Emotion
2006, Vol. 6, No. 1, 1–9

1528-3542/06/$12.00 DOI: 10.1037/1528-3542.6.1.1

Embodied Temporal Perception of Emotion

Daniel A. Effron
Yale University

Paula M. Niedenthal
Centre National de la Recherche Scientifique and
Blaise Pascal University

Sandrine Gil and Sylvie Droit-Volet
Blaise Pascal University

The role of embodiment in the perception of the duration of emotional stimuli was investigated with a temporal bisection task. Previous research has shown that individuals overestimate the duration of emotional, compared with neutral, faces (S. Droit-Volet, S. Brunot, & P. M. Niedenthal, 2004). The authors tested a role for embodiment in this effect. Participants estimated the duration of angry, happy, and neutral faces by comparing them to 2 durations learned during a training phase. Experimental participants held a pen in their mouths so as to inhibit imitation of the faces, whereas control participants could imitate freely. Results revealed that participants overestimated the duration of emotional faces relative to the neutral faces only when imitation was possible. Implications for the role of embodiment in emotional perception are discussed.

For better or for worse, emotional experiences often seem to last longer than they really do. An argument with an angry lover may seem to last an eternity; time may seem to stand still as people delight in a child's joy upon opening a longed-for gift. Recent empirical evidence supports the idea that the subjective temporal experience of at least some kinds of emotional events differs from that of neutral events (Angrilli, Cherubini, Pavese, & Manfredini, 1997; Droit-Volet, Brunot, & Niedenthal, 2004). For example, simply by altering the facial expressions depicted in a series of photographs, Droit-Volet et al. (2004) were able to affect subjects' estimations of the length of time for which the photographs were displayed, such that the duration of emotional faces was overestimated relative to neutral ones. Why did the subjective duration of these stimuli depend on the emotions that they represented? As we develop below, arousal seems to be implicated. However, although the few previous studies devoted to the exploration of effects of emotion on time perception have used emotional stimuli both to induce emotions and to represent the passage of time, none of the studies has considered how perceived emotional stimuli instigate arousal. We address this question from the perspective of recent theories of embodied cognition. We begin by reviewing recent models of time perception and their account of the influences of emotion in this process. We then suggest how the embodiment of the stimulus may be required for stimulus characteristics, such as its emotionality, to influence time perception.

Daniel A. Effron, Department of Psychology, Yale University; Paula M. Niedenthal, Centre National de la Recherche Scientifique and Department of Psychology, Blaise Pascal University, Clermont-Ferrand, France; Sandrine Gil and Sylvie Droit-Volet, Department of Psychology, Blaise Pascal University, Clermont-Ferrand, France.

Preparation of this article was supported in part by the Robert C. Bates Summer Traveling Fellowship from Jonathan Edwards College, Yale University, to Daniel A. Effron; by Prosodie ACI Grant PRO-0052, Ministère de la Recherche (France), to Sylvie Droit-Volet and Paula M. Niedenthal; and by National Science Foundation Grant 0350687 to Piotr Winkielman and Paula M. Niedenthal. We thank Markus Brauer and Anne-Claire Rattat for their insightful comments about data analysis and to Aurélie Oziol for her help with data collection.

Correspondence concerning this article should be addressed to Sylvie Droit-Volet or Paula M. Niedenthal, Laboratoire de Psychologie Sociale et Cognitive, CNRS (UMR 6024), Université Blaise Pascal 34, Avenue Carnot, 63000, Clermont-Ferrand, France. Electronic mail: droit@srvpsy.univ-bpclermont.fr or niedenthal@srvpsy.univ-bpclermont.fr

Emotion and Time Perception

According to the most developed models of time perception (i.e., scalar timing models), humans as well as animals are equipped with a biologically based internal clock (Gibbon & Church, 1984; Gibbon, Church, & Meck, 1984). The clock is assumed to be composed of a pacemaker, a switch, and an accumulator. The switch closes at the beginning of an event to be timed, thereby causing the pulses emitted by the pacemaker to enter the accumulator, and opens at the end of the event to terminate the collection of pulses. Perceived duration is thus based on the number of pulses collected in the accumulator; the more pulses accumulated, the longer the perceived duration.

Two mechanisms, those of attention and arousal, can influence the functioning of the internal clock in such a way as to bias temporal perception. A large number of studies using dual-task or attention-distracting paradigms have shown that when attentional resources are diverted from the processing of time, duration is typically underestimated (e.g., Brown, 1997; Casini & Macar, 1997; Macar, Grondin, & Casini, 1994; Zakay, 1989). This underestimation occurs because the lack of attention to time processing disrupts the accumulation process, resulting in fewer pulses accumulated (Burle & Casini, 2001; Lejeune, 1998; Zakay, 2005). In contrast, arousal has been shown to increase the speed of the pacemaker (e.g., Droit-Volet & Wearden, 2002; Maricq, Roberts, & Church, 1981; Meck, 1983; Treisman, Cook, Naish, & McCrone, 1994; Wearden & Penton-Voak, 1995). This increase in speed in turn increases the number of pulses emitted per unit of time and, consequently, collected in the accumulator. Thus, when individuals are aroused, they typically overestimate duration. The clearest demonstrations of this arousal-lengthening effect come from pharmacological studies that have selectively increased the pacemaker speed by administering amphetamine (for a review, see Harrington & Haaland, 1999; Meck, 1996). It is interesting that felt emotions and emotional events are arousing, but could also distract attention away from the processing of time. Which of these two mechanisms wins out in the case of the temporal perception of emotion?

Few studies have investigated the effect of emotion on time perception. However, in a recent study, Angrilli et al. (1997) showed participants images depicting scenes that were fully crossed for valence (positive, negative) and arousal (high, low) at durations of 2, 4, and 6 s. Participants were then instructed to either estimate or reproduce the slides' durations. Results revealed an interaction between valence and arousal in the perceived duration of the images. For low-arousal slides, the duration of unpleasant slides was underestimated relative to pleasant ones, whereas for high-arousal slides, the duration of unpleasant slides was overestimated relative to pleasant ones. Given that negative events often arouse more attention than do positive ones (e.g., Öhman, Lundqvist, & Esteves, 2001), Angrilli et al. concluded that an attentional mechanism is most influential in the temporal perception of low-arousal events, whereas for high-arousal events, the effect of attention is minimized, and arousal provoked by the images plays a greater role.

Droit-Volet et al. (2004) pointed out a number of potential shortcomings of the work of Angrilli and colleagues (1997), including the complexity of participants' task as well as the possible insensitivity of the relatively long durations used to detect influences of arousal. Droit-Volet et al. (2004) therefore used a temporal bisection task, which is typically used in tests of scalar timing models (e.g., Church & Deluty, 1977; Wearden, 1991), to investigate the temporal perception of emotional events at short durations (i.e., less than 2 s). In the first phase of this task, participants were presented with a neutral visual stimulus (a pink oval) for 400 and 1,600 ms, identified as the short and long standard durations, respectively. In a subsequent test phase, participants were shown pictures of faces that expressed anger, happiness, sadness, or neutrality. Each face appeared for one of the standard durations or for intermediate durations. Participants were required to categorize the comparison durations as the short or the long standard. Results supported the predictions of an arousal-based mechanism in several ways. First, subjects categorized more of the emotional faces than the neutral faces as long, indicating that the duration of presentations of emotional expressions was overestimated relative to neutral expressions. Second, this overestimation effect was larger for faces expressing anger, a highly arousing emotion, than for faces expressing the less arousing emotions of happiness and sadness (see Russell & Mehrabian, 1977). Third, consistent with an arousal interpretation, the overestimation of especially the angry faces increased with the duration values, such that overestimation was more marked at longer durations. Such an interaction between emotion and duration is not expected under an attentional hypothesis, which predicts not a multiplicative but an additive effect, that is, one independent of the durations judged (for a discussion, see Burle & Casini, 1999). Droit-Volet et al. (2004) therefore concluded that, at least at quite short durations (i.e., <2 s), emotional faces increase the speed of the pacemaker of the internal clock, with the result that duration is overestimated. It thus seems that observing emotional expressions affects the subjective experience of time by increasing the level of arousal of the perceiver.

Whereas the overestimation of time can arise from nonemotional sources of arousal, such as drugs in rats (Maricq et al., 1981; Meck, 1983) and body heat in humans (Wearden & Penton-Voak, 1995), the temporal perception of emotion is especially noteworthy because it allows us to investigate the social mechanisms that might be at play in time perception. The study by Droit-Volet et al. (2004) did not address the mechanisms by which emotions cause the arousal that yields the overestimation effect. The present study was designed to investigate a particular social mechanism by which this arousal may be accomplished: imitation of emotional facial expressions.

Theories of Embodied Cognition

Why posit that imitation plays a role in time perception? The justification comes from the literature on theories of embodied cognition. *Embodiment* refers to physical states that arise during interaction with the world and that arise from introspection. These physical states appear to play an important role in cognition (Barsalou, Niedenthal, Barbey, & Ruppert, 2003; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, in press, for reviews), and they include postures, facial expressions, or partial simulations of physical states in the relevant neurological sensory systems. Most important for the present discussion is the observation that embodied states occur in the imitation of others' gestures and expressions. Individuals spontaneously mimic positive and negative facial expressions (Dimberg, 1982, 1990), even when the faces are presented below conscious awareness (Dimberg, Thunberg, & Elmehed, 2000) or when the perceivers consciously attempt to inhibit their own facial musculature (Dimberg, Thunberg, & Grunedal, 2002). Evidence from neuropsychology suggests that facial mimicry plays an important role in the perception of emotions in others (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000; Décety & Chaminade, 2003; Gallese, 2003). It thus seems reasonable to speculate that spontaneous mimicry contributes to other forms of emotional cognition. Indeed, embodied emotion seems to affect memory, stimulus identification, and evaluation (see Barsalou et al., 2003, for a review). Given these previous observations, it seems plausible that embodiment would also play a role in the temporal perception of emotion.

A more specific reason to posit a relationship between embodiment and the temporal perception of emotion relates to research associated with the facial feedback hypothesis, which states that feedback from facial expressions by itself can induce or at least enhance or suppress an emotion (see Adelmann & Zajonc, 1989; McIntosh, 1996, for reviews). In one relevant study (Lanzetta, Cartwright-Smith, & Kleck, 1976), participants simulated with their facial expressions the anticipation of either a painful shock or no shock. When subjects simulated painful-shock anticipation, they rated the actual shock as more painful and experienced a higher level of autonomic arousal (measured by skin conductance) as compared with when they simulated anticipating no shock. Similarly, Kleck et al. (1976) found that when, due to the presence of an observer, participants inhibited their facial reactions to receiving a shock, they experienced less autonomic arousal and reported feeling less discomfort than when not observed. In a related paradigm, Zuckerman, Klorman, Larrance, and Spiegel (1981) reported that exaggeration of emotional facial expressions led to increased arousal (measured by skin conductance, blood volume, and heart rate) upon viewing pleasant, unpleasant, and neutral film clips relative to arousal when inhibiting expression. Finally, Vaughan and Lanzetta (1981) instructed participants to either amplify or inhibit their facial reactions to a film of a model wincing with pain. A previous study (Vaughan & Lanzetta, 1980) showed that participants not asked to inhibit their reactions would imitate the model's facial expressions. In the 1981 Vaughan and Lanzetta study, subjects instructed to amplify their reactions (and thus exaggerate their mimicry) displayed greater arousal (i.e., heightened skin conductance and heart rate acceleration) than those instructed to inhibit. Taken together, these studies suggest that exaggeration or suppression of facial expressions can, respectively, induce or inhibit physiological arousal. Perhaps mimicry of such emotional expressions can therefore activate the arousal-based mechanism that seems to be responsible for the temporal overestimation effect (Droit-Volet et al., 2004).

It is worth noting that these studies in general do not make clear the precise mechanism by which arousal arises from embodied emotion. Other embodiment effects have been explained by vicarious experience of the embodied emotion (e.g., Hsee, Hatfield, Carlson, & Chemtob, 1990; Laird, Wagener, Halal, & Szegda, 1982), simple association of the embodied state with arousal (e.g., Chartrand & Bargh, 1999), or a more direct mechanism in which both arousal and embodied states represent the core knowledge of the emotional concept (e.g., Barsalou, 1999). Although any of these explanations could account for an embodied instigation of arousal, the point of greater importance for our study is simply that the embodiment of emotional facial expressions is required for arousal to be produced and to affect subsequent processing.

To summarize, previous research has found that individuals spontaneously imitate emotional expressions and that the embodiment of facial expressions can affect autonomic arousal. Considering these findings, and given that arousal facilitates the ability of emotional faces to cause a subjective lengthening in time perception (Droit-Volet et al., 2004), it seems likely that the embodiment of facial expressions is directly involved in this overestimation effect. If this were the case, we would predict that subjects who are free to imitate emotional facial expressions would show the subjective lengthening effect, whereas subjects whose imitation is inhibited would show no such change in time perception. From the perspective of the time perception literature, such a finding should be noteworthy because it would help explain why merely viewing pictures of faces for short durations is sufficient to activate the arousal-based mechanism that causes the subjective lengthening effect; of importance to the embodied cognition literature, such a finding would also suggest that mimicry plays an important role in a basic cognitive process that functions during social interactions.

Overview of the Study

To test the hypothesized effects of imitation on time perception, we used a temporal bisection task (Allan & Gibbon, 1991) with emotional faces as stimuli (as in Droit-Volet et al., 2004) to examine participants' perception of time while imitation was either inhibited or allowed to take place spontaneously. Because the effect of emotional expression on time perception in the 2004 study by Droit-Volet and her colleagues was greatest for angry faces, and next greatest for happy faces, we chose to use these two emotions in the present study. We expected to replicate the overestimation of the duration of emotional faces relative to neutral ones when imitation was allowed to occur spontaneously, but not when imitation was inhibited. As a secondary hypothesis, we also expected to replicate the finding, predicted by an arousal-based mechanism, of a larger overestimation effect for anger than for happiness.

Method

Participants

Forty female[1] students were recruited from the University of Clermont-Ferrand, France, for participation in the study. They received course credit as compensation.

Materials

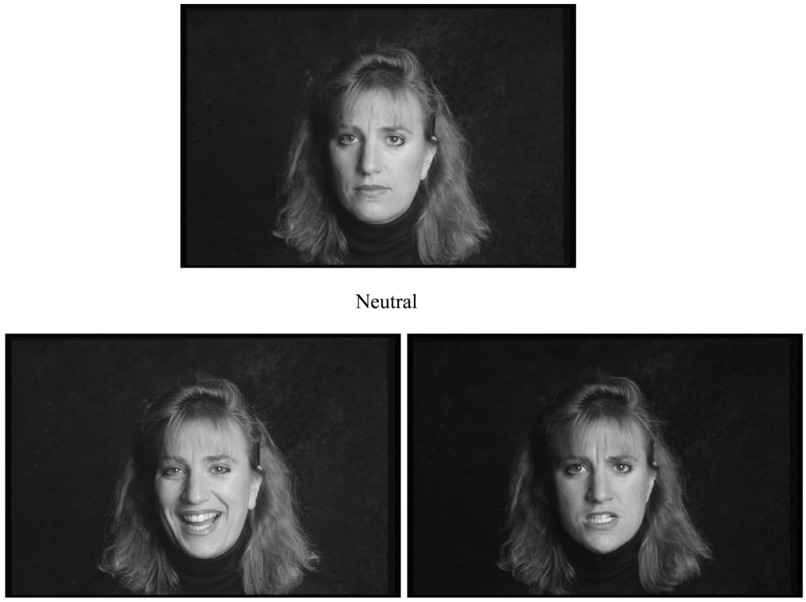
Participants sat in a quiet room in front of a computer that presented the stimuli, one at a time, in the center of each participant's field of vision. Stimuli were presented and data recorded with a program created on PsyScope for Macintosh (Cohen, MacWhinney, Flatt, & Provost, 1993). For the training phase of the experiment, a pink oval 12 × 16 cm was used as the stimulus. The testing phase of the experiment used six photographs, each showing one of three women expressing anger, happiness, or neutrality (see Figure 1 for examples). These photographs had been normed to verify their depiction of these facial expressions (Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001).

Procedure

The temporal bisection task consisted of a training phase and a test phase. During the training phase, the neutral stimulus (a pink oval) was presented to participants five times in alteration, for standard durations labeled as either *short* (400 ms) or *long* (1,600 ms). For each presentation, participants were instructed to indicate whether they had seen the short or the long duration by pressing either the *D* or *K* key on the computer keyboard. The key assigned to each of the two standard durations was counterbalanced across participants. Next, participants completed eight practice trials with the neutral stimulus, which had a 50% chance of appearing for each of the two standard durations on each trial. The computer displayed accuracy feedback after each trial for 2 s, after which it paused for 1–3 s before beginning the next trial.

During the test phase, participants were shown the women's faces and asked to indicate on the keyboard whether these stimuli were presented for a duration closer to the long or the short standard. The actual duration of the presentation of the face was 400, 600, 800, 1,000, 1,200, 1,400, or 1,600 ms, that is, one of the two standard durations or one of five intermediate values. The faces were presented in three blocks of 63 trials, in which the nine photographs (3 different women × 3 different expres-

[1] Only female subjects were used because the subject population to which we had access was primarily female, and we anticipated that gender congruity between participants and the models used in the stimuli would be a significant factor in our hypothesized effect. Other research using the present paradigm has found that such congruity leads to the largest effects (Chambon & Droit-Volet, 2004).



Neutral

Happy Angry

Figure 1. Examples of happy, angry, and neutral faces used as stimuli.

sions) were presented for each of the seven durations in a random order. Each participant thus completed 189 trials. The interval between trials varied randomly between 1 and 3 s; participants paused for 1–2 min between blocks.

Participants were randomly assigned to one of two conditions in order to manipulate imitation. In the *inhibited imitation* condition, participants held a pen lightly in their mouth, between their lips and their teeth, in such a way that their lower facial musculature remained fixed in a neutral expression for the entire test phase of the experiment. While this task does not, of course, prevent participants from moving their upper facial musculature, it does prevent complete imitation of the faces without inducing an emotional state (Niedenthal et al., 2001). In the *spontaneous imitation* control condition, participants were given the standard instructions for the bisection task without reference to the pen. As discussed in the introduction, previous research has shown that people spontaneously imitate the expressions of faces that are presented for short periods (Dimberg et al., 2002), so we can assume that imitation takes place spontaneously in this condition.

Results

One woman in the inhibited imitation condition was excluded due to her status as an outlier.[2] The sample therefore consisted of 39 women, 19 in the inhibited imitation condition and 20 in the spontaneous imitation condition.

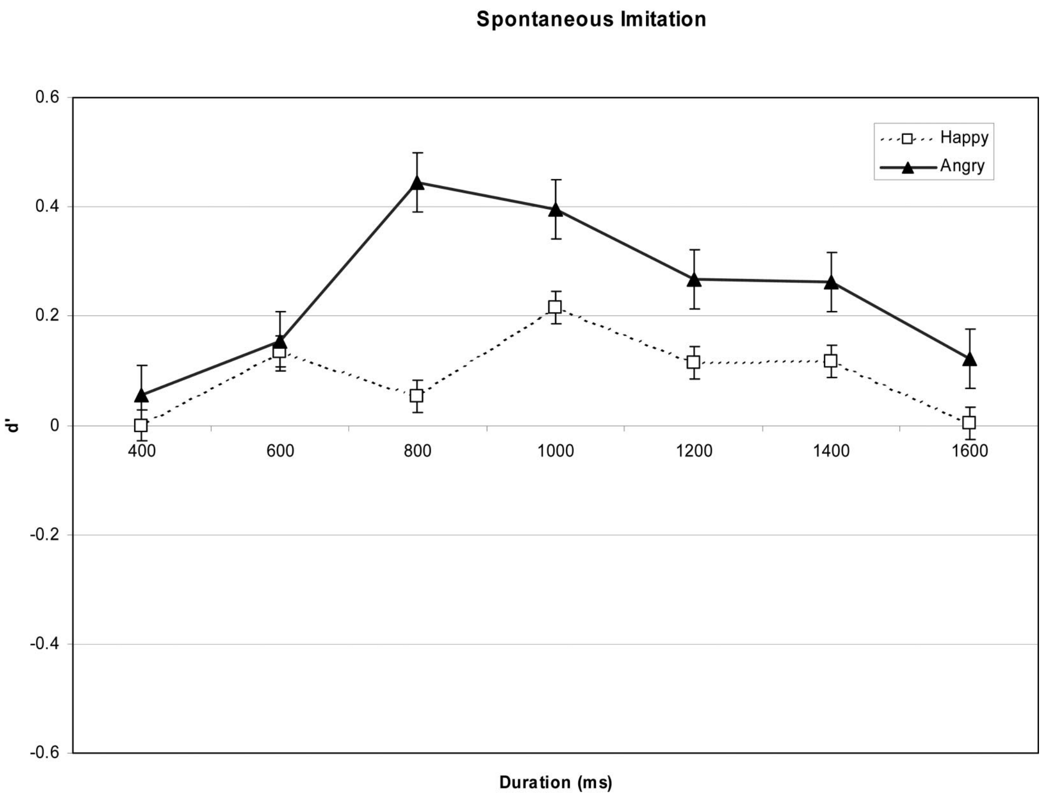
It was hypothesized that women in the spontaneous imitation condition but not in the inhibited imitation condition would overestimate the duration of angry and happy faces as compared with neutral faces. We also expected the overestimation effect to be larger for angry than for happy faces (Droit-Volet et al., 2004).

To test these predictions, the average proportion of trials that participants categorized as long at each duration were first transformed with the probit function into z scores.[3] Then d' was calculated in accordance with signal detection theory (Macmillan & Creelman, 1991) for each stimulus duration by subtracting the z scores for each emotional face from the z scores for the neutral face. The 7 durations and 2 emotion pairs (happy–neutral and sad–neutral) yielded 14 d' scores. Each score represents the extent to which participants' categorization of emotional faces differed from that of neutral faces; a positive score therefore represents an overestimation, and a negative score represents an underestimation of duration relative to the neutral baseline. The d' scores for each duration and emotion are shown in Figure 2. Note that participants seemed to overestimate duration overall for angry faces, and to a lesser extent happy faces, in the spontaneous imitation condition (top) but not in the inhibited imitation condition (bottom).

To test this apparent pattern statistically, d' scores were submitted to a $7 \times 2 \times 2$ repeated-measures analysis of variance (ANOVA), using, respectively, actual stimulus duration and emotion as within-subject factors and condition as a between-subjects factor. We found main effects of emotion, $F(1, 37) = 27.98$, $p < .001$, and condition, $F(1, 37) = 10.43$, $p < .01$, as well as an interaction between these two variables, $F(1, 37) = 5.10$, $p < .05$. Because there was no main effect of stimulus duration, $F(6, 222) = 1.95$, we averaged d' across duration and tested whether this average was different from 0 for both emotions in both

[2] Post hoc examination, however, showed that inclusion of this subject did not significantly alter the results.

[3] It should be noted that, although z scores sometimes refer to standardized scores, signal detection theory defines z as the inverse function of the normal distribution curve (Macmillan & Creelman, 1991), which is how we use the term. Note also that, in order for this transformation to be accomplished on proportions, values of 1 and 0 had to be replaced with a high and low decimal, respectively. We substituted .944 for 1, and .056 for 0.



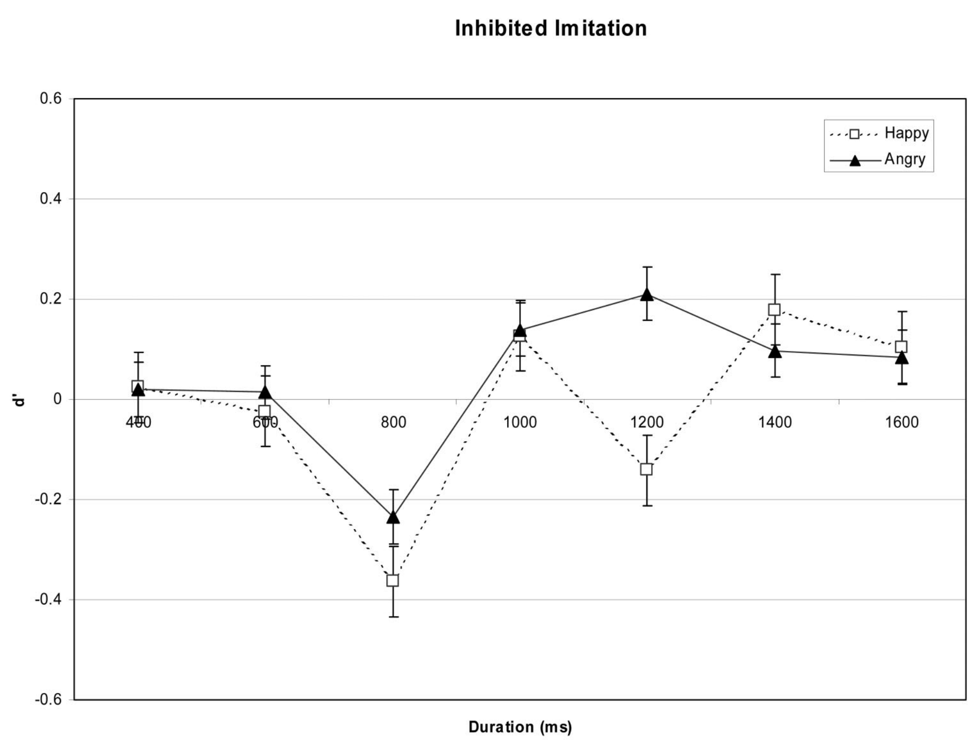


Figure 2. d′ scores plotted against actual stimulus duration for each emotion-neutral pair.

conditions.[4] Single-sample t tests confirmed the hypothesized difference between conditions. In the spontaneous imitation condition, participants significantly overestimated the duration (relative to neutral) of both angry and happy faces, $t(19) = 6.65$, $p < .001$, and $t(19) = 2.15$, $p < .05$, respectively. In contrast, no significant differences between categorizations of emotional and neutral faces were found in the inhibited imitation condition for angry faces, $t(18) = 1.30$ or for happy faces, $t(18) = -.55$. Furthermore, consistent with our prediction, paired-samples t tests revealed that d' was significantly larger for angry than for happy faces in the spontaneous imitation condition, $t(18) = 4.57$, $p < .001$. This was also the case in the inhibited imitation condition, $t(18) = 2.79$, $p < .02$, but to a lesser extent ($M = 0.06$ for inhibited imitation, and $M = 0.15$ for spontaneous imitation).

No three-way interaction was found for stimulus duration, emotion, and condition, $F(6, 222) = 1.40$, *ns*. However, stimulus duration did seem to play some role, as revealed by a Stimulus Duration × Emotion and a Stimulus Duration × Condition interaction, $F(6, 222) = 2.42$, $p < .05$, and $F(6, 222) = 2.65$, $p < .05$, respectively. Although the hypotheses central to the present experiment did not specify how duration would interact with emotion, the arousal hypothesis nonetheless predicts that the difference between emotional and neutral faces will increase as (relatively short) durations lengthen (as discussed in the introduction; see Burle & Casini, 1999; Droit-Volet et al., 2004). We tested to see if this would be the case in our results by first recoding the stimulus durations into two groups: longer (i.e., greater than 1,000 ms) and shorter (i.e., less than 1000 ms). As expected, d' at longer durations was greater than d' at shorter durations for both happy (M difference = 0.09) and angry (M difference = 0.10) faces. This difference did not reach significance for happy faces, $t(38) = 1.53$ but represented a trend for angry faces, $t(38) = 1.80$, $p = .08$. Thus, as predicted by an arousal hypothesis, d' tended to be larger for longer than for shorter durations, at least by a marginally significant amount for angry faces.

Because we made no a priori predictions concerning how stimulus duration would affect d' within conditions, we took the exploratory step of decomposing the Stimulus Duration × Condition interaction. The d' scores were averaged across both emotions at each stimulus duration, and two repeated-measures ANOVAs were performed, one within each condition, on these averaged scores. Results revealed a simple effect of duration in the inhibited imitation condition only, $F(3.89, 69.98) = 2.99$, $p < .05$. Note that this statistic contains degrees of freedom adjusted with a Greenhouse–Geisser epsilon ($\varepsilon = .69$), used because the sphericity assumption was violated, Mauchley's $W(20) = 0.11$, $p < .05$. To determine the nature of the effect of duration, post hoc single-sample t tests examined the difference from 0 of d', averaged across both emotions, at each duration in the inhibited imitation condition. A significant difference was found only at 800 and 1,400 ms, $t(18) = -2.60$, $p < .05$, and $t(18) = 2.25$, $p < .05$, respectively. Note that participants appear to have overestimated the duration of emotional relative to neutral faces in this condition at 1,400 ms ($M = 0.14$), but *underestimated* the duration of emotional relative to neutral faces at 800 ms ($M = -0.30$).

In summary, these results indicate that, overall, participants categorized emotional faces more frequently than neutral faces as long in the spontaneous imitation condition but not in the inhibited imitation condition, with the exception of the 1,400-ms duration in the latter condition. This finding is clearly consistent with our primary hypothesis. Consistent with our secondary hypothesis, the tendency to categorize emotional faces as long more frequently than neutral faces was greater overall for angry faces than for happy faces.

Discussion

When participants were able to spontaneously imitate the faces they saw, they overestimated the duration of angry and, to a lesser extent, happy faces as compared with neutral faces. Replicating the findings of Droit-Volet et al. (2004), these results suggest that viewing emotional faces can cause a subjective lengthening of their duration and that this effect may be more pronounced for more arousing emotions (i.e., anger as opposed to happiness).

When imitation was inhibited by holding a pen in the mouth, however, participants' overall estimates of the duration of all three facial expressions were equivalent. This result is consistent with the hypothesis that imitation facilitates the effect of emotional stimuli on time perception. Given that the subjective lengthening effect for emotions seems to function via a quickening of the internal pacemaker in response to arousal (Droit-Volet et al., 2004), it therefore appears that spontaneous imitation of emotional facial expressions plays a central role in instigating this arousal. Specifically, we can extrapolate based on scalar timing models that viewing arousing facial expressions seems to quicken the cognitive pacemaker, leading to a greater number of pulses accumulating in the timer and an overestimation of the duration of these emotional stimuli.

It was somewhat surprising that participants in the inhibited imitation condition significantly underestimated the duration of emotional relative to neutral faces at the 800-ms actual stimulus duration. This underestimation was not observed across durations, however, as would have been expected if attentional mechanisms, as discussed in the introduction, had played a significant role in this condition. We attribute this finding simply to variability inherent in the task. We favor a similar explanation for why participants overestimated the duration of emotional faces at 1,400 ms in the inhibited imitation condition, although it is possible that a small amount of arousal was able to take place at this relatively long duration regardless of the pen task (which inhibited, but may not have eliminated, imitation), thus causing an overestimation. Indeed, our results suggest that the women had a small tendency to show a greater difference in time estimations between emotional and neutral faces at longer durations than at shorter ones, which is predicted by the arousal hypothesis (see Burle & Casini, 1999; Droit-Volet et al., 2004).[5] Future research, however, should rep-

[4] For tests in this ANOVA involving stimulus duration and its interactions, Mauchley's test of sphericity indicated that we needed to adjust the degrees of freedom. In no cases did adjusting with either a Greenhouse–Geisser or a Huynh–Feldt epsilon significantly alter the p value associated with these tests, except where indicated. We thus report unadjusted degrees of freedom and p values.

[5] Longer durations should be more likely to reveal an overestimation effect only to a point. As duration increases, so does the potential for attention (which begets underestimation; e.g., Brown, 1997; Casini & Macar, 1997; Macar et al., 1994; Zakay, 1989) to confound arousal (see Droit-Volet et al., 2004). Thus, Angrilli et al. (1997) found that highly arousing stimuli elicited an overestimation at 2 s, but elicited an underestimation at 4 and 6 s when attention may have played more of a role.

licate the 800- and 1,400-ms findings before drawing conclusions about what happened at these durations.

An alternative explanation for the present results might argue that attention, rather than imitation, facilitates the effect of emotion on time perception. Specifically, perhaps participants did not display the overestimation effect in the inhibited imitation condition simply because the task of holding a pen in the mouth distracted them from attending to the stimuli and fully processing the emotional content. While future research is needed to test this explanation directly, several considerations make it unlikely. First, previous research in which participants held a pen in their mouths found evidence that this task was not distracting (Niedenthal et al., 2001). Second, as discussed above, when people do not attend to stimuli, they tend to underestimate duration (e.g., Brown, 1997; Casini & Macar, 1997; Macar et al., 1994; Zakay, 1989). If holding a pen distracted participants from attending to the stimuli, we would thus expect to see an underestimation of the duration of neutral faces in the inhibited imitation condition as compared with neutral faces in the spontaneous imitation condition, in which the only task was to attend to the stimuli. Instead, our data showed no significant differences between the estimations of neutral faces between conditions, $t(37) = .22$. Therefore, it seems unlikely that the results of the current study can be attributed to attention required for the pen-in-mouth task.

It is possible, though, that the pen task somehow drew attention *to*, rather than away from, the faces, perhaps by first drawing attention to participants' own faces. Although it might seem that attending to the faces would increase the accuracy of temporal perception (thereby eliminating the overestimation effect), the same counterargument advanced above against attention applies here. The pacemaker–accumulator model of time perception implies that anything that distracts attention away from the *duration* of a stimulus, even nontemporal properties of the stimulus itself (e.g., emotion), will lead to an underestimation effect. In this case, as above, an attentional mechanism would thus predict an underestimation of the neutral faces' duration in the inhibited imitation condition relative to that in the spontaneous imitation condition, which is at odds with our results.

Perhaps, then, the pen in the mouth drew attention to the stimuli's duration without drawing attention to their other (emotional) features. This suggestion could explain the overall lack of an overestimation of the duration of emotional relative to neutral faces in the inhibited imitation condition. Without any theoretical reason to posit a connection between a motor task and increased attention to duration only, however, we favor the explanation from arousal.

Although attention does not seem to play a significant role in these results, we did not assess arousal directly, so it is possible that some other embodied mechanism was responsible for the overestimation effect. Although the observation that angry faces were overestimated to a greater extent than happy faces seems best explained by the fact that anger is more arousing than happiness (Russell & Mehrabian, 1977), it is possible that other characteristics of anger were more important in this paradigm. For example, perhaps something about an angry expression made participants imitate it longer, past the stimuli's actual duration, than they imitated happy expressions. If time estimation of facial expressions were based on the duration of one's imitation, then such an effect would lead to the same overestimation of angry as compared with happy faces that the present data revealed. Although these data cannot rule out such an explanation, it seems unlikely given the results of the Droit-Volet et al. (2004) study. As mentioned above, support for an arousal-based mechanism in this study came not only from the observation that the overestimation of angry faces was greater than that of faces with happy and sad (i.e., less arousing) expressions, but also from the finding that all emotional faces were overestimated relative to neutral ones and that the actual stimulus duration interacted with the degree of overestimation. Given the diverse support offered by Droit-Volet et al. (2004) for arousal's role in the temporal perception of emotion, it seems unparsimonious to posit the existence of a second mechanism that functions with embodiment to create the same pattern of results that are predicted by arousal.

It is also perhaps worth noting that the different degrees of overestimation found between anger and happiness in this study might have been obtained if anger instigated a prolonged state of arousal relative to happiness, rather than causing a heightened degree of arousal. In this view, the cognitive pacemaker would increase its speed by the same amount for happy and angry faces, but more pulses would accumulate in the cognitive timer while viewing angry faces because the pacemaker would maintain this increased speed for a longer period. Although our data cannot rule out this explanation, it seems unlikely given previous research that shows that anger is more arousing than happiness is (e.g., Russell & Mehrabian, 1977) and that arousal increases the speed of the pacemaker (e.g., Droit-Volet & Wearden, 2002). Furthermore, the distinction between these two models is peripheral to the present study's focus; in either case, arousal would play a role.

It is interesting to consider whether heightened emotional states would cause a similar subjective lengthening effect in the temporal perception of nonemotional stimuli. Participants in our study as well as those in the study by Angrilli et al. (1997) estimated the duration of the same emotional events that presumably instigated emotional arousal. It seems extremely likely, however, that substituting nonemotional stimuli for emotional ones would not significantly change time estimations, so long as subjects remained aroused. Studies that used amphetamine (Maricq et al., 1981; Meck, 1983) or body heat (Wearden & Penton-Voak, 1995) to instigate arousal demonstrated an apparent subjective lengthening of time using nonemotional stimuli. These findings are predicted by the pacemaker–accumulator model of time perception, which posits that, since arousal increases the speed of the pacemaker, the duration of any stimulus viewed while aroused should be overestimated (at least at the relatively short durations examined in our study).

This study joins the research reviewed above in providing evidence for the role of embodiment in social perception. Just as imitating or affecting a facial expression can modulate autonomic arousal and phenomenological experience of pain (Kleck et al., 1976; Lanzetta et al., 1976; Vaughan & Lanzetta, 1981; Zuckerman et al., 1981), the results of our study suggest that imitating emotional faces can facilitate the subjective experience of time, presumably by inducing arousal. But what is the precise nature of embodiment's role in social cognition? Until recently, no one theory had attempted to unify the diverse embodiment effects shown throughout the literature (Barsalou et al., 2003). In the context of modern cognitive theories, embodied effects have been traditionally viewed as stemming from or resulting in the activation of amodal concepts—abstract symbols that bear no direct relation to physical states (see Niedenthal, Barsalou, Ric et al., 2005). In such a view, for example, the concept *anger* might be represented by a feature list of related or definitional components, and imitation of an angry face could activate them through association. In contrast to such amodal theories, Barsalou (1999) has proposed a modal theory of cognition in which embodiment, whether expressed by full enactment of bodily states or by partial simulation in relevant sensorimotor areas, represents the concepts themselves. In this view, imitating an angry face would be a central component in processing anger (Barsalou et al., 2003; Niedenthal, Barsalou, Ric et al., 2005). Inhibiting imitation would therefore inhibit the perception of the emotion and hinder its related effects (i.e., arousal, subjective lengthening).

Our data also bolster other recent studies that found a role for embodiment in temporal perception in particular. In a study by Chambon and Droit-Volet (2004), for example, male and female participants performed a temporal bisection task similar to the one we used. Durations were represented by faces of young and old men and women (expressing neutral emotion). Results showed that men tended to underestimate the duration of presentations of the elderly faces, as compared with the young faces, but more particularly for elderly men's rather than elderly women's faces. On the other hand, women tended to underestimate the duration of presentations of elderly women's compared with young women's faces, whereas their perception of the durations of young and elderly male faces were identical. We interpret the findings to mean that male participants embodied the motoric style of young and old men and the women embodied the motoric style of young and old women. Because older men (and women) tend to produce slower motor movements, the embodiment of an old man (or woman) would have the effect of slowing the cognitive pacemaker, which would result in fewer pulses collected in the accumulator. This slowing effect would result in an underestimation of duration (see Chambon, Gil, Niedenthal, & Droit-Volet, 2005, for discussion). Furthermore, the finding that embodiment occurred within sex is not only unsurprising but is even consistent with the embodiment hypothesis. Other work has shown that the imitation of expressions of other individuals is moderated by factors such as the motivation to empathize (e.g., Zajonc, Adelmann, Murphy, & Niedenthal, 1987). It is indeed difficult to interpret the specific effects of sex without the notion of embodiment and the psychological and biological ability to embody some individuals better than or more than others.

A limitation of the present study is that the sample was composed entirely of women, which was the sample available to us. There are some differences between men's and women's ability to accurately decode and to accurately encode facial expression of emotion (e.g., McClure, 2000). However, our study did not examine the types of facial expression processing that are known to differ across the sexes. We would expect the role of embodiment in the effect of emotion on time perception to be largely the same for males and females, and have not yet seen any findings in the literature to suggest otherwise. Still, future work should certainly redress this limitation.

Future research should also seek to establish a clearer link between imitation and arousal and to rule out attention more decisively as an explanatory mechanism for the present results. For example, physiological measures could be used during a bisection task to correlate the extent of facial imitation (measured by electromyography) with the level of physiological arousal (sensitive measures of, e.g., skin conductance, heart rate, or blood pressure) and the relative overestimation of emotional faces. Our results suggest that a positive correlation would be found between all three variables. In addition, neutral faces exclusively could be used as stimuli in the bisection task while participants expressed anger, happiness, or neutrality with their own faces, covertly induced via muscle-by-muscle instruction (as in Laird, 1974) or by holding a pen in the mouth in different ways (Strack, Martin, & Stepper, 1988). We would expect participants to overestimate the duration of the neutral stimuli while simulating an emotional expression as compared with when holding the face in a neutral position. This procedure has the advantage of controlling for effects of attention, because all conditions contain essentially the same task.

In summary, this study supports the idea that imitating emotional faces facilitates the effect of emotion on the subjective experience of time. Physically inhibiting imitation seems to prevent or at least significantly reduce the overestimation of the duration of emotional faces that occurs when imitation is permitted to occur spontaneously. These findings thus add to the mounting evidence suggesting that embodiment plays an important, if not a central, role in social cognition.

References

Adelmann, P., & Zajonc, R. (1989). Facial efference and the experience of emotion. *Annual Review of Psychology, 40,* 249–280.

Adolphs, R., Damasio, H., Tranel, D., Cooper, G., & Damasio, A. R. (2000). A role for somatosensory cortices in the visual recognition of emotion as revealed by three dimensional lesion mapping. *Journal of Neuroscience, 20,* 2683–2690.

Allan, L., & Gibbon, J. (1991). Human bisection at the geometric mean. *Learning and Motivation, 22,* 39–58.

Angrilli, A. Cherubini, P. Pavese, A., & Manfredini, S. (1997). The influence of affective factors on time perception. *Perception & Psychophysics, 59,* 972–982.

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22,* 577–609.

Barsalou, L. W., Niedenthal, P. M., Barbey, A. K., & Ruppert, J. A. (2003). Social embodiment. In B. H. Ross (Ed.), *The psychology of learning and motivation* (Vol. 43, pp. 43–92). Sand Diego, CA: Academic Press.

Brown, S. W. (1997). Attentional resources in timing: Interference effects in concurrent temporal and nontemporal working memory tasks. *Perception & Psychophysics, 59, 7,* 1118–1140.

Burle, B., & Casini, L. (2001). Dissociation between activation and attention effects in time estimation: Implication for internal clock models. *Journal of Experimental Psychology: Human Perception and Performance, 27,* 195–205.

Casini, L., & Macar, F. (1997). Effects of attention manipulation on judgments of duration and of intensity in the visual modality. *Memory & Cognition, 25,* 812–818.

Chambon, M., & Droit-Volet, S. (2004). *The effect of elderly stereotype activation on time perception.* Manuscript submitted for publication.

Chambon, M., Gil, S., Niedenthal, P. M., & Droit-Volet, S. (2005). Psychologie sociale et perception du temps: l'Estimation temporelle des stimuli sociaux et émotionnels [Temporal estimation of social and emotional stimuli]. *Psychologie Française.*

Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: The perception–behavior link and social interaction. *Journal of Personality and Social Psychology, 76,* 893–910.

Church, R. M., & Deluty, M. Z. (1977). Bisection of temporal intervals.

Journal of Experimental Psychology: Animal Behavior Processes, 3, 216–228.

Cohen, J., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychological laboratory using Macintosh computers. *Behavioral Research Methods, Instruments & Computers, 25,* 257–271.

Décety, J., & Chaminade, T. (2003). Neural correlates of feeling sympathy [In special issue on Social Cognition]. *Neuropsychologia, 41,* 127–138.

Dimberg, U. (1982). Facial reactions to facial expressions. *Psychophysiology, 19,* 643–647.

Dimberg, U. (1990). Facial electromyography and emotional reactions. *Psychophysiology, 27,* 481–494.

Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science, 11,* 86–89.

Dimberg, U., Thunberg, M., & Grunedal, S. (2002). Facial reactions to emotional stimuli: Automatically controlled emotional responses. *Cognition & Emotion, 16,* 449–473.

Droit-Volet, S., Brunot, S., & Niedenthal, P. M. (2004). Perception of the duration of emotional events. *Cognition & Emotion, 18,* 849–858.

Droit-Volet, S., & Wearden, J. (2002). Speeding up an internal clock in children? Effects of visual flicker on subjective duration. *Quarterly Journal of Experimental Psychology, 55B,* 193–211.

Gallese, V. (2003). The roots of empathy: The shared manifold hypothesis and the neural basis of intersubjectivity. *Psychopathology, 36,* 171–180.

Gibbon, J., & Church, R. (1984). Sources of variance in an information processing theory of timing. In H. Roitblat, T. Bever, & H. Terrace (Eds.), *Animal cognition* (pp. 465–488). London: Erlbaum.

Gibbon, J., Church, R. M., & Meck, W. (1984). Scalar timing in memory. In J. Gibbon & L. Allan (Eds.), *Annals of the New York Academy of Sciences*: *Vol. 423. Timing and time perception* (pp. 52–77). New York: New York Academy of Sciences.

Harrington, D., & Haaland, K. (1999). Neural underpinnings of temporal processing. *Reviews in the Neurosciences, 10,* 91–116.

Hsee, C. K., Hatfield, E., Carlson, J. G., & Chemtob, C. (1990). The effect of power on susceptibility to emotional contagion. *Cognition & Emotion, 4,* 327–340.

Kleck, R. E., Vaughan, R. C., Cartwright-Smith, J., Vaughan, K. B., Colby, C. Z., & Lanzetta, J. T. (1976). Effects of being observed on expressive, subjective, and physiological responses to painful stimuli. *Journal of Personality and Social Psychology, 34,* 1211–1218.

Laird, J. D. (1974). Self-attribution of emotion: The effects of expressive behavior on the quality of emotional experience. *Journal of Personality and Social Psychology, 29,* 475–486.

Laird, J. D., Wagener, J., Halal, M., & Szegda, M. (1982). Remembering what you feel: Effects of emotion on memory. *Journal of Personality and Social Psychology, 42,* 646–657.

Lanzetta, J. T., Cartwright-Smith, J., & Kleck, R. E. (1976). Effects of nonverbal dissimulation on emotional experience and autonomic arousal. *Journal of Personality and Social Psychology, 33,* 354–370.

Lejeune, H. (1998). Switching or gating? The attentional challenge in cognitive models of psychological time. *Behavioural Processes, 44,* 127–145.

Macar, F., Grondin, S., & Casini, L. (1994). Controlled attention sharing influences time estimation. *Memory & Cognition, 22,* 673–686.

Macmillan, N. A., & Creelman, C. (1991). *Detection theory: A user's guide.* New York: Cambridge University Press.

Maricq, A. V., Roberts, S., & Church, R. M. (1981). Methamphetamine and time estimation. *Journal of Experimental Psychology: Animal Behavior Processes, 7,* 18–30.

McClure, E. B. (2000). A meta-analytic review of sex differences in facial expression processing and their development in infants, children, and adolescents. *Psychological Bulletin, 126,* 424–453.

McIntosh, D. (1996). Facial feedback hypotheses: Evidence, implications, and directions. *Motivation and Emotion, 20,* 121–147.

Meck, W. H. (1983). Selective adjustment of the speed of the internal clock and memory processes. *Journal of Experimental Psychology: Animal Behavior Processes, 9,* 171–201.

Meck, W. H. (1996). Neuropharmacology of timing and time percpetion. *Cognitive Brain Research, 3,* 227–242.

Niedenthal, P. M., Barsalou, L. W., Ric, F., & Krauth-Gruber, S. (2005). Embodiment in the acquisition and use of emotion knowledge. In L. Feldman-Barrett, P. M. Niedenthal, & P. Winkielman (Eds.), *Emotion and consciousness* (pp. 21–50). New York: Guilford Press.

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in attitudes, social perception, and emotion. *Personality and Social Psychology Review, 9,* 184–211.

Niedenthal, P. M., Brauer, M., Halberstadt, J. B., & Innes-Ker, A. H. (2001). When did her smile drop? Contrast effects in the influence of emotional state on the detection of change in emotional expression. *Cognition & Emotion, 15,* 853–864.

Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: An anger superiority effect with schematic stimuli. *Journal of Personality and Social Psychology, 80,* 381–396.

Russell, J. A., & Mehrabian, A. (1977). Evidence for a three-factor theory of emotions. *Journal of Research in Personality, 11,* 273–294.

Strack, F., Martin, L. L., & Stepper, S. (1988). Inhibiting and facilitating conditions of the human smile: A nonobtrusive test of the facial feedback hypothesis. *Journal of Personality and Social Psychology, 54,* 768–777.

Treisman, M., Cook, N., Naish, P., & McCrone, J. (1994). The internal clock: Electroencephalographic evidence for oscillatory processes underlying time perception. *Quarterly Journal of Experimental Psychology, 47A,* 241–289.

Vaughan, K., & Lanzetta, J. (1980). Vicarious instigation and conditioning of facial expressive and autonomic responses to a model's expressive display of pain. *Journal of Personality and Social Psychology, 38,* 909–923.

Vaughan, K., & Lanzetta, J. (1981). The effect of modification of expressive display on vicarious emotional arousal. *Journal of Experimental Social Psychology, 17,* 16–30.

Wearden, J. H. (1991). Human performance on an analogue of an interval bisection task. *Quarterly Journal of Experimental Psychology: Comparative & Physiological Psychology, 43B,* 59–81.

Wearden, J., & Penton-Voak, I. (1995). Feeling the heat: Body temperature and the rate of subjective time, revisited. *Quarterly Journal of Experimental Psychology, 48B,* 129–141.

Zajonc, R. B., Adelmann, P. K., Murphy, S. T., & Niedenthal, P. M. (1987). Convergence in the physical appearance of spouses. *Motivation and Emotion, 11,* 335–346.

Zakay, D. (1989). Subjective and attentional resource allocation: An integrated model of time estimation. In I. Levin & D. Zakay (Eds.), *Time and human cognition: A life-span perspective* (pp. 365–393). Amsterdam: North-Holland.

Zakay, D. (2005). Attention et jugement temporal [Attention and temporal judgment]. *Psychologie Française, 50,* 65–79.

Zuckerman, M., Klorman, R., Larrance, D. T., & Spiegel, N. H. (1981). Facial, autonomic, and subjective components of emotion: The facial feedback hypothesis versus the externalizer–internalizer distinction. *Journal of Personality and Social Psychology, 41,* 929–944.

Received July 29, 2004
Revision received May 19, 2005
Accepted May 25, 2005 ■