Embodied emotion perception:

Amplifying and dampening facial feedback modulates emotion perception accuracy

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In press, *Social Psychological and Personality Science*

How do we recognize the emotions other people are feeling? One source of information may be facial feedback signals generated when we automatically mimic the expressions displayed on others' faces. Supporting this "embodied emotion perception," dampening (Experiment 1) and amplifying (Experiment 2) facial feedback signals respectively impaired and improved people's ability to read others' facial emotions. In Experiment 1, emotion perception was significantly impaired in people who had received a cosmetic procedure that reduces muscular feedback from the face (Botox) compared to a procedure that does not reduce feedback (a dermal filler). Experiment 2 capitalized on the fact that feedback signals are enhanced when muscle contractions meet resistance. Accordingly, when the skin was made resistant to underlying muscle contractions via a restricting gel, emotion perception improved, and did so only for emotion judgments that theoretically could benefit from facial feedback.

Facial expressions provide powerful cues to people's inner thoughts and emotions, but how do perceivers successfully read these cues? Embodied cognition theories suggest that humans decode each other's expressions partly by simulating the perceived expression in their own facial musculature. The mechanisms underlying this simulation process have been clearly theorized (Goldman & Sripada, 2005; Niedenthal, Mermillod, Maringer, & Hess, 2010), but not fully demonstrated empirically. To test this embodied cognition account, the present research examined whether people's perception of emotional facial expressions becomes less and more accurate, respectively, when muscular signals from their own face have been dampened versus amplified.

Theories of embodied cognition typically postulate three steps in explaining how facial feedback might aid emotion perception. First, perceivers subtly and unconsciously mimic a target's facial expression; second, these subtle muscle contractions in the perceiver's face generate an afferent muscular feedback signal from the face to the brain; third, the perceiver uses this feedback to reproduce and thus understand the perceived expression's emotional meaning. The first two steps in this process have received solid support in prior research. The tendency to mimic facial expressions is rapid, automatic, and highly emotion-specific (Dimberg, Thunberg, & Elmehed, 2000). Moreover, the existence and influence of facial feedback has been demonstrated for numerous social-cognitive processes, including humor judgments (Strack, Martin, & Stepper, 1988), language comprehension (Havas, Glenberg, Gutowski, Lucarelli, & Davidson, 2010), and emotional experience (Davis, Senghas, Brandt, & Ochsner, 2010).

Although facial mimicry and facial feedback are well established as independent phenomena, it remains unclear if people can use facial feedback to make more accurate judgments about other people's expressions. Studies of neurological disorders that impair facial feedback (e.g., Moebius syndrome, Guillaine Bare syndrome) have yielded mixed findings regarding emotion perception deficits (Bogart & Matsumoto, 2010; Keillor, Barrett, Crucian, Kortenkamp, & Heilman, 2002), perhaps due to compensatory strategies that develop in response to long-term impairment (Goldman & Sripada, 2005). Studies with normal populations where facial feedback is temporarily altered—for example, by chewing, biting, or intentionally preventing mimicry—have generally found emotion perception deficits (Davis, Senghas, & Ochsner, 2009; Oberman, Winkielman, & Ramachandran, 2007; Stel & van Knippenberg, 2008). However, such manipulations plausibly alter central nervous system processes (CNS; e.g., reducing attention, increasing cognitive load) in addition to their effects on peripheral muscles. These studies were careful to use control conditions that imposed apparently similar cognitive demands; however, it difficult to be entirely sure that conditions varied only on the disruption of peripheral muscle activity. Thus, we use an alternative and complementary approach by using manipulations that place little or no demands on the CNS in the first place. Finally, prior work has not addressed the intriguing question of whether emotion perception can actually improve by amplifying facial feedback signals.

The Present Research

Two experiments isolated the role that facial feedback plays as perceivers attempt to decode the expressions on other people's faces. As a measure of facial emotion perception, both experiments employed the revised "Reading the Mind in the Eyes Task" (RMET; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). Improved performance on the RMET has been linked with mirror neuron activity (Shamay-Tsoory, Aharon-Peretz, & Perry, 2008) and impaired performance is observed in disorders that involve reduced mimicry (e.g., autism; Baron-Cohen et al., 2001). Thus, the task is ideal for exploring the role that facial feedback may play in emotion perception.

Experiment 1 tested whether emotion perception accuracy declines when perceivers' facial feedback has been dampened. To do this, we recruited a matched sample of patients receiving either Botox injections or Restylane injections for the cosmetic treatment of expressive facial wrinkles. Botox paralyzes the expressive muscle through blocking acetylcholine release at the neuromuscular junction (Dolly & Aoki, 2006). Critically, this paralysis reduces afferent feedback from the injected muscles to the brain (Hennenlotter et al., 2009). Restylane is a dermal filler and does not alter muscle function, thus leaving facial feedback intact (Brandt & Cazzaniga, 2007). We predicted that if facial feedback helps people decode perceived expressions, the Botox group would exhibit significantly impaired accuracy of emotion perception compared with the Restylane control group.

Experiment 2 tested whether emotion perception accuracy improves when perceivers' facial feedback is amplified. To amplify feedback, we employed a well-validated principle of proprioception whereby afferent feedback signals from muscles to the brain are boosted when the muscle meets resistance or load during contraction (Gandevia & Burke, 1992; Vallbo, 1974). A restricting gel was applied to participants' faces, which allowed the muscles to contract (unlike the Botox injections in Experiment 1), but created a subjective experience of resistance to these contractions. We predicted that emotion perception accuracy would be significantly higher among those wearing the restrictive gel on their face (versus their arm). In addition, several control tasks were included to determine if the predicted improvements were unique to emotion perception tasks that theoretically could leverage facial feedback signals.

Experiment 1

Emotion perception accuracy (via the RMET) was assessed in two patient groups 1-2 weeks after they had received either Botox injections (botulinum toxin Type A; Allergan, Inc. California) or Restylane injections (Medicis Pharmaceutical Corp., Arizona) for the cosmetic treatment of expression-related facial wrinkles.

Method

Thirty-one female patients (age, *M*=52 years, *SD*=3.9) were recruited from cosmetic surgery clinics and paid $200 for completing the study. Medical history, treatment details and efficacy were confirmed with the treating physician prior to testing. Patients in both groups (N_{Botox}=16, $N_{\text{Restylane}}$=15) had received injections specifically for the treatment of expression-related wrinkles. The primary injection sites were the glabellar lines, forehead, and crows feet in the Botox group and the glabellar lines and nanasolabial folds in the Restylane group. Botox and Restylane reach maximal effectiveness around 1-2 weeks post procedure (Dolly & Aoki, 2006; Brandt & Cazzaniga, 2007), and all participants were tested within that window. The two patient groups did not differ in mean age, ethnicity, or SES. In addition, although random assignment was not possible given the clinical setting, prior research shows that patients receiving Botox and Restylane do not differ from one another in their baseline reactivity to emotional stimuli prior to treatment (Davis et al., 2010). Thus, self-selection is not a viable explanation for the predicted effects.

Participants were tested individually via computer. RMET instructions and procedure mirrored those described in Baron-Cohen (2001). Responses were recorded using Millisecond keyboards (Empirisoft Corp.). On each RMET trial a black a white photograph appeared at central fixation. The photograph depicted only the eyes and immediate surrounding area. Four adjectives appeared simultaneously with the image: one adjective represented the correct answer and the other three were foils typically of the same valence as the correct response. Participants were instructed to select the emotion that best matched the expression and to maximize accuracy and speed. One practice trial was given prior to the 36 test trials.

Results

For each individual, the percentage of correct responses, and the mean reaction time (RT) for correct responses were computed. Because prior research has found that the valence of a facial expression can moderate effects of facial feedback (Davis et al., 2009), accuracy was computed separately for positive and negative expressions. The accuracy data were then analyzed using repeated measures ANOVA, with procedure

(Botox vs. Restylane) as the between participants factor and RMET accuracy for positive and negative expressions as the repeated measure. The model yielded a main effect for valence, *F*(1,29)= 27.75, *p*= .001, reflecting that accuracy was significantly higher for positive expressions (*M*=85.31%, *SD*=12.95) than negative expressions, (*M*=70.77, *SD*=12.64). Critically, a main effect of procedure also emerged, *F*(1,29)= 4.33, *p*= .046. Consistent with an embodied perception account, accuracy in the Botox group (*M*=69.91, *SD*= 10.00) was significantly lower than in the Restylane group (*M*=76.92, *SD*=8.29; see Figure 1). The Procedure x Valence interaction was not significant, *F*(1,29)= 0.38, *p*= .541, reflecting that impaired accuracy in the Botox group emerged consistently for both positive and negative expressions. Finally, mean RTs did not differ across the two procedure groups, *t*(30) = 0.53, p= .600. Thus, lowered accuracy in the Botox group could not be accounted for through differences in how quickly each patient group responded in the RMET.

Discussion

The results of Experiment 1 support a causal role for afferent facial feedback signals in helping people accurately decode other people's facial expressions. When afferent signals were dampened by Botox injections, people's emotion perception declined significantly compared to a gender, age and demographically-matched control sample who had received Restylane injections. This decline emerged consistently for both positive and negative target expressions.

It is unlikely that Experiment1's findings can be explained either by selection biases (i.e., that individuals with poorer baseline emotion perception tend to choose Botox), or by possible improvements in emotion perception caused by Restylane injections. First, Davis et al. (2010) found that, prior to treatment, individuals choosing Botox do not differ in baseline emotional reactivity from those choosing Restylane. Second, whereas Botox is injected intramuscularly, Restylane is typically injected into the dermis (Carruthers & Carruthers, 2007) hence limiting its ability alter muscle function. In addition, mean accuracy in the Restylane control group (76.92%) was in line with previously published performance levels for normal adult female samples (e.g., mean accuracy across the two normal female groups in the initial RMET validation studies was 76.35%, Baron-Cohen et al., 2001). Thus, the present findings appear best explained by an embodiment perspective, in which Botox reduces facial feedback and, in doing so, reduces the accuracy of recipients' facial emotion perception.

Experiment 2

A logical corollary of Experiment 1's findings is that amplifying afferent facial signals should lead to improved emotion perception. There are two possible methods for enhancing afferent feedback. First, the strength of the initial signal from the CNS to the face can be enhanced (e.g., by having people exaggerate their facial muscle contractions), leading to a stronger afferent signal from the face back to the CNS. Second, the afferent response can be enhanced directly. The first strategy must be delivered through the CNS (e.g., instructing people to engage in intentional exaggeration of expressive mimicry) and thus is not ideal for isolating the unique contribution of facial feedback, which is crucial in testing the embodied cognition account of emotion perception.

In Experiment 2, we pursued the second strategy of directly amplifying perceivers' afferent muscle signals to test for improvements in emotion perception. To do this, we relied on a well-established principle of proprioceptive feedback whereby afferent muscle signals are amplified when the initiating muscle meets resistance or load during contraction (e.g., Vallbo, 1974). In the proprioceptive literature this resistance is created by adding small weights to a contracting muscle or by taping the skin overlying a muscle such that the skin provides a subjective experience of resistance when the muscle contracts (for a review, see Gandevia & Burke, 1992). Both techniques yield the same result—when the contracting muscle meets heightened resistance, the afferent signal back to the CNS is strengthened.

To create resistance in response to facial muscle contractions, we used a gel composed of polyvinyl alcohol and polyvinylpyrrolidone, which dry and contract upon exposure to air (in approximately 7 minutes), forming a tight, translucent film over the skin.[1] To test whether this gel could indeed create a subjective experience of resistance to facial muscle contractions, we conducted an initial pilot study (n=25) in which the gel was applied to participants' faces in the area corresponding to the RMET stimuli (i.e., lower forehead, brow, and area immediately surrounding the eyes). Both before applying the gel and after wearing it for 10 minutes, participants were instructed to try moving the relevant muscles and rate (1) whether they felt they could currently contract the muscles (yes/no), and (2) whether their skin currently felt resistant to underlying muscle movements (11-point scale, *not at all resistant* to *extremely resistant*). All 25 participants reported being able to move the relevant muscles at both time points, but ratings of resistance were significantly higher when wearing the gel than when not, $t(24)= 9.71$, $p <.001$. Thus, the pilot study provided preliminary evidence that the gel manipulation can amplify facial feedback signals by preserving the initiation of muscle movements, but increasing people's subjective experience of resistance to these movements.

Method

Ninety-five participants (56 females; age *M*=20.2 years, *SD*= 1.5) completed Experiment 2, which was framed as two unrelated studies. The first study ostensibly involved evaluating a cosmetic product, which created a believable cover story for applying the restricting gel. Participants were informed that they would complete the second study, on emotion and personality, while the cosmetic product was working. Via random assignment, half of the participants had the restricting gel applied to their upper face in the regions corresponding to those depicted in the RMET stimuli. The remaining half were in the control condition and had the gel applied instead to their non-dominant inner arm.

After 10 minutes to allow for drying,[2] participants completed the dependent measures, which included the RMET plus two control measures presented in counterbalanced order across participants. The first control was an auditory version of the RMET in which participants judged which of four adjectives best captured the emotion conveyed in brief audio clips of emotional speech. This Reading the Mind in the Voice Test (RMVT; Golan, Baron-Cohen, Hill, & Rutherford, 2007) was included because improved emotion perception in response to amplified afferent feedback should be limited to stimuli that can readily be mimicked through the facial musculature (i.e., photos of emotional faces, but not audio clips of emotional speech). As a final control, participants completed 15 modular arithmetic (MA) questions that are highly sensitive to variations in working memory (Beilock, Kulp, Holt, & Carr, 2004). These MA items were included to assess whether the restricting gel was more distracting or consumed more cognitive resources when applied to the face compared to the arm, perhaps leading participants to adopt a different and better cognitive strategy in evaluating the emotional stimuli (e.g., a more intuitive approach). The order of the three dependent measures (RMET, RMVT, MA) was counterbalanced across participants, but no order effects were observed.

Results

As depicted in Figure 2, RMET accuracy was significantly higher when the restricting gel was applied to the face (M=77.17, SD=8.72) than the arm, (M=72.49, SD=13.02), $t(94)=2.03$, $p=.045$. This effect was unique to the visual emotion stimuli and did not extend to the auditory RMVT, $t(94)=.72$, $p=.470$. Thus, increased resistance at the skin's surface led to improved emotion perception, but only for stimuli that could be mimicked with the facial musculature, and thus benefit from afferent facial feedback (i.e., images of emotional faces, but not audio clips of emotional speech). In addition, MA scores did not differ across condition, $t(94)=1.15$, $p=.253$, nor were there condition effects on RTs for any dependent variable (all ts < 1). Thus, the significant improvements in RMET performance cannot be attributed to inadvertent CNS effects of the manipulation, such as distraction or cognitive load leading people to adopt an alternative, superior strategy.

To test whether the observed effects of the gel varied according to participant gender or the valence of the expression being judged, RMET performance was further probed using repeated measures GLM. Participant gender and experimental condition were between participant factors and target expression valence (positive vs. negative) served as the repeated measure. The model yielded a main effect of valence, $F(1,91)= 9.30$, $p= .003$, reflecting that participants were more accurate in judging positive than negative faces.[3] A significant main effect for condition also emerged, $F(1,91)= 6.85$, $p= .01$, reflecting the higher accuracy of those in the face condition, as reported above. No interactions were significant (all *F*s < 2), establishing that the effects of the gel on emotion perception did not vary as a function of the valence of the target expression, the gender of the perceiver, or any combination of these factors.

General Discussion

Both Darwin and James contended that the bodily expression and mental processing of emotion are bi-directionally linked (see Adelmann & Zajonc, 1989). Demonstrating a unique causal path from the former to the latter has proven complex, however, because existing research has relied on bodily manipulations that inherently require mental processing (e.g., instructing people to chew, bite, or to inhibit mimicry) or on clinical disorders where compensatory strategies likely play a role (e.g., Stel & van Knippenberg, 2008; Goldman & Sripada, 2005). The present research addresses these limitations by manipulating facial feedback using two techniques that act directly on afferent feedback signals in ways that do not demand cognitive processing.

In Experiment 1, emotion perception was significantly impaired in individuals whose facial feedback had been dampened through Botox injections. This finding complements recent evidence that Botox dulls affective reactions to emotionally evocative stimuli (Davis et al., 2010). Thus, reducing facial feedback appears to have broad functional effects on emotional processing, encompassing both emotional reactivity and emotion perception.

The present results are also the first to demonstrate bi-directional effects of facial feedback, such that emotion perception not only declined in accuracy when feedback was dampened, but also improved when feedback was enhanced. Specifically, Experiment 2 showed that people become better judges of facial emotion when their own facial skin has been made resistant to underlying muscle contractions, via a restricting gel. This novel manipulation leverages the well-established finding that muscular resistance amplifies afferent feedback signals from the restricted muscle to the brain (see Gandevia & Burke, 1992; Vallbo, 1974). Further triangulating facial feedback as the mechanism driving this effect, the restricting gel was associated with improved emotion perception only for stimuli that could be mimicked with the facial muscles (images of emotional expressions, but not audio clips of emotional speech).

In both experiments, facial feedback effects were observed consistently for positive and negative expressions. Some prior research has reported differential effects of facial feedback for expressions of different valence or for different specific emotions. For example, Davis et al. (2009) found that intentionally inhibiting mimicry impaired perception of negative and neutral expressions, but not positive expressions. Olberman et al. (2007) found, however, that a bite manipulation impaired recognition of happy and disgust expressions, but not fear or sadness. Thus, a conservative interpretation of existing evidence would be that facial feedback likely does contribute to the perception of both positive and negative expressions, although the magnitude of these effects may vary somewhat for specific emotions. Simple valence may not, however, be the appropriate organizing construct for these variations. In addition, the present research did not vary the specific muscle groups subject to dampening or amplification, but focused instead on altering facial feedback using more global techniques encompassing multiple muscle groups. Effects for specific emotions are can be identified by studies that use more targeted disruption of isolated muscles (e.g., Olberman et al., 2007).

These findings point to several future avenues of research. First, although Botox acts in a highly localized manner and does not cross the blood-brain barrier, we note that there is some evidence that peripheral muscle paralysis may lead eventually to changes in CNS emotion processing (Hennenlotter et al., 2009). Such CNS changes could theoretically compensate for, or exacerbate, diminished facial feedback. Thus, it is as yet unclear whether prolonged use of Botox would increase or attenuate the perceptual deficits reported in Experiment 1. Second, future research might explore possible effects of reduced facial feedback within social interactions and close relationships. Mimicry promotes liking and emotional sharing (see Chartrand & van Baaren, 2009) and may contribute to long-term relationship satisfaction (Zajonc, Adelmann, Murphy, & Niedenthal, 1987). Botox conceivably may undermine these outcomes by reducing mimicry and thus dampening the facial feedback signals that otherwise would promote emotional understanding.

Importantly, the present results align more closely with theories that describe facial feedback as moderating, rather than mediating, emotional processes. Although significantly impaired, the Botox group in Experiment 1 still performed at around 70% accuracy. Indeed, relatively intact emotion perception has also been reported in those with congenital (Bogart & Matsumoto, 2010) and acquired (Keillor et al., 2002) facial paralysis. Thus, a critical next step is to understand how facial feedback may integrate with other moderating factors in the emotion perception process, such as perceivers' current processing goals (Niedenthal, Mondillon, Winkielman, & Vermeulen, 2009), and variable features of the interpersonal context (Zaki, Bolger, Oschner, 2008).

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Acknowledgements

The authors extend their thanks to Adam Galinsky, Simon Gandevia, Cassie Govan, and Wendy Wood for comments on earlier drafts. We thank Sian Beilock and Andrew Mattarella-Micke for providing the modular arithmetic items used in Experiment 2.

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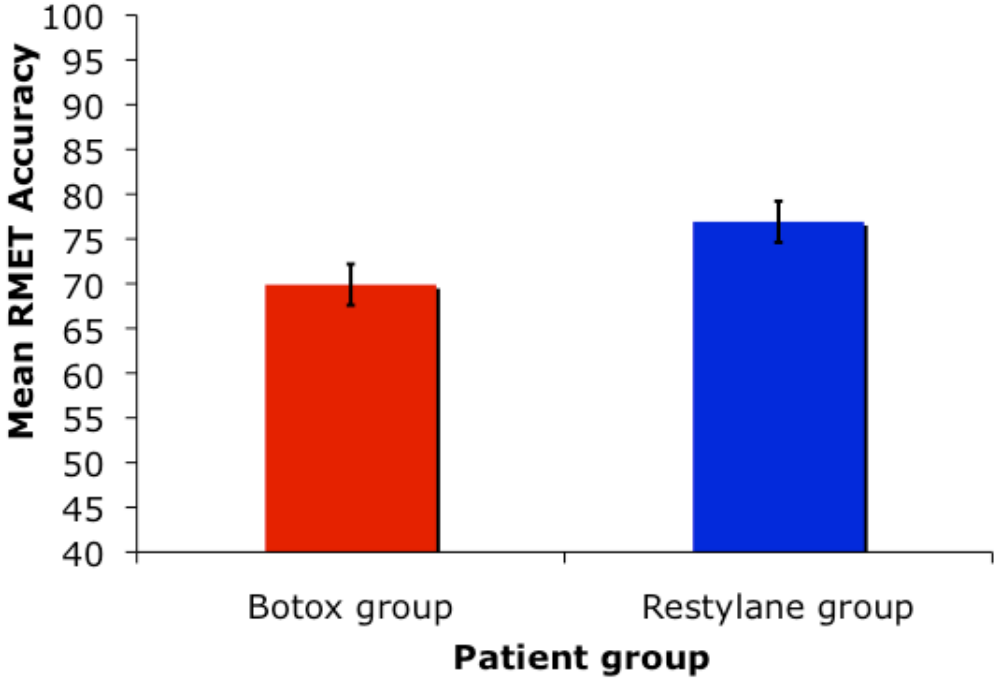
[1] The restricting gel was a commercially available cosmetic treatment, the DaVinci™ Peel-Off Face Mask (Cosmex International, Pty).

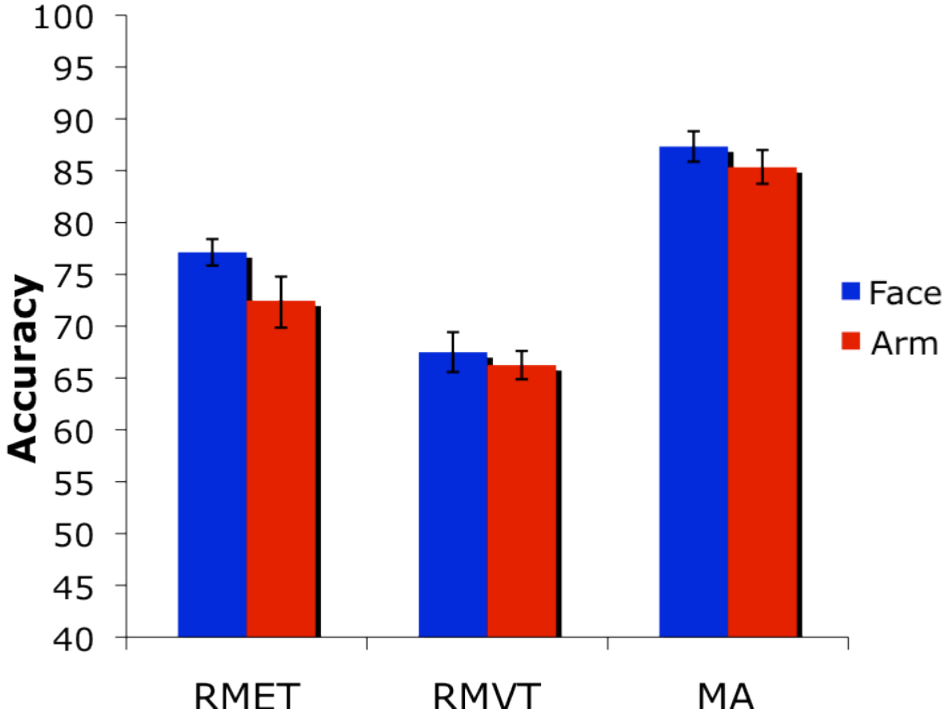
[2] As a manipulation check, a large subset of participants (*N*=70) were asked at the end of the study to rate how resistant their face felt to underlying muscle movements. Replicating the pilot study, those with the gel applied to their face reported significantly higher restriction (*M*=7.17, *SD*=2.29) than those in the control condition, (*M*=3.12, *SD*=2.91), *t*(68)=6.43, *p* =.001.

[3] We note that higher accuracy for positive expressions in the RMET task was also evident in the normal adult sample data reported in Baron-Cohen et al. (2001). However, because this effect did not interact with our experimental manipulation, we do not discuss valence effects further here.

Figure 1.
Experiment 1: Mean accuracy (%) on the Reading the Mind in the Eyes Test (RMET) for Botox and Restylane-control participants. Bars represent standard errors.

Figure 2.
Experiment 2: Mean accuracy (%) for participants in facial resistance condition and arm control condition across the three dependent measures: RMET, RMVT, and Modular Arithmetic (MA). Bars represent standard errors.


Mean RMET Accuracy
100
95
90
85
80
75
70
65
60
55
50
45
40
Botox group
Restylane group
Patient group


Accuracy
100
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RMET
RMVT
MA
Face
Arm