# Smiling By Way of Zygomatic Electrical Stimulation: Investigating the Facial Feedback Hypothesis

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**Abstract**

While it is widely accepted that affective states precede facial expressions, the facial feedback hypothesis (FFH) proposes the inverse. The FFH postulates that facial muscle region activity (e.g., smiling or frowning) directly influences the experience of emotion. The purpose of the present study was to evaluate the validity of the FFH—specifically whether smiling independently enhances positive mood. A methodological error in previous similar studies was inadequate control of variability between participants in the activity of the zygomaticus major (i.e., muscle region producing smiles). This methodological error was addressed here with the introduction of a novel procedure. Intermittent electrical stimulation to the zygomaticus was administered to 56 participants while they viewed a randomized sequence of affectively positive and neutral images. Half of the images were presented along with electric zygomatic stimulation while the remaining half were displayed without stimulation. Throughout the procedure, participants' zygomatic activity was measured with facial electromyography in order to precisely monitor variability. Overall, participants rated all images as more positive when displayed synchronously with zygomatic stimulation than without. Positive images were rated more positively while viewed concurrently with electrical stimulation, but no significant effect was seen with neutral images. These findings suggest that induced zygomatic activity enhances positive affect when experiencing positive stimuli, thereby supporting the FFH and offering an innovative methodology that can be used to further investigate the relationship between zygomatic activation and positive affect and other dimensions of the FFH.

*Keywords*: facial electromyography, electric stimulation, facial muscle, facial feedback hypothesis, emotion

The facial feedback hypothesis (FFH) suggests that facial expression has an effect on the experience of emotion. According to this hypothesis, simply the act of smiling will cause one to feel happy, or at least happier. Given that smiling is universally associated with happiness (Hofmann et al., 2017), this idea appears reasonable; although, in reality, the FFH has become a matter of controversy due to inconsistent findings in research conducted over the past five decades (Coles et al., 2019; Tourangeau & Ellsworth, 1979; Wagenmakers et al., 2016).

The FFH can be considered an expansion of the James-Lange theory (i.e., body movement affects emotional experience), especially considering James' interest in muscular feedback (Tourangeau & Ellsworth, 1979). The roots of the FFH may be traced back to the late-nineteenth century writings of Darwin (1872) and James (1890), both of whom rejected the idea that internal experience always precedes outward expression. Darwin argued that facial expression *modulates* emotion, while James argued that facial expression *is* the emotion. Eventually, the speculated role of facial feedback in emotional experience evolved into a matter of considerable dimensionality (i.e., sub-hypotheses for the FFH) and became more complex as further research was conducted in the mid-to-late twentieth century (Ekman, 1973; Gellhorn, 1964; Izard, 1971; Lanzetta et al., 1976; Tomkins, 1962). Once the facial feedback hypothesis became ubiquitous in facial feedback research, it had already expanded to encompass an array of more specific sub-hypotheses, each serving to further explain the relationship between facial expression and emotion (Coles et al., 2019). Many studies have investigated the validity of the FFH. The general finding of FFH research is that facial expression indeed modulates emotional experience, though inconsistencies in findings exist among specific FFH sub-hypotheses (Coles et al., 2019).

Research on the facilitative effect of zygomatic (i.e., muscle region associated with smiling) feedback on positive emotion—both when defined dimensionally (e.g., positive affect) and discretely (e.g., amusement, happiness)—has mixed findings (Coles et al., 2019; Wagenmakers et al., 2016). Strack et al., (1988) published what is arguably the most influential, albeit controversial, study to examine the FFH. The controversy derives from studies that supported the FFH and used methodology in which participants were unaware of experimental facial feedback manipulation. Strack et al. (1988) tested the hypothesis that the act of smiling enhances ratings of funniness in response to humorous stimuli (i.e., a cartoon); the procedure required participants to hold a pen in between their teeth in a manner that induces a facial expression bearing a high resemblance to an open mouth smile (i.e., wide grin with visible teeth), an expression associated with affectively positive discrete emotions of interest (e.g., funniness, amusement). Since its publication, Strack et al. (1988) became widely known as a critical piece of evidence for the FFH, and often is referenced in introductory psychology courses and textbooks (Wagenmakers et al., 2016). The fascination revolving around the study's methodology and conclusions inspired similar FFH studies (i.e., measuring the facilitative effect of facial expression on affect in response to emotional stimuli) in the following decades; studies used either the pen-in-mouth technique or an alternative method of zygomatic manipulation (e.g., Ekman, 1993; Kleinke et al., 1998; Söderkvist et al., 2018; Soussignan, 2002; Wagenmakers et al., 2016). This wave of studies—either adapting elements from or replicating Strack et al. (1988)—produced mixed outcomes, thus stirring the debate on the FFH's validity. Most interestingly, Wagenmakers et al. (2016) conducted a wide-scale Registered Replication Report that compiled the findings of 17 independent replications of the 1988 study. Despite efforts to meticulously and precisely replicate the procedure used by Strack et al. (1988), the replications failed to produce statistically strong evidence for the FFH. Nonetheless, Wagenmakers et al. (2016) noted that their findings did not necessarily refute FFH but may have suffered from flawed methodology. This suspicion is reasonable considering much of prior research provided overall support of the FFH (Coles et al., 2016). Through an examination of FFH studies concerning the zygomaticus, it seems possible that discrepancies in results across specific FFH studies may be attributed to methodology having low statistical power.

Low statistical power in FFH research can be attributed to two key factors: (1) inconsistent levels of zygomatic activation across participants or, (2) imprecise monitoring of zygomatic activity allowing unknown variability. First, previous studies have used unreliable methods of consistently activating the zygomaticus major across participants (Coles et al., 2019) possibly yielding inconsistent effect sizes of facial feedback manipulation on emotional response. This suggests procedures such as the pen-in-mouth technique have low power. Second, previous studies have used imprecise means of monitoring participants' zygomatic activity. In some FFH studies, researchers verified appropriate facial expression through visual observation of video recordings of participants (Hennenlotter et al. 2009; Kleinke et al., 1998; Soussignan, 2002; Tourangeau & Ellsworth, 1979; Wagenmakers et al., 2016); however, human observation of zygomatic activity is far from precise and objective—it is not feasible to use human visual observation alone to examine the variability of zygomatic activation between participants given the dynamic and complex nature of facial muscle activity. Thus, studies that use imprecise means of both manipulating facial feedback and measuring this variability, cannot reliably determine the true effect size of facial feedback. In addition, knowledge of being videotaped may have interfered with participants' emotional experiences and facial expressions (Strack, 2016). As such, facial electromyography (fEMG) is likely better suited for zygomatic observation than human visual observation. This argument is supported by findings from previous fEMG studies showing that participants presented with affectively positive stimuli will exhibit an autonomic response of activation in the zygomaticus major region before the participant is consciously aware of the stimuli's affective nature; this effect occurs before a smile is even visible to the human eye (Söderkvist et al., 2018; Soussignan, 2002). Additionally, though Strack et al. (1988) investigated the discrete emotions of funniness and amusement in response to humorous stimuli, it is possible that the subjective nature of humor served to hamper replication of the study's findings (Strack, 2016). In the present study, a more general, dimensional rating of positive affect was used to account for variability between individual interpretations of positive affect.

The primary purpose of the present study was to investigate whether or not activation in the zygomaticus major (i.e., muscle region related to smiling) facilitated the experience of positive affect (i.e., how positively a participant felt) while perceiving affective stimuli. A secondary purpose was to provide a more controlled test of the FFH by introducing a novel procedure allowing the researcher control over typical variability of zygomatic activity between participants. Examining facial muscle activity as an independent enhancer of affective responses to positive stimuli allows for insight into the effect of facial feedback alone on emotional experience. This novel procedure utilized a high voltage stimulator to electrically stimulate and activate the zygomaticus major at a consistent level for each trial across participants while fEMG was used to verify consistent zygomatic activation as a product of electrical stimulation between participants. Two hypotheses were (1) participants will report overall higher positive feelings when viewing all images (positive and neutral) while experiencing zygomatic electrical stimulation than in the absence of zygomatic stimulation, and (2) participants will demonstrate more variability in zygomatic activation when expressing a baseline (i.e., natural) smile and less variability in zygomatic activation when the researcher directly administers electrical stimulation to the zygomaticus major.

## Method and Procedure

Participants ($n$ = 56), primarily young adults, were recruited from introductory psychology courses at a southern California community college. Informed consent forms were approved by the Institutional Review Board (IRB). The forms were subsequently signed by each participant, thus expressing their consent to participate in the study. After being welcomed into the study room and completing the consent form, the researcher applied bilateral electrodes for the high voltage stimulator and facial electromyography to the participants' zygomaticus major regions. To verify consistent muscle activity across participants, zygomatic activation was quantitatively recorded with fEMG. Participants then viewed a randomized sequence of the same 20 images (10 positive and 10 neutral) displayed on a laptop as electrical stimulation was simultaneously administered to participants' zygomatici during the display of every other image (i.e., participants were stimulated for 10 out of the 20 images). Each image was displayed for 10 seconds, with a blank image being shown between all images to avoid carryover effects. Responding to a Google Form, participants were instructed to rate how positively they felt about each image as it was displayed. Responses were rated based on a 10-point Likert scale, ranging from 1 (*not positive at all*) to 10 (*extremely positive*), defining affect from a dimensional approach. After viewing all 20 images, fEMG was used to record participants' baseline zygomatic activity during natural neutral and smiling expressions after being presented with a display of prompts on the laptop, instructing them to hold a *smile* and *neutral* position for the 10 seconds that each prompt was displayed. A blank image was displayed between each expression to minimize carryover effects.

**Materials**

An iWorx IX-TA-220 data recorder and iWire-BG3 were used in conjunction with a high voltage (HV) stimulator and facial electromyography (fEMG) to stimulate and record the zygomaticus major muscles. The HV stimulator and fEMG devices were applied to participants' zygomatici with electrodes secured with medical tape. fEMG recorded participants' facial muscle activity data throughout trials. Labscribe 4, a data acquisition and analysis program, was used alongside the iWorx system to program and safely administer electric stimulation sequences while displaying randomized image sequences and recording fEMG data. The HV stimulator was used to administer 0.5 milliamperes (mA) of electrical current to each participant's zygomaticus major region. In an earlier pilot study, the electrical stimulation was found to be painless, unintrusive, and most often undetectable by participants, while still creating feedback in the zygomatic region. Only 5 out of 20 participants in a pilot study reported feeling the stimulation, each reporting a very minor sensation. The use of electrical stimulation in the present study allowed experimental zygomatic stimulation to be entirely controlled by the experimenter, requiring no effort on part of the participant to engage the zygomaticus. fEMG was specifically utilized in this study to (a) confirm electrical stimulation mitigated variability between participants, and (b) observe the difference in variability between the artificial and baseline stimulation conditions (i.e., zygomatic activation from electrical stimulation compared to a natural smile).

Images used in the image sequences were borrowed from the Open Affective Standardized Image Set (OASIS) developed by Kurdi et al. (2017)—an expansive collection of photographs containing data on mean participant ratings of valence (i.e., degree of positive or negative affect) and arousal (i.e., intensity of emotional experience) for each image. The present study selected affectively positive images (e.g., dogs, a cat, fireworks, lakes, and a sunset) based on high valence and neutral images (e.g., blank walls, office supplies, and rocks) based on moderate valence and low arousal. A set of 10 neutral ($M$ = 4.10, $SD$ = 0.07 [valence]; $M$ = 1.81, $SD$ = 0.04 [arousal]) and 10 positive photographs ($M$ = 6.28, $SD$ = 0.12 [valence]; M = 4.46, $SD$ = 0.42 [arousal]) were used.

## Results

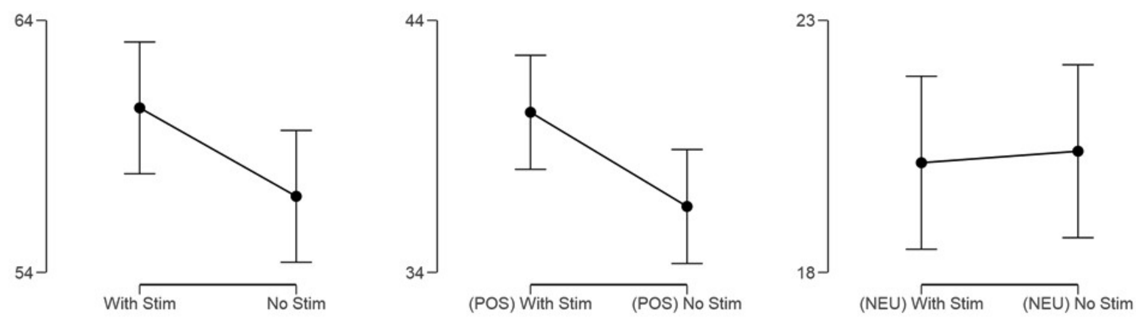
Dependent samples *t*-tests were used to compare stimulated versus non-stimulated conditions (see Table 1). Participants rated images significantly more positively when receiving zygomatic stimulation than when not receiving zygomatic stimulation, $t(54) = 2.341$, $p = .031$. The effect size was small ($d = 0.252$). When comparing only positive images, participants rated images more highly when viewed while receiving zygomatic stimulation than when viewed while not receiving zygomatic stimulation, $t(54) = 2.341$, $p = .011$.

The effect size was also small ($d$ = 0.310). In addition, participants did not significantly rate neutral images higher when receiving zygomatic stimulation than when not receiving zygomatic stimulation, $t(54) = -0.188$, $p = 0.851$. Moreover, a difference was found in zygomatic activity across participants (see Figure 1). High variability between participants ($M$ = 1.930, $SD$ = 2.157) was found when examining baseline (i.e., smiling expressions in the absence of affective stimuli and electrical stimulation) electrical zygomatic activity in millivolts (mV) during a natural smile.

**Figure 1**

*Positivity Ratings for Overall, Positive, and Neutral Images with and without Electric Zygomatic Stimulation*

**Overall Positive Neutral**




*Note.* Error bars represent standard error. (POS) = positive images and (NEU) = neutral images

**Table 1**

*Positivity Ratings for Images Displayed with and without Electrical Zygomatic Stimulation*

| | | | | | | | 95% CI for Cohen's $d$ | |
|---|---|---|---|---|---|---|---|---|
| | | | $t$ | $df$ | $p$ | Cohen's $d$ | Lower | Upper |
| With Stimulation | - | No Stimulation | 1.902 | 56 | 0.031* | 0.252 | -0.013 | 0.515 |
| (Positive) With Stimulation | - | (Positive) No Stimulation | 2.341 | 56 | 0.011* | 0.310 | 0.043 | 0.575 |
| (Neutral) With Stimulation | - | (Neutral) No Stimulation | 0.188 | 56 | 0.423 | -0.025 | -0.284 | 0.235 |

*Note.* *$p$ < .05

## Discussion

The results of the present study supported the hypothesis that the activity of the zygomaticus major directly enhances the experience of positive affect in response to affectively positive stimuli. Electrical stimulation to the zygomaticus major facilitated higher levels of positive affect while viewing positive stimuli compared to without electrical stimulation. The same effect was seen with all images overall, although no effect was seen with only neutral images. Furthermore, high variability was found between the zygomatic activity of participants while engaging in a natural smile. This variability indicates individuals naturally vary significantly in the magnitude of zygomatic activation. As such, it is pertinent in FFH studies to account for variability between subjects in facial muscle activation. Moreover, through using fEMG, the present study allowed for substantial control over zygomatic activation induced by electrical stimulation as opposed to testing participants' natural smiles. These results provide evidence for the viability of the novel procedure of using electrical stimulation in conjunction with fEMG as a method of testing the FFH.

One limitation of the present study is that it only measured one dimension of the FFH. Nonetheless, the present study's method of using electric stimulation with fEMG as a means of facial feedback manipulation may be useful for testing other dimensions of the FFH investigated previously with conflicting outcomes. For example, while only the effects of the zygomatic activation were investigated in the present study, the same methods could be used to mimic the muscle activity of the naturalistic Duchenne smile, which engages both the orbicularis oculi (i.e., muscle region around eyes) and the zygomaticus (Ekman, 1993; Sossignan, 2002) and measure its effect on positive affect. Similarly, the effects of corrugator supercilii (e.g., facial muscle region associated with frowning and negative affect) stimulation alongside low valence stimuli on negative affect could be tested. Likewise, the novel procedure introduced may be used to investigate the attenuating effects of facial feedback on emotion, given past evidence for the attenuating effects on existing emotional states stemming from facial feedback (Söderkvist et al., 2018). The effects of corrugator stimulation on emotional states, for example, could also be compared to the apparent attenuation of negative affect when the corrugator undergoes dissimulation (Hennenlotter et al., 2009; Davis et al., 2010). Moreover, some studies investigating a different dimension of the FFH have used an alternate method of limiting variability in facial muscle activity by inhibiting muscle activity with the injection of botulinum toxin (Botox) in the corrugator supercilii region, hypothesizing that corrugator inhibition attenuates negative affect; these studies have yielded consistent findings in support of this hypothesis (Coles et al., 2019; Davis et al., 2010; Hennenlotter et al., 2009). Methods such as this could also be used alongside fEMG as an alternate manner of precisely testing other dimensions of the facial feedback hypothesis.

Using modern methods of physiological experimentation, the present study provides insight to a decades-long debate over the validity of the facial feedback hypothesis. At the time of the current study, no prior studies had investigated the affective implications of facial muscle activity while also using highly controlled methods of facial feedback manipulation and monitoring of facial muscle activity. These findings provide not only promising evidence in support of the FFH but also a reliable method in which to conduct further research on the FFH. For example, the effects of orbicularis oculi and corrugator supercilii activation or inhibition are both facets of the FFH that, if tested while incorporating the present study's methods, may provide further and stronger evidence for the FFH as opposed to tests that did not include electrical stimulation and fEMG. The next logical step would be to test the effectiveness of using this study's novel procedure in mitigating variability across participants compared to other artificial methods of zygomatic stimulation—particularly the pen-in-mouth technique. Through combining the utilization of facial electrical stimulation and facial electromyography, the present study's procedure provides exceptional control to the extent in which these methods may be the key to obtaining the last word on the facial feedback hypothesis.

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