Facial Mimicry in Response to Song

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We examined facial responses to audio-visual presentations of emotional singing. Although many studies have now found evidence for facial responses to emotional stimuli, most have involved static facial expressions and none have involved singing. Singing represents a dynamic ecologically valid emotional stimulus with unique demands on orofacial motion that are independent of emotion, related to pitch and linguistic production. Observers' facial muscles were recorded with electromyography while they saw and heard recordings of a vocalist's performance sung with different emotional intentions (happy, neutral, and sad). Audio-visual presentations successfully elicited facial mimicry in observers that were congruent with the performer's intended emotions. Happy singing performances elicited increased activity in the zygomaticus major muscle region of observers, while sad performances evoked increased activity in the corrugator supercilii muscle region. These spontaneous facial muscle responses occurred within the first three seconds following onset of video presentation indicating that emotional nuances of singing performances can elicit dynamic facial responses from observers.

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Singers are renowned for their expressive and often dramatic use of facial expressions (Thompson, Graham, & Russo, 2005). Are these expressions superfluous, or do they serve a role in the perception of singing performance? One mechanism that may account for their prevalence is *facial mimicry*, a process where observers spontaneously and rapidly imitate others' facial expressions (Dimberg, 1982; Lundqvist & Dimberg, 1995). Facial mimicry is thought to improve observers' accuracy of emotional identification and decrease response time (Niendenthal, Brauer, Halberstadt, & Innes-Ker, 2001; Oberman, Winkielman, & Ramachandran, 2007; Stel & van Knippenberg, 2008), while enhancing emotional empathy (Stel, Van Baaren, & Vonk, 2008). These traits are likely to facilitate observers' perception and enjoyment of singing performance. However, it is unknown if the facial expressions produced by singers during vocal performance can elicit mimicry in observers.

During singing performance vocalists must balance the requirements of expressing the structural and linguistic content of the music (Thompson & Russo, 2007; Thompson, Russo, & Livingstone, 2010) with the emotional demands of the performance (Thompson, Russo, & Quinto, 2008). Orofacial movements related to the production of sung syllables (e.g., motion of the lips and jaw) may compete with orofacial movements used to convey emotion (e.g., raising or lowering of the lip corners in happiness and sadness). Thus, it is unclear if vocalists' facial expressions are sufficiently expressive to elicit facial mimicry in observers.

Previous investigations of facial mimicry have largely examined observer responses to static presentations of facial emotion. In these studies, photographs typically showing the apex of an expression are used. However the ecological validity of using static facial expressions in emotion research has been questioned. Facial motion is known to convey emotion in complex and subtle ways that are more accurate than static presentations (Bassili, 1979; Cunningham & Wallraven, 2009). Recently, Sato and Yoshikawa (2007) reported that observers' mimicry responses to dynamic facial expressions were larger than those in response to static presentations. Stimuli consisted of movies of facial expressions that continuously morphed from a neutral pose to an emotional apex. It is unknown, however, if the more complex facial movements that accompany singing production are capable of eliciting facial mimicry in observers.

A central aspect of all singing performance is the acoustic component. However, the contribution of the singing voice in eliciting facial mimicry remains unclear, particularly when paired with moving faces. Early investigations by Dimberg (1990) showed that pure auditory tones could elicit partial mimicry responses. Subsequent investigations using a range of stimuli found that facial responses could be elicited by

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auditory-only emotional presentations (Bradley & Lang, 2000; Dimberg, 1990; Hietanen, Surakka, & Linnankoski, 1998). Music has also been shown to elicit emotional facial responses in listeners. Lundqvist, Carlsson, Hilmersson, and Juslin (2009) presented listeners with acoustic recordings of pop music that conveyed either happiness or sadness. Happy music was found to elicit increased zygomaticus major muscle activity (raised lip corners), while sadness elicited increased corrugator supercilii activity (furrowed eyebrows). This suggests that acoustic-only recordings of singing may elicit facial responses in observers, but that the interacting role of vocalist facial expressions is unknown. Recently, Magnée and colleagues (2007) showed that the integration of vocal and facial affect can influence facial mimicry responses. Using pairings of static facial expressions with vocal recordings, Magnée showed that emotionally congruent pairings elicited facial mimicry responses in observers, while incongruent pairings did not. These findings suggest that the vocal channel can contribute to the facial mimicry response. In the present study, emotionally congruent pairings of vocal and facial affect were used so as to increase the likelihood of eliciting the facial mimicry response in observers.

Tentative support for singing-elicited facial mimicry was recently provided by Livingstone, Thompson, and Russo (2009). In their task, participants were asked to watch an audio-visual recording of a vocalist singing with a particular emotional expression. Following a short delay, participants were then required to reproduce the observed performance. On the basis of motion tracking and facial electromyography (EMG), it was found that participants appeared to mimic the happy emotion of the vocalist with contraction of the zygomaticus major muscle (raised lip corner). The onset of mimicry occurred during the perception of the vocalist. As the authors noted, however, it was not possible to conclude if the facial movements reflected emotional mimicry, or a form of motor-planning associated with the singing task. Thus it is remains unclear if singing performance can elicit facial mimicry in an observation-alone context.

The current study examined facial mimicry in response to audio-visual recordings of emotional singing performance in either an Observation or Imagery condition. Participants in the Observation group were asked to observe the video clips, while participants in the Imagery group were asked to observe the video clips and to subsequently imagine producing the song. The Imagery condition aimed at encouraging mimicry during the perception of emotional singing without imposing the motor demands of a singing production task. Participants were recorded with EMG while watching audio-visual recordings of a singer producing short lyrical phrases with a variety of emotions (happy, neutral, and sad). It was hypothesized that participants would exhibit facial mimicry responses that were congruent with the emotion expressed by the singer. Specifically, it was predicted that happy singing performance would evoke increased activity in the zygomaticus major muscle region in participants, and that sad utterances would evoke increased activity in the corrugator supercilii muscle region. It was also hypothesized that participants in the Imagery group would show larger mimicry responses that those in the Perception group.

Method

PARTICIPANTS

Thirty-seven participants (35 female, $M = 21.6$ years, $SD = 4.4$ years) were recruited from the Ryerson community and undergraduate psychology testing pool.[1] Participants were randomly assigned to the Observation group ($N = 21$) or the Imagery group ($N = 16$). Participants had varying amounts of general music training ($M = 4.5$ years, $SD = 3.5$ years) and singing experience ($M = 1.4$ years, $SD = 2.5$ years). Neither level of music training nor singing training differed significantly between the two groups. Participants received either course credit or $10 for participation. The model participant was a 50-year old woman with eight years of formal singing instruction and 40 years of music experience. Ethical consent for the study was approved by the Ryerson University Research Ethics Board.

STIMULUS

Stimuli consisted of audio-visual recordings of the model target singing brief lyrical phrases set to a melody and an audible metronome. Two statements were used ("grass is green in summertime" and "autumn leaves are turning red") and embedded within a common stimulus timeline, illustrated in Figure 1.

The timeline was 14.52 s in total duration and consisted of four main epochs, each 3,080 ms in duration: Perception, Count-in, Task, and Post-task. Each audio-visual recording was preceded by 1,300 ms of silence followed by a 200 ms audible beep. The video recording of the singer was then presented (Perception). The recording was followed by a 384 ms IOI audio-visual count-in timer ('4', '3', '2', '1'). A green-circle was then

[1] Thirty-nine additional participants were dropped from the study due to: equipment failure ($n = 25$), not completing the experiment ($n = 7$), or for having guessed the purpose of the electrodes ($n = 7$).

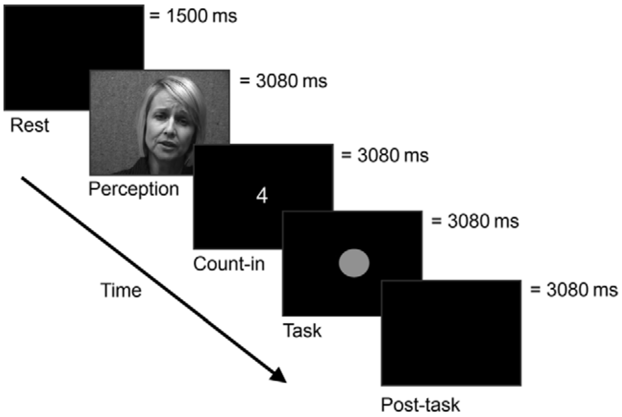

FIGURE 1. Timeline of stimulus shown to participants. Facial EMG recordings were collected throughout the trial.

displayed to signal the onset of the Task epoch. The Post-task epoch continued to display a black screen. The timeline ended with a 200 ms audible beep.

In recordings of the singer, an audible 384 ms IOI metronome (61dB) was used to maintain a consistent tempo for singing production. The metronome continued throughout the Count-in phase to facilitate timing onset for the Imagery group. Previous research has indicated that a 75 dB tone prior to silence can elicit a small orientating response in corrugator and zygomatic activity (Dimberg, 1990). However, any such effects would presumably be constant across the three emotional conditions.

APPARATUS AND MATERIALS

EMG was used to measure facial muscle activity. Electrode placement followed the guidelines described by Fridlund and Cacioppo (1986). Participants' skin was cleaned with alcohol before the electrodes were attached. Shielded 4 mm silver-silver chloride (Ag/AgCI) miniature surface electrodes (Biopac, EL 208 S) were filled with electrode gel. Electrodes were placed on the left side of the face to facilitate mimicry detection (Dimberg & Petterson, 2000). Two electrodes were placed on the zygomaticus major and two on corrugator supercilii muscle regions, both separated by a distance of 25 mm (Tassinary & Cacioppo, 2000). A ground wire was attached to the back of the participant's neck.

Voltage data were sampled at 200 Hz using a Biopac EMG100C amplifier and an MP100 (Biopac Systems, Santa Barbara, CA) data acquisition system under the control of a Mac mini computer running AcqKnowledge software (Biopac Systems), version 3.9.2 for Mac. EMG data were analyzed using FeatureFinder (Andrews, Nespoli, & Russo, 2011), a freely available Matlab toolbox for custom analysis of physiological signals.

Stimuli were presented using PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993) to participants on an Intel-based PC connected with a 19" LCD monitor and two Logitech X120 speakers. Participants were tested in an IAC double-walled sound-attenuated chamber.

PROCEDURE AND DESIGN

Participants were given a cover story regarding the purpose of the surface electrodes to reduce any demand characteristics stemming from deduction of the experimental hypothesis; specifically, they were told that the electrodes would record sweat gland activity (Dimberg, Thunberg, & Elmehed, 2000). Participants sat facing the screen and speakers at a distance of approximately 1 m. The experiment began with a brief training example using a recording not shown in the experimental trials. Participants in both groups (Observation, Imagery) were told to watch the video and to "please be absorbed by the music." Participants in the Imagery group had additional instructions; they were told that during the Task epoch they were to imagine themselves singing what they had observed during the Perception epoch. All participants were instructed to refrain from making any major body movements, to reduce the presence of motion artifacts. Following training, participants sat quietly for 6 min to bring their physiological responses to a steady state. For each experimental trial, participants were asked to identify the emotion of the performer using a forced-choice categorical response measure (Happy, Neutral, Sad), and the intensity of the vocalist's emotion using a 5-point unipolar scale ("1" = "least intense" to "5" = "most intense") using the computer keyboard. A 1 min rest was inserted between trials to allow participants' physiological measures to return to baseline. After the experiment, participants completed a background questionnaire, and were asked whether they thought anything else besides sweat was measured. The seven participants who correctly guessed the purpose of the leads were removed from further analysis. Participation in the experiment took approximately 30 min, and participants received either monetary compensation or course credit.

The experiment design was defined by 3 (emotion: happy, neutral, sad) $\times$ 2 (statement) $\times$ 3 (repetition) within-subjects factors, with a between-subjects factor of Task-group. Trials were blocked by Repetition, with Emotion and Statement presented in random order. This design yielded 18 trials per participant. All analyses were run with collapsed factors of Repetition and Statement.

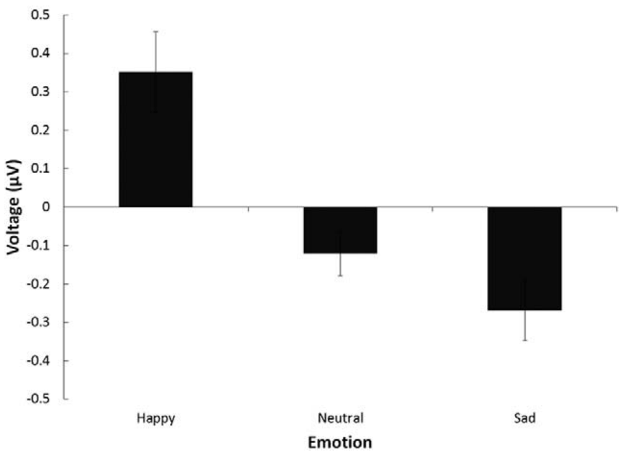

FIGURE 2. Mean zygomaticus major muscle region activity in observers for happy, neutral, and sad singing presentations. The figure shows activity following baseline subtraction. Error bars denote the standard error of the means.

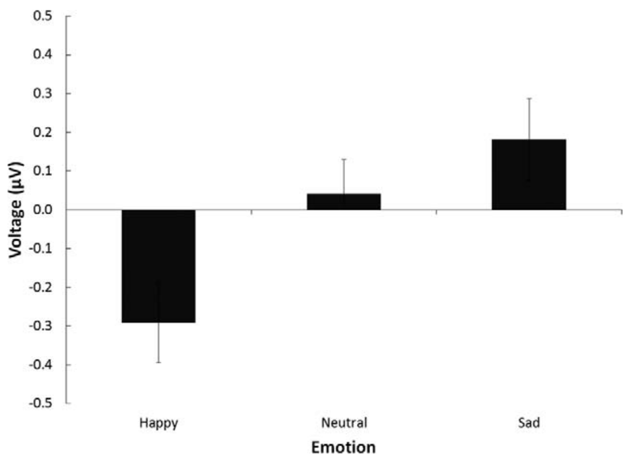

FIGURE 3. Mean corrugator supercilii muscle region activity in observers for happy, neutral, and sad singing presentations. The figure shows activity following baseline subtraction. Error bars denote the standard error of the means.

ANALYSES

EMG data were filtered using a notch filter to attenuate ambient electrical noise (Butterworth, first order, 59-61 Hz), and were then high-pass filtered to minimize motion artifacts (Butterworth, fifth order, 10 Hz cut-off). Data were full-wave rectified and then smoothed using an RMS filter with a 50 ms sliding window and overlap of 49 ms. Filtered data were also visually inspected for DC offsets, identified as protracted changes in voltage away from the zero crossing. Trials with DC offsets were removed (5% of all trials).

Data were zeroed using a baseline subtraction procedure. A baseline window of 2,000 ms prior to video onset was selected. The average value within the baseline window was subtracted from the target window. The target window was defined as the duration spanning the start and end of the video presentation of the singer (the Perception epoch; duration = 3,080 ms).

Results

A mixed-design analysis of variance (ANOVA) was conducted on the zygomaticus muscle region responses with Emotion (Happy, Neutral, Sad) as a within-subjects factor and Group (Perception, Imagery) as a between-subjects factor. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 20.72$, $p < .001$. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, $\varepsilon = .69$. A significant main effect of Emotion was found, $F(2, 70) = 9.18$, $p = .002$, $\eta^2 = .21$. Figure 2 presents the mean zygomaticus activity for each presented emotion, collapsed across task groups. Planned contrasts confirmed that zygomaticus activity for Happy trials ($M = .34$, $SE = .18$) was significantly higher than in Neutral trials ($M = -.12$, $SE = .08$), $F(1, 35) = 6.58$, $p < .05$. Contrasts also revealed that activity in Neutral trials was higher than activity in Sad trials ($M = -.28$, $SE = .09$), $F(1, 35) = 3.72$, $p < .05$. The main effect of Task-group was not significant, $F(1, 35) < 1$, nor was its interaction with Emotion, $F(2, 70) < 1$, indicating that the Imagery task had no effect on participants' mimicry responses for the zygomaticus muscle region.

A mixed-design analysis of variance (ANOVA) was conducted on the corrugator muscle region responses with Emotion (Happy, Neutral, Sad) as a within-subjects factor and Group (Perception, Imagery) as a between-subjects factor. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 11.83$, $p < .001$. As Greenhouse-Geisser estimates of sphericity were greater than .75, the degrees of freedom were corrected using Huynh-Feldt estimates of sphericity ($\varepsilon = .83$) (Girden, 1992). A marginally significant main effect of Emotion was found, $F(2, 70) = 3.14$, $p = .06$, $\eta^2 = .08$. Figure 3 presents the mean corrugator activity for each presented emotion, collapsed across task groups. Planned contrasts confirmed that corrugator activity for Neutral trials ($M = .02$, $SE = .14$) was significantly higher than in Happy trials ($M = -.31$, $SE = .18$), $F(1, 35) = 4.50$, $p < .05$. There was no difference between Neutral vs. Sad trials ($M = .16$, $SE = .17$), $F(1, 35) < 1$. The main effect of Task-group was not significant, $F(1, 35) = 1.41$, $p = .24$, nor was its interaction with Emotion, $F(2, 70) < 1$, suggesting that the Imagery task had no effect on participants' mimicry responses for the zygomaticus muscle region.

Figure 3 illustrates that happy singing elicited an apparent relaxation of the corrugator muscle region, as calculated from the stimulus-evoked changes relative to baseline activity. This pattern of negative corrugator activity is commonly observed in EMG facial literature (Achaibou, Pourtois, Schwartz, & Vuilleumier, 2008; Dimberg & Petterson, 2000; Dimberg et al., 2000; Lundqvist et al., 2009) and may result from a tendency to frown slightly during the baseline period preceding stimulus onset, as typically observed in anticipatory states or "effortful" task conditions (van Boxtel, Damen, & Brunia, 1996; van Boxtel & Jessurun, 1993).

We examined the relationship between participants' music and singing experience, and their mimicry responses. To assess general muscle activity for emotional stimuli, composite measures were obtained for emotional and neutral productions. An emotional composite measure was obtained by summing average zygomaticus responses for happy trials and average corrugator responses for sad trials (Brown, Bradley & Lang, 2006). A composite neutral measure was obtained by summing average zygomaticus responses and average corrugator responses for neutral trials. Four correlations were conducted on the emotional and neutral composites: years of music training with (1) emotional composite, (2) neutral composite; and years of singing training with (3) emotional composite, (4) neutral composite. No correlations reached significance, indicating that neither singing nor music experience affected the intensity of participants' mimicry responses.

Discussion

Audio-visual presentations of song successfully elicited facial mimicry in observers that was congruent with the performer's intended emotions. Happy singing performances elicited increased zygomaticus major region activity relative to neutral and sad trials, while sad and neutral singing performances elicited increased corrugator supercilii region activity relative to happy performances. It is important to note that these congruent muscle responses occurred within the first 3 seconds following onset of video presentation. Therefore, the nature of the facial responses observed here are qualitatively different from those that have been observed in studies of musical mood induction, which typically observe facial or physiological responses over much longer periods (Khalfa, Roy, Rainville, Dalla Bella, & Peretz, 2008; Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2009).

The present study demonstrated that brief audio-visual recordings of emotional singing elicit facial mimicry in an observation context. These results clarify findings by Livingstone et al. (2009), which used a perception-then-production paradigm, by confirming that mimicry can be elicited in a perception-only context. We were also interested in this study on the effect of mental imagery on facial mimicry responses. No effects involving task group were found, suggesting that the imaging task did not affect participants' mimicry responses during perception. However, as no behavioral measure of imaging performance was collected, it is unknown if participants imaged as requested (for a discussion of this issue see Zatorre & Halpern, 2005).

Studies of facial mimicry have typically used presentations of silent facial expressions. In contrast, this study used the facial expressions of singers, a complex and dynamically rich stimulus to elicit facial mimicry. An important consequence of using facial movements during singing performance is that they contain movements related to acoustic production as well as movements related to emotional expression. For example, an ascending interval in singing is often accompanied by a raising of the eyebrows (Thompson et al., 2005, 2010), yet this motion is also used for the expression of happiness (Kohler et al., 2004). While the present study did not address what effects these concomitant movement types have on observers' facial mimicry, the results do confirm that singers' facial movements elicit emotionally differentiable mimicry in observers.

In the present study participants were composed primarily of women. Previous research has indicated that females show larger facial muscle reactions to facial expressions than that of males (Dimberg & Lundquist, 1990). While the use of more women in our study may have produced larger facial responses, we would expect the pattern of reported effects to generalize to both males and females.

Facial mimicry may be the product of underlying circuitry that supports perception of intentional movement by mapping observed movement onto action plans. In this regard, facial mimicry can be linked to the mirror neuron system, which has been associated with music, theory of mind, and empathy (Gallese, 2003; Livingstone & Thompson, 2009; Molnar-Szakacs & Overy, 2006; Schulte-Rüther, Markowitsch, Fink, & Piefke, 2007; Sonnby-Borgström, Jönsson, & Svensson, 2003; Stel et al., 2008; Watkins, Strafella, & Paus, 2003). The lack of effect between observation and imagery task groups suggests that facial mimicry may occur automatically during the perception of sung emotion, without the explicit instruction to imagine or imitate.

Future studies might investigate questions of automaticity by manipulating task demands and instructions. Automatic reactions are considered to be those not requiring attention or awareness (Eyesenk & Keane, 1995). The present experiment could be repeated with the addition of a cognitively demanding secondary task in addition to the emotion judgment (e.g., number counting). If facial mimicry continues to occur in the presence of a cognitively demanding secondary task, this would support the view that facial mimicry is automatic in the context of song perception (Thompson et al., 2008, 2010).

In conclusion, this investigation confirms that facial mimicry occurs in response to audio-visual presentations of emotional song. This dynamic example of mapping perception onto action extends the evidence for spontaneous facial mimicry to the domain of song. Although the present study was not designed to directly assess emotion understanding, facial mimicry may well be a critical mechanism contributing to the nuanced discriminations of emotion that are commonplace in the perception of song.

Author Note

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