.1±15.8</td>
<td>18.06%±16.7%</td>
<td>4.80±0.8</td>
<td>3.07±1.9</td>
<td>2.88±1.7</td>
</tr>
<tr>
<td></td>
<td>High (Hard)</td>
<td>170.2±9.0</td>
<td>18.70%±13.3%</td>
<td>7.40±0.5</td>
<td>5.55±2.4</td>
<td>6.07±1.9</td>
</tr>
</tbody>
</table>
Table 2. Correlation between subject’s RPEs, HR and observer’s RPE

<table>
<thead>
<tr>
<th>Gender</th>
<th>Subject’s RPE</th>
<th>Static RPE</th>
<th>Dynamic RPE</th>
<th>Subject’s RPE</th>
<th>Static RPE</th>
<th>Dynamic RPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>0.785**</td>
<td>0.562**</td>
<td>0.604**</td>
<td>0.718**</td>
<td>0.562**</td>
<td>0.752**</td>
</tr>
<tr>
<td>Female</td>
<td>0.835**</td>
<td>0.649**</td>
<td>0.654**</td>
<td>0.529**</td>
<td>0.529**</td>
<td>0.661**</td>
</tr>
</tbody>
</table>

In Table 3, there was no gender difference between observers to estimate subject’s RPE. However, male observers have the tendency of a smaller error of judgment than males for both display conditions but no significant difference. Although there is no gender effect from observers, the gender difference between subjects was matter. Overall, the estimated error by observing female subjects was significantly higher than observing male subjects for both display conditions.

Table 3. Sex difference in estimated error of observers

<table>
<thead>
<tr>
<th>Subject Gender</th>
<th>Display conditions</th>
<th>Observer gender</th>
<th>Mean±SD</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Static</td>
<td>Male</td>
<td>1.71±1.36</td>
<td>-1.60</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>1.84±1.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dynamic</td>
<td>Male</td>
<td>1.84±1.37</td>
<td>-1.42</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>1.96±1.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>Static</td>
<td>Male</td>
<td>1.44±1.27</td>
<td>-0.59</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>1.50±1.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dynamic</td>
<td>Male</td>
<td>1.86±1.38</td>
<td>-0.97</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>1.97±1.48</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1 showed the estimated error (observer estimate – subject’s self-report) associated with observers estimation of exertion expression through static and dynamic faces for males and females. A two-way analysis of variance (ANOVA), with factors perceived exertion levels of subjects (low, medium and high) and display type (dynamic, static), revealed main effects of perceived exertion level, display type, and an interaction between these factors for both genders. For males, the subject’s RPE are at low level, estimated error of dynamic face was significantly lower than static face. At medium and high level of estimated error of dynamic face was significantly higher than static face. For females, the subject’s RPE at low and high level, estimated error of dynamic face was significantly lower than static face. There was no significant difference between static and dynamic condition when female are at medium level.
4. Discussion

4.1 Observation exertion by facial expression

This study hypothesized that both RPE of face display condition estimated by the observer and subject would be positively correlated. The findings supported this hypothesis, the observer estimated RPE through facial pictorial RPE scale which was significantly correlated with the subject’s self-rated RPE who used the same scale. This result indicated that only observing static or dynamic facial expression for perceiving others’ exertion could be possible and the correlation coefficient of dynamic RPE would be slightly higher than static RPE. The result of significant correlation was consistent with previous studies by using different RPE scales. Observer-estimated RPE was positively and linearly related to subject’s self-rated RPE through OMNI RPE scale over the submaximal cycle ergometer exercise stages (r=0.87–0.92) (Robertson et al., 2006). Ljunggren (1986) showed that to estimate RPE of subjects performing cycle ergometer power outputs through Borg scale. The observer-estimated RPE and subject’s self-rated RPE were also highly correlated (r=0.99). Drury et al. (2006) also showed that observers-estimated RPE through Borg scale correlated highly
with the self-rated RPE of the subjects performing the static holding tasks. However, the correlation between both observer RPE and subject’s RPE of this present study was significantly correlated (r=0.56–0.65) but lower than above studies. The result may be explained by the type of observation, in previous studies observers estimated exertions by dynamic observation cues with direct observations or video clips such as body language, facial expression and postures. Although dynamic exertion faces was also observed in this present study, only facial cues remained limited. The detail difference between static and dynamic is discussed in next section.

4.2 The difference between static and dynamic display conditions for observing

The results of this study showed that static face of exertion seems to have less estimated error than dynamic. However, from the view of the three subject’s RPE levels, when both gender subjects feel easy (subject’s RPE from 0-3), observers estimated error through their dynamic faces would be significantly less than static one for both male and female observers. One explanation for this is that dynamic facial expression offering more information to estimate the slight changes in facial activity when subjects are perceiving low-level exertion. The result is in line with previous studies of emotion recognition. Bould and Morris (2008) demonstrated that dynamic facial expressions could be a useful cue in the recognition process, especially when the expressions are subtle. Ambadar et al. (2005) also suggested that dynamic presentation might be particularly beneficial for the recognition of emotional expressions at low intensity.

When male subjects reported somewhat hard (subject’s RPE from 4-6) or hard (subject’s RPE from 7-10) they were facially expressive, the observer-estimated error through these dynamic faces would be significantly higher than static one. The more likely explanation rets in too much confusing information for exertion estimation through dynamics faces. As Bould and Morris (2008) suggested that when an emotion is intense, a static face is able to provide sufficient information to recognize an emotional state of someone else from a still photograph. It therefore seems that static faces are already strong carriers of emotional signals by corresponding to the shared stereotypes, leaving little scope for improvement through the provision of dynamic information. Other studies also suggested that the dynamic facial expression was not always better than static, for instant, facial attractiveness rating (Rhodes et al., 2011), emotion recognition of anger (Recio et al., 2011) and mental status recognition (Back et al., 2009). Therefore, the effect of dynamic face depends on different situations.

On the other hand, when female subjects reported hard during task, the observer-estimated error through dynamic faces would be much less than observing static faces. This result is in contrast with male subjects, this may be explained that females didn’t change facial activity obviously even when they perceived hard. Therefore, whether male and female subjects whom were not facially expressive, the dynamic facial expression could be a better cue in the rating of perceived exertion.

4.3 Gender difference of perceiving exertion

The present study showed that there was no gender difference between observers to estimate subject’s RPE through both display conditions. Male observers through both display conditions have the tendency of a smaller error of judgment than females but no significant difference. The result wasn’t in line with previous emotional studies. Previous studies revealed that females have an advantage in the decoding of non-verbal emotional cues and have more sensitivity perceiving facial expression of emotion (Hall et al., 2000; McClure, 2000; Montagne et al., 2005). One explanation is that the difference of neural mechanism of empathy between emotional processing and exertion perceiving. Future research could examine the difference between neural mechanism of emotion and exertion.

5. Conclusion

The results of this study suggested that observers could perceive exertion by others only based on static or dynamic facial expression. Type of face display conditions influenced on rating of perceiving others’ RPE. Its effect, however, depends on the subject’s sex and level of subject’s RPE. The dynamic characteristic of facial display is an important factor in the perception of the low intensity of exertional expressions. The static
exertional face of males had less estimated error than dynamic exertional faces for perceiving incense facial expression.

References