

Supporting information

Stimulus sentences used in EMG and BTX experiments

Norming study: For the sentence norming experiment, participants were recruited from the same sources as the EMG and BTX studies in exchange for class credit.

Participants viewed the sentences one at a time on a computer screen, and they were asked to rate each sentence according to extent that the sentence suggested each of four emotions (Sadness, Fear, Happiness, and Anger) on a scale from 1 (not at all) to 3 (very much). Angry sentences were rated as describing anger ($M = 1.37$) more than sadness ($M = .67$), fear ($M = .55$), or happiness ($M = .20$). Sad sentences were rated as describing sadness ($M = 1.42$) more than fear ($M = .75$), happiness ($M = .23$), or anger ($M = .81$). Happy sentences were rated as describing happiness ($M = 1.30$) more than sadness ($M = .36$), fear ($M = .37$), or anger ($M = .37$). Five happy sentences were replaced after the norming study, and did not contribute to these means.

Comprehension questions: For sentences used in the EMG and BTX studies, two short Yes/No comprehension questions were constructed for each sentence, one for which the correct answer was “Yes” and one for which the correct answer was “No.” For example, if the sad sentence “You wish a long goodbye to your friend who is leaving forever” was followed by the question, “Do you and your friend say goodbye?” then the correct answer would be “yes,” whereas if it was followed by the question, “Will you see your friend again?” then the correct answer would be “no.” Within each block, a random half of the comprehension questions were those for which the correct answer was “yes,” and half were those for which the correct answer was “no.” For those trials (4 trials randomly selected in each block) in which a comprehension question appeared after the

sentence, the question always pertained to the immediately preceding sentence, and was presented under the words “yes or no question.”

EMG study

We used EMG recording from the facial muscles involved in producing expressions of happiness (zygomaticus major, and orbicularis oculi), and anger and sadness (corrugator supercilii) while participants read sentences (also used in the BTX experiment) describing angry, sad, and happy situations. We compared activity among the three muscle groups during reading of angry, sad, and happy sentences.

Twenty-four undergraduate research participants (14 women, 10 men) viewed sentences presented individually on a computer screen separated by three-second pauses.

Participants used their right hands to press a key after reading the sentence, and their left hands to answer the comprehension questions. Participants were told the purpose of the study was to measure skin conductance during reading. We compared activity among the three muscle groups during reading of angry, sad, and happy sentences.

Muscle activation patterns differed according to the sentence emotion, $F(4,20) = 4.553, p = .009, \eta_p^2 = .48$, with significant differences occurring in corrugator, $F(2,46) = 9.397, p = .005, \eta_p^2 = .29$, zygomaticus major, $F(2,46) = 7.536, p = .012, \eta_p^2 = .25$, and orbicularis oculi muscles, $F(2,46) = 7.622, p = .011, \eta^2 = .25$. For the frown muscle (corrugator supercilii), both Sad and Angry sentences elicited greater activity than Happy sentences. For the cheek-raising muscle (zygomaticus major), Happy sentences elicited greater activity than both Sad and Angry sentences. For activity in the eye-squint

(orbicularis oculi) muscle, both Happy and Angry sentences eliciting greater activity than Sad sentences. Thus, comprehending sentences describing different emotional situations produces differential facial muscle activity used in the corresponding emotional expressions.

BTX injection

Physicians at participating clinics performed subcutaneous BTX injections in medial to lateral corrugator supercilii muscle for cosmetic treatment of glabellar lines. All but one participant (who was not treated) received injections of between 12 and 20 mouse units of Botox® (botulinum toxin type A) manufactured by Allergan, Inc. (Irvine, CA). A physician assessed treatment efficacy during the second session, two weeks after initial injection. In all cases, the treatment successfully induced complete or partial paralysis of the corrugator supercilii muscle by the time of the second session.

Analyses of residual reading time and comprehension accuracy in the BTX experiment

In residual reading times, there was a main effect of sentence emotion, where residual reading times were longer for Angry sentences ($M = 59, SE = 32$) than for Sad ($M = -273, SE = 38$) or Happy sentences ($M = -320, SE = 39$), $F(2,74) = 40.38, p < .001, \eta^2 = .177$. The interaction of sentence emotion and session was significant, $F(2,74) = 3.489, p = .036, \eta^2 = .015$. Paired samples t-tests revealed that Angry sentence residual reading times were longer in the second session than in the first session, $t(37) = 2.135, p = .039, D = .60$. Similarly, Sad sentence residual reading times were longer in the second session than in the first session, $t(37) = 2.443, p = .019, D = .64$. For Happy sentences,

there was no difference in residual reading times between the second session and the first session, $t(37) = .338, p = .737$.

The ANOVA on comprehension accuracy rates revealed no significant main effects or interaction (all $F < 3.1$). However, the suggested pattern of mean accuracy is consistent with increased difficulty in session 2 processing for angry and sad, but not happy, sentences. Overall, accuracy rates were lower in session 2 than in session 1, $F(1,37) = 3.073, p = .088$, but session 2 accuracy rates were lower only for angry and sad sentences, $F(2,36) = 2.925, p = .066$.

PANAS-Now analysis from the BTX experiment

Survey results were analyzed for changes in mood between sessions to test whether the pattern of reading times in the BTX study reflects greater pre-injection anxiety during the first session than the second session with a consequent increase in second-session reading times for the negative sentences.

For each session, scores on individual items of the positive and negative subscales of the PANAS-NOW (Watson & Clark, 1988) were summed to form positive and negative affect composite scores, and the composite scores were subjected to paired-samples t-tests. For the positive affect composite scores, there was a significant decrease from the first session ($M = 33, SE = 1.5$) to the second session ($M = 30, SE = 1.8$), $t(15) = 2.936, p = .01, D = .51$. For negative affect scores, there was no significant change from the first session ($M = 13, SE = .85$) to the second session ($M = 12, SE = 1.0$), $t(15) = .499, p = .625$.

We computed Pearson's correlation coefficients among participants' change in reading times and change in scores on the PANAS. For each participant, difference scores from session 1 to session 2 were calculated separately for angry, sad, and happy sentence reading times, and for the positive and negative subscale scores on the PANAS-NOW. Two-tailed, bivariate correlation analyses revealed no significant correlations between change in positive affect and change in reading times for angry ($r = .024$), sad ($r = .020$), or happy sentences ($r = -.027$; all $p > .922$). Correlations were stronger, though not significant, between change in negative affect and angry ($r = -.384$), sad ($r = -.243$), and happy sentences ($r = -.338$; all $p > .141$). A similar analysis using residual reading times instead of raw reading times also yielded no significant correlations of change in positive affect and changes in residual reading times for angry ($r = .071$), sad ($r = -.045$), and happy sentences ($r = .077$; all $p > .778$). As with raw reading times, correlations were larger, but not significant, between change in negative affect and changes in residual reading times for angry ($r = -.446$), sad ($r = -.199$), and happy sentences ($r = -.430$; all $p > .084$). That is, the longer the reading times of the angry and sad sentences in session 2, the smaller the change in negative affect. This finding is the reverse of what would be expected if change in negative affect mediated the change in reading times.