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Face the Noise: Embodied Responses to Nonverbal Vocalizations of Discrete Emotions

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Extensive prior research has shown that the perception of an emotional facial expression automatically elicits a corresponding facial expression in the observer. Theories of embodied emotion, however, suggest that such reactions might also occur *across* expressive channels, because simulation is based on integrated motoric and affective representations of that emotion. In the present studies, we examined this idea by focusing on facial and experiential reactions to nonverbal emotion vocalizations. In Studies 1 and 2, we showed that both hearing and reproducing vocalizations of anger, disgust, happiness, and sadness resulted in specific facial behaviors, as well as congruent self-reported emotions (Study 2). In Studies 3 and 4, we showed that the inhibition of congruent facial actions impaired listeners' processing of emotion vocalizations (Study 3), as well as their experiences of a concordant subjective state (Study 4). Results support the idea that cross-channel simulations of others' states serve facilitative functions similar to more strict imitations of observed expressive behavior, suggesting flexibility in the motoric and affective systems involved in emotion processing and interpersonal emotion transfer. We discuss implications for embodiment research and the social consequences of expressing and matching emotions across nonverbal channels.

Keywords: embodied emotions, cross-channel simulation, emotion vocalization, facial expression, empathy

It is a well-established phenomenon that individuals adopt the nonverbal emotional behaviors of interaction partners. Facial expressions of anger and happiness elicit corresponding frowns and smiles (Dimberg, Thunberg, & Elmehed, 2000), for example, and hearing someone speak in an upbeat tone adds a cheerful sparkle to listeners' own speech (Neumann & Strack, 2000). Popular theories of emotional embodiment interpret such responses as simulations of others' nonverbal expressions and affective states, which provide a basis for understanding and facilitate the interpersonal transfer of emotion (Barsalou, Niedenthal, Barbey, & Ruppert, 2003; Niedenthal, 2007). A lingering question concerns whether this nonverbal emotion matching, and the benefits that follow, occur only in terms of strict imitations of an observed behavior. Alternatively, a simulation perspective might suggest that matching another's emotion displays *across* expressive channels,[1] such as smiling upon hearing laughter (e.g., Provine, 1992, 1996), can serve similar functions. This idea highlights the flexibility with which a range of nonverbal behaviors—and not only exact mirroring of an observed expression—can help individuals understand and connect emotionally with others. The aim of the present article is to examine this account of cross-channel simulation by focusing on facial and experiential reactions to emotion sounds.

An Embodied Emotion Perspective

Embodiment theories (e.g., Barsalou et al., 2003; Niedenthal, 2007) propose that individuals process emotion-related information by reactivating neural states involved in their own prior perceptual, expressive, and affective experiences. Facial and vocal expressions hold differential associations with the visual and auditory perceptual modalities, respectively, but both represent examples of behaviors that bridge motoric and affective modalities. When individuals experience a combination of emotional states and nonverbal expressions with sufficient frequency, such as feeling happy, smiling, and laughing, later introspection about a stimulus (e.g., another's laughter) can activate dynamic simulations of associated behaviors and feelings. This *pattern completion* "fills

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[1] The terms *modality* and *channel* have been used interchangeably in much prior literature. In the present article, however, we use the term modality to refer to sensory or introspective components of experience (e.g., visual, auditory, motor, or affective), and the term channel to refer to a particular means of emotion expression (e.g., facial, vocal, or postural). *Producing* one's own emotion expressions in any channel typically recruits the motor and introspective modalities, but *perceiving* these expressions in others recruits different modalities, depending on channel (i.e., visual for faces and postures, auditory for vocalizations).

in" unperceived elements of the original experience (Barsalou et al., 2003) and may manifest as overt motor behavior (e.g., smiling) and subjective states (e.g., feeling happy). These simulations, based on limited perceptual information, facilitate cognitive, emotional, and behavioral engagement with related stimuli.

In the present studies, we focused on individuals' behavioral and subjective responses to emotion vocalizations. Nonverbal vocalizations representing discrete states such as joy, sadness, and disgust have been relatively neglected in prior embodiment research, even though they are recognized as easily as facial expressions (e.g., Hawk, Van Kleef, Fischer, & Van der Schalk, 2009; Schröder, 2003; Simon-Thomas, Keltner, Sauter, Sinicropi-Yao, & Abramson, 2009). Instead, the majority of research has focused on facial stimuli and observers' corresponding facial actions. Indeed, the vocal and facial channels may be differentially advantageous for simulating the emotions observed in others. Vocalizations have an on/off quality that typically requires conscious initiation, while the face provides a continuous flow of information (Scherer, 1980, 1988). This analog quality may also make the facial channel especially suited for rapid, online matching of others' states (e.g., Niedenthal, Mermillod, Maringer, & Hess, 2010), which in turn may facilitate observers' ability to process and respond to a variety of nonverbal emotion signals. We propose that the same facial behaviors recruited for individuals' own production of emotion vocalizations are also activated when individuals *hear* similar sounds. We further suggest that these "cross-channel" simulations may influence vocal cue processing and subjective emotional responding.

Producing Emotion Vocalizations Entrains Relevant Facial Behaviors

Facial activity accompanies naturalistic emotion vocalization (Provine, 1996; Scherer, 1994), particularly when expressing intense emotions (Krumhuber & Scherer, 2011; Scherer, 1994). Some facial movements may even be essential for shaping the distinguishing acoustics of particular emotion sounds (Scherer, 1994). Krumhuber and Scherer (2011) also showed that differentiated facial actions occurred when actors used the same vowel (/a/) to vocalize anger, sadness, and joy,but did not include some emotions commonly referenced in examples of nonverbal sounds, such as disgust (Scherer, 1994). A standardized utterance may also not be conducive for prototypical sounds such as crying or retches of disgust (e.g., Hawk et al., 2009; Schröder, 2003). We extend research on emotion-specific facial behavior while vocalizing by examining both additional emotions and a range of prototypical emotion sounds that are not constrained by a standard utterance.

Hearing Emotion Vocalizations Activates Relevant Facial Behaviors and Subjective States

Individuals engage in automatic, within-channel matching of others' facial expressions and vocal intonations, both overtly (e.g., Dimberg et al., 2000; Neumann & Strack, 2000; Sonnby-Borgström, Jönsson, & Svensson, 2008), and at the neural level (e.g., Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Van der Gaag, Minderaa, & Keysers, 2007). Auditory and visual stimuli may also activate motor responses in similar ways; prior research has shown, for example, that exposure to yawning sounds activates areas in the brain involved in executing mouth actions and increases the urge to yawn (Arnott, Singhal, & Goodale, 2009). Partly resulting from this motor resonance, facial actions recruited when vocalizing may also occur when *hearing* such sounds, and thus represent a cross-channel simulation of the expression. Earlier research has demonstrated concordant frowning and smiling both to general groups of negative and positive vocalizations (Verona, Patrick, Curtin, Bradley, & Lang, 2004) and to speech-embedded voice fragments representing happiness, anger, and fear (Hietanen, Surakka, & Linnankoski, 1998; Magnée, Stekelenburg, Kemner, & De Gelder, 2007). To our knowledge, however, prior studies have made only general distinctions between positive and negative emotions, in combination with valenced actions (smiling or frowning). No research, to date, has examined whether discrete emotion sounds evoke more differentiated facial responses.

Previous studies have also shown that emotional expressions activate observers' congruent subjective states. For example, exposure to facial expressions of anger, joy, and sadness can directly and automatically activate matching states (e.g., Blairy, Hererra, & Hess, 1999; Hess & Blairy, 2001; Lundqvist & Dimberg, 1995; Sonnby-Borgström, Jönsson, & Svensson, 2003; Sonnby-Borgström et al., 2008; Wicker et al., 2003; Wild, Erb, & Bartels, 2001). This may also hold for vocal expressions, which can potentially transmit important response preparations (e.g., Vermeulen & Mermillod, 2010) even before relevant visual information is available (e.g., Guilford & Dawkins, 1991; Owren, Rendall, & Bachorowski, 2005). A variety of acoustic stimuli can induce positive and negative affect in listeners, including tones (e.g., Dimberg, 1990), complex nonhuman sounds (e.g., machine noises, beer being poured; Bradley & Lang, 2000), human laughter (Bachorowski & Owren, 2001), and scenes or text spoken with emotional inflections (Bradley & Lang, 2000; Coyne, 1976; Neumann & Strack, 2000). To date, research on the communicative functions of vocal expression has primarily adopted more general models of affect induction (see Owren et al., 2005, and Russell, Bachorowski, & Fernández-Dolz, 2003, for extensive reviews) that argue for minimal emotion specificity in both signaling and listeners' congruent responding. As recent stimulus sets of nonverbal vocalizations are quite effective in conveying particular states (e.g., Hawk et al., 2009; Simon-Thomas et al., 2009), they can provide a useful avenue for testing whether discrete vocalizations can also activate more specific emotional responses.

Inhibiting Facial Responses to Vocalizations Disrupts Emotional Processing and Responding

Embodiment theories suggest that expressive simulations, regardless of the nonverbal channel, help observers to process and adaptively respond to emotional information. Spontaneous, congruent facial expressions occur when individuals judge the meaning, but not surface features, of emotional stimuli (Niedenthal, Winkielman, Mondillon, & Vermeulen, 2009). Furthermore, performing conceptual emotion tasks appears to activate related simulations in multiple expressive channels, including the face and bodily posture (Oosterwijk, Rotteveel, Fischer, & Hess, 2009; Oosterwijk, Topper, Rotteveel, & Fischer, 2010). Inhibiting individuals' facial expressions reduces the accuracy and speed of emotional language processing (Havas, Glenberg, Gutowski, Lucarelli, & Davidson, 2010; Niedenthal et al. 2009), impairs recognition of emotional faces (Oberman, Winkielman, & Ramachandran, 2007; Stel & Van Knippenberg, 2008), and disturbs the detection of changes between different facial expressions (Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001). The ability to spontaneously imitate facial expressions also increases temporal overestimations of their presentation length (Effron, Niedenthal, Gil, & Droit-Volet, 2006) and may boost attention for congruent stimuli in the environment (Vermeulen & Mermillod, 2010). These various effects have all been interpreted as evidence that interfering with facial simulation disturbs the processing of affective content.

It is not yet clear whether facial responses are similarly involved in individuals' processing of a broader range of others' nonverbal behaviors. It appears, however, that visually presented emotional faces bias the selective processing of emotional tones of voice and vice-versa. Pairings of facial and vocal expressions communicating the same emotion facilitate quick and accurate recognition of stimuli, and incongruent parings reduce speed and accuracy, regardless of whether target stimuli are facial or vocal (De Gelder, Pourtois, & Weiskrantz, 2002; De Gelder & Vroomen, 2000; Dolan, Morris, & De Gelder, 2001; Hietanen, Leppänen, Illi, & Surakka, 2004; Massaro & Egan, 1996; Pell, 2005). On the basis of this preliminary evidence, in conjunction with the previously described theorizing, we suggest that listeners' own facial behavior may play a role in the processing of emotion vocalizations.

Adopting emotion-specific facial and vocal behaviors can also trigger related states, even in the absence of context (e.g., Flack, 2006; Flack, Laird, & Cavallaro, 1999; Hatfield, Hsee, Costello, Weisman, & Denney, 1995), and intensify emotional judgments of nonexpressive stimuli, such as cartoons and pictures (e.g., Larsen, Kasimatis, & Frey, 1992; Strack, Martin, & Stepper, 1988). Adopting expressions in several nonverbal channels further intensifies subjective feelings (Flack et al., 1999). Conversely, inhibiting facial expression through instruction, Botox injections, or incompatible muscular activity reduces emotional responding (e.g., Davis, Senghas, & Ochsner, 2009; Davis, Senghas, Brandt, & Ochsner, 2010; Strack et al., 1988). In a recent experiment, Foroni and Semin (2011) also showed a mimicry-to-emotion effect, where subliminally presented smiling faces increased subsequent positive ratings of cartoons, except when facial imitation was not possible. These findings suggest that individuals' own experiences and expressions of emotion ground the understanding of others' feelings, and that expressive behaviors and introspective states can activate one another in a dynamic fashion (Barsalou et al., 1999; Keysers & Gazzola, 2009; Niedenthal, 2007; Van der Gaag et al., 2007). This notion of "crosstalk" also implies that interfering with facial expressions may disrupt pattern completion more generally, with negative implications for emotional processing and responding.

Overview and Hypotheses

From an embodied emotions perspective, we expected to findthat facial responses to emotion vocalizations are based on individuals' prior motor actions when producing similar sounds, and thus can be fairly specific to discrete emotions (e.g., Niedenthal et al., 2009). We additionally expected that congruent facial reactions can promote processing of these signals, as well as congruent emotional states. A more general affect induction model of vocal emotion communication (e.g., Owren et al., 2005; Russell et al, 2003), in contrast, might suggest that these facial reactions could be symptoms of less specific affective responses, in which case they may be less congruent with the specific vocalization, have no direct ties to listeners' own vocal–facial integration, or have little influence on processing or discrete subjective responding to the stimuli. This research can contribute new information regarding the overlaps between experiencing and expressing discrete emotions, and the extent to which individuals can represent others' states through a variety of nonverbal behaviors.

We examined several vocalizations and a diverse set of facial muscles to address, for the first time, whether discrete emotion sounds engage matching facial behaviors. In Study 1, we expected that hearing joyful laughs, disgusted gags, sad cries, and angry growls would activate emotion-congruent facial behaviors (*Hypothesis 1*) and that these actions would also occur during vocal production (*Hypothesis 2*). We also expected facial actions made when *hearing* emotion sounds to correlate with those made when actually *vocalizing* (*Hypothesis 3*). In Study 2, we expected that emotion sounds would activate discrete, matching states in listeners (*Hypothesis 4*). Prior studies have demonstrated general positive/negative responses to both nonvocal and vocal sounds (e.g., Bradley & Lang, 2000; Dimberg, 1990; Neumann & Strack, 2000), but our research is the first to investigate an emotion-specific account. We also predicted positive correlations between facial and subjective responses (*Hypothesis 5*).

We then examined whether interfering with facial matching of vocalizations would affect the extent to which individuals process and subjectively respond to these stimuli. In Study 3, we expected that participants who could spontaneously match their faces to an initial sound would focus more strongly on this stimulus, at the expense of an emerging, facially incompatible sound (*Hypothesis 6*). Prior research has shown that impairing facial expressions interferes with the processing of facial expression, and that pictures of emotional faces can facilitate congruent vocal expression processing. This is the first study, however, to address whether similar effects whether similar effects occur when respondents cannot match their own faces to expressions in a different nonverbal channel. Finally, in Study 4, we predicted that blocking listeners' facial matching of disgust sounds would disrupt the activation of the same emotional state (*Hypothesis 7*). This would be the first evidence, to our knowledge, that cross-channel matching of an emotional expression influences corresponding subjective responses.

Study 1

In Study 1, participants listened to prerecorded nonverbal vocalizations representing four discrete emotions (anger, disgust, happiness, and sadness) and were instructed to reproduce these sounds while their faces were recorded with a hidden camera. We held three major expectations in this initial study. We predicted, first, that emotion-congruent facial actions would occur when participants heard emotion sounds and, second, that these facial actions would also occur when they subsequently reproduced the vocalizations. Third, we expected significant correlations between particular facial actions during the two tasks.

Method

Participants. A sample of 40 female undergraduates from a large Dutch university participated in this study. Four of these participants were excluded from data analyses: one who reported in debriefing that she did not participate in the study sincerely, two who suspected being filmed during the study, and one who did not consent to her films being analyzed. The age of the remaining 36 participants ranged from 18 to 34 years ($M = 22.41$, $SD = 4.11$). All participants received either credit toward their psychology courses or 7 euros as compensation.

Stimuli and apparatus. Professional actors produced nonverbal vocalizations representing the emotions of anger, disgust, happiness, and sadness, as well as affectively "neutral" vocalizations (5,000 ms each). The development and validation of these stimuli have been described in a previous empirical study (Hawk et al., 2009). The neutral vocalizations consisted of humming sounds. Anger sounds consisted of throaty grunts and growls. The disgust noises included gagging and retching sounds. The happiness sounds were recordings of laughter, and the sadness sounds were mixtures of sniffles, sobs, and cries. All recordings were very well recognized in previous research.[2] Since gender and other idiosyncratic speaker differences can influence the perception and interpretation of vocal expressions (e.g., Banse & Scherer, 1996), we used stimuli from two male and two female actors. As facial reactions can be affected by an orienting response when different types of emotional stimuli are intermixed (e.g., responses such as squinting and frowning, as well as changes in autonomic nervous system activity; Dimberg, 1996), sounds of each respective emotion were presented in blocked fashion. This design is similar to previous studies demonstrating distinct facial electromyographic (fEMG) reactions to emotion expressions (e.g., Dimberg, 1982; Dimberg & Petterson, 2000; Dimberg & Thunberg, 1998). Stimuli were randomly ordered within each emotion block. Sounds were controlled for volume and were presented through an audio/microphone headset.

Measures of facial activity. Participants' facial actions when hearing and reproducing the emotional sounds were recorded via a hidden camera. Facial responses were then measured using the Facial Action Coding System (FACS; Ekman & Friesen, 1978; Ekman, Friesen, & Hager, 2002). There were four sound exemplars for each emotion category, and the frequency of each facial movement was scored on a 5-point scale, from 0 (*response to no sounds in a stimulus block*) to 4 (*response to each sound in a stimulus block*). This scoring was repeated for each of the five stimulus blocks. For the listening, a facial action was coded only if its onset occurred during stimulus presentation. We thus avoided coding movements not directly associated with online processing of the stimuli. Similarly, facial actions in the vocalizing task were recorded only if they occurred immediately before or during actual vocalizing.

Upon a review of the prototypical facial configurations for each respective emotion in the FACS investigator's guide (Ekman et al., 2002; see also Ekman, 2007), we chose specific action units (AUs) that were mainly present in the codes for only one target emotion (see Figures 1a–1d), that represented characteristic movements included in guided facial action tasks (e.g., Duclos et al., 1989; Ekman, 2007; Flack, 2006), and that were roughly equivalent in visibility. We predicted that AU 4[3] ("brow lowerer,"corrugator supercilii), which produces a frowning expression in the upper face, would be a more frequent response to anger noises. Two distinct AUs can contribute to the characteristic grimace of disgust, namely AU 9 ("nose wrinkler," levator labii superioris alaeque nasi) and AU 10 ("upper lip raiser," levator labii superioris). Because both AUs can occur independently and both are listed separately as prototypical actions, we used a combined score so that a response was said to occur if one or both of these AUs showed activity. We further expected that AU 12 ("lip corner puller," zygomaticus major), which creates a smile, would occur in response to happiness sounds. Finally, AU 15 ("lip corner depressor," depressor anguli oris), which turns down the corners of the mouth, was predicted as a response to sadness sounds. Only movement was recorded (i.e., new movements or intensity increases in expressions already present at stimulus onset). A certified FACS coder, blind to which stimuli were being presented in each block, scored the facial reactions.

Figure 1. Modeled facial actions predicted for (a) anger (Action Unit [AU] 4, brow lowerer), (b) disgust (AU 9/10, nose wrinkler/upper lip raiser), (c) happiness (AU 12, lip corner puller), and (d) sadness (AU 15, lip corner depressor). The Facial Action Coding System and action unit descriptions were developed by Ekman and Friesen (1978). Exemplars are still photos produced from the Amsterdam Dynamic Facial Expressions Set (ADFES; Van der Schalk, Hawk, Fischer, & Doosje, 2011, *Emotion*, *11*, p. 912 and p. 913). Copyright 2011 by the American Psychological Association.

Procedure. We utilized a completely within-participants design. Participants were instructed to put on the audio headset at the beginning of the study and to move the microphone to a fixed position and distance from their mouths. Participants then read and

[2] The ranges of decoding accuracy for the sound clips per emotion were 61.4%–70.5% for neutral, 90.9%–100% for anger, 97.7%–100% for disgust, 88.6%–97.7% for happiness, and 97.7%–100% for sadness.

[3] While AU 4 is technically present for a variety of negative emotions, only for anger is it not combined with additional actions in the forehead.

signed an informed consent document. The cover story was similar to that used in a prior experiment (Hatfield et al., 1995): The experimenter claimed to be an applied psychologist working for a well-known Internet telephone service. Participants were told that the company wanted information about voices in digital sound patterns in order to optimize the sending and receiving qualities of their software. They were told they would hear a variety of vocalizations through a headset and would then be asked to reproduce each sound as accurately as possible. We further emphasized the importance of accurate reproduction by explaining to participants that deviations from the original sound would be considered as a fault with the software.

After this, all participants began with the block of neutral vocalizations. Participants heard each sound clip and, following a 5-s countdown, reproduced the sound into the microphone. In order to increase attention to the task and provide support for the cover story, we asked the participants to rate the recordings after every sound block on the dimensions of activation, valence, and control. After making these judgments with regard to the block of neutral stimuli, participants were exposed to the remaining angry, disgusted, happy, and sad stimulus blocks in random order. After the presentation of all sound blocks, participants provided demographic information and were probed for their ideas about the study's purpose. They were then debriefed and given the opportunity to exclude their films from further analyses.

Results

Strategy of analyses. To test Hypotheses 1 and 2—that emotion-specific facial actions occur for both the listening and vocalizing tasks, respectively—we analyzed each of the four predicted facial patterns in separate 5×2 repeated-measures analyses of variance (RM-ANOVAs),[4] with emotion (neutral, anger, disgust, joy, and sadness) and task (listening vs. vocalizing) as within-participants factors. As the sphericity assumption was violated in three of four cases (for AU 4, AU 9/10, and AU 15, all ps $< .001$), results for these tests were interpreted on the basis of Greenhouse–Geisser corrections (as indexed by ε). Raw means and standard deviations of the frequencies for each action unit, in each stimulus block, can be seen in Table 1. Planned pairwise comparisons specified the nature of the within-participants effects. We performed four pairwise tests for each RM-ANOVA, comparing the score within the concordant stimulus block to the score for every other measurement point. In the case of interactions between emotion and task, pairwise tests were again carried out separately for each of the tasks, as were tests comparing the two tasks for each block of emotion sounds. To investigate Hypothesis 3, that facial responses when hearing sounds are correlated with facial behaviors that occur when producing emotion vocalizations, we examined correlations between participants' relevant facial actions while listening and while vocalizing for each stimulus block (e.g., AU 9/10 activity while listening to and vocalizing disgust sounds). Results for each action unit are reported separately below.

Facial responses.

AU 4 (brow lowerer). The RM-ANOVA performed on AU 4 frequency revealed a main effect of emotion, $F(4, 140) = 43.16$, $p < .001$, $\eta_p^2 = .55$, $\varepsilon = .71$. As predicted, pairwise comparisons showed that participants frowned more frequently in the anger block, compared with all other emotion blocks (all ps $< .001$). A main effect of task was also observed, $F(1, 35) = 18.14$, $p < .001$, $\eta_p^2 = .34$; participants frowned more during the vocalizing task ($M = 1.32$, $SD = 1.57$) than during the initial listening task ($M = 0.78$, $SD = 1.14$). These main effects were qualified by an Emotion $\times$ Task interaction, $F(4, 140) = 7.41$, $p < .001$, $\eta_p^2 = .18$, $\varepsilon = .71$. Pairwise tests showed greater frowning frequency in the anger block than in any other block both during the listening task and during the vocalizing task, all ps $< .03$. Frowning in the anger block was also more frequent during the vocalizing task than during the listening task ($p < .001$). Within the anger block, AU 4 activity while listening was significantly correlated with AU 4 activity while vocalizing ($r = .42$, $n = 36$, $p = .01$).

AU 9/10 (nose wrinkler/upper lip raiser). The RM-ANOVA performed on AU 9/10 frequency revealed a main effect of emotion, $F(4, 140) = 40.96$, $p < .001$, $\eta_p^2 = .54$, $\varepsilon = .71$. Pairwise comparisons revealed that, as predicted, participants wrinkled their noses and/or raised their upper lips more frequently in the disgust block compared with all other emotion blocks (all ps $< .001$). A main effect of task also existed, $F(1, 35) = 34.77$, $p < .001$, $\eta_p^2 = .50$; participants showed higher AU 9/10 activity during the vocalizing task ($M = 1.46$, $SD = 1.56$) than during the initial listening task ($M = 0.75$, $SD = 1.15$). These main effects were qualified by an Emotion $\times$ Task interaction, $F(4, 140) = 4.42$, $p = .005$, $\eta_p^2 = .11$, $\varepsilon = .76$. Pairwise tests showed higher AU 9/10 frequency in the disgust block than in any other block during both the listening and vocalizing tasks (all ps $< .001$). AU 9/10 activity in the disgust block was more frequent during the vocalizing task than during the listening task ($p < .001$). Within the disgust block, AU 9/10 activity while listening was significantly correlated with AU 9/10 activity while vocalizing ($r = .33$, $n = 36$, $p = .05$).

AU 12 (lip corner puller). The RM-ANOVA performed on AU 12 showed a main effect of emotion, $F(4, 140) = 41.25$, $p < .001$, $\eta_p^2 = .54$. Pairwise comparisons revealed that, in line with expectations, participants smiled more frequently in the happiness stimulus block compared with all other emotion blocks (see Table 1; all ps $< .001$). A main effect of task was also found, $F(1, 35) = 50.20$, $p < .001$, $\eta_p^2 = .59$; participants smiled more during the vocalizing task ($M = 2.62$, $SD = 1.52$) than during the initial listening task ($M = 1.86$, $SD = 1.45$). These main effects were qualified by an Emotion $\times$ Task interaction, $F(4, 140) = 3.50$, $p < .01$, $\eta_p^2 = .09$. Pairwise tests showed there was higher smiling frequency in the happiness block than in any other block during the listening and vocalizing tasks (all ps $< .001$). Smiling in the happiness block was more frequent during the vocalizing task than during the listening task ($p < .001$). Within the happiness block, AU 12 activity while listening was not significantly correlated with AU 12 activity while vocalizing ($r = -.13$, $n = 36$, $p = .46$).

AU 15 (lip corner depressor). The films of three participants were excluded in the RM-ANOVA performed for AU 15 because that portion of the face was obscured for at least one of the five stimulus blocks (obstruction occurred for one participant during the reproduction task in the sadness block, and the rest occurred in other stimulus blocks). The analysis activity revealed a main effect of emotion stimulus block, $F(4, 128) = 44.45$, $p < .001$, $\eta_p^2 = .58$,

[4] Initial analyses included as a covariate the order in which a given emotion block was presented. No significant order effects were found, and thus they are not reported further. This is also true for the results of Study 2.

Table 1
Descriptive Statistics of Action Unit Activation Frequency in Response to Each Stimulus Block During Listening and Vocalizing Tasks (Study 1)

	Listening task								Vocalizing task							
	AU 4		AU 9/10		AU 12		AU 15		AU 4		AU 9/10		AU 12		AU 15	
Stimulus block	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Neutral	0.28	0.85	0.00	0.00	0.61	0.84	0.23	0.57	0.17	0.45	0.36	0.83	2.06	1.39	0.70	0.85
Anger	**1.72**	1.26	0.75	1.05	1.81	1.41	0.82	0.92	**2.67**	1.35	1.75	1.36	2.67	1.49	0.70	1.08
Disgust	0.89	1.17	**1.86**	1.52	1.61	1.34	0.97	0.92	2.11	1.51	**3.14**	1.46	2.14	1.62	2.00	1.32
Happiness	0.19	0.52	0.64	0.96	**3.28**	0.97	0.42	0.71	0.19	0.71	1.28	1.47	**3.97**	0.17	0.33	0.82
Sadness	0.83	1.06	0.50	0.70	2.00	1.21	**1.88**	1.22	1.44	1.59	0.75	0.91	2.25	1.54	**2.82**	1.24

Note. Action unit (AU) frequency scores ranged from 0 (*no AU activity for any sound in a given emotion block*) to 4 (*AU activity for each sound*). Values in bold signify the emotion stimulus block in which respective scores were predicted to be highest.

ε = .80. Hypotheses regarding AU 15 were supported, in that pairwise comparisons showed this behavior to occur more frequently in the sadness block than in the other stimulus blocks (all *p*s $<$ .001). There was also a main effect of task, $F(1, 32) = 13.78$, $p < .001$, $\eta^2_p = .30$; participants showed higher AU 15 activity during the vocalizing task ($M = 1.31$, $SD = 0.11$) than during the initial listening task ($M = 0.87$, $SD = 0.09$). These main effects were qualified by an Emotion $\times$ Task interaction, $F(4, 128) = 7.88$, $p < .001$, $\eta^2_p = .20$. While AU 15 activity was highest within the sadness block for both the listening and vocalizing tasks, vocalizing scores were significantly higher than listening scores only in the neutral ($p = .03$), disgust ($p < .001$), and sadness ($p < .001$) stimulus blocks. In contrast, there were no differences between the tasks in the anger ($p = .61$) or happiness ($p = .64$) blocks. Within the sadness block, AU 15 activity while listening was significantly correlated with AU 15 activity while vocalizing ($r = .55$, $n = 35$, $p = .001$).

Discussion

We examined discrete patterns of facial activity related to vocalizations of four distinct emotions. On the basis of Ekman and Friesen's (e.g., 1978) studies on prototypical facial expression (see also Ekman, 2007; Ekman et al., 2002), we identified emotion-congruent facial behaviors that occurred when participants both listened to and reproduced the vocalizations (supporting Hypotheses 1 and 2). It should be noted, however, that the frequency of AU 4 was also heightened for other negative emotions across both the listening and vocalizing tasks. Thus, facial responses generally involving AU 4 appeared to have a broader negative valence connotation (cf. Bradley & Lang, 2000; Dimberg, 1990; Niedenthal et al., 2009; Verona et al., 2004).

As also may be expected, there was a greater amount of discrete facial activity when participants were vocalizing as compared to when they merely listened to the sounds. If facial responses while listening indeed result from partial simulations of participants' own vocalizing behavior, it makes sense that actually producing the sounds would result in more complete simulations. More important for a simulation account, significant correlations existed between facial behaviors during the listening and vocalizing tasks for sounds of anger, disgust, and sadness. The more frequently participants displayed particular facial behaviors when initially processing these stimuli, the more often they also utilized those actions when producing the emotion sounds (supporting Hypothesis 3). The exception concerned the nonsignificant correlation for AU 12 in the happiness block, as there was a near-ubiquitous presence of smiling while vocalizing laughter (other AUs were activated with more variability during the respective vocalizing tasks). This creates restriction-of-range problems for finding such a relationship, while also underscoring the notion of co-activation between the facial and vocal channels. These data thus support the idea that processing of the different vocal stimuli recruited emotion-specific facial behaviors and that the same motor programs operating during actual vocal production were also active when participants were hearing the sounds (cf. Carr et al., 2003; Dapretto et al., 2006; Leslie, Johnson-Frey, & Grafton, 2004).

These data offer preliminary evidence for the notion that hearing vocalizations of specific emotions can prompt concordant and discrete facial behaviors in listeners. Further, the correlations for facial action between the two tasks lend support to an embodied emotion account. While the paradigm of instructing participants to first listen to the sounds and then reproduce them was necessary for ensuring that emotions were vocalized in a consistent way, and also for examining the hypotheses without actually presenting participants with words such as *sadness* or *crying*, this procedure may have produced some unintended effects. For example, there was a relatively large amount of smiling behavior across the different emotion blocks, as compared with other actions. Although smiling was most frequent in the happiness stimulus block, it is plausible that participants found aspects of the task amusing or embarrassing, which may account for the more frequent smiling in each task.

Participants' facial behaviors during the listening tasks and the correlations in the patterns of activity may also be explained by the participants' explicit goal to reproduce the sounds. In other words, participants may have been mentally rehearsing the upcoming performance, attending to their impending motor behaviors (cf. Carr et al., 2003; Dapretto et al., 2006; Leslie et al., 2004), or "feeling" their way into their assigned role (e.g., Hatfield et al., 1995). While such active simulation is entirely consistent with an embodiment account, it is important to consider (a) whether the same patterns of behavior occur in absence of explicit intent to repeat the vocalizations (cf. Van der Gaag et al., 2007) and (b) whether such facial activity correlates with participants' subjective emotions. These issues are addressed in Study 2, where we examined whether hearing emotion sounds with no intent to vocalize engages both congruent facial and subjective responses. Additionally, we examined correlations between participants' facial activity when hearing the stimuli and their self-reported emotions.

Study 2

In Study 2, we sought further support for Hypothesis 1, predicting that the matching facial responses to emotion vocalizations observed in Study 1 would occur even in absence of instructions to repeat the sounds. We also examined Hypothesis 4, addressing whether participants' processing of the vocalizations also involved the activation of concordant emotional states. To this end, we collected emotion self-reports from participants. Finally, we tested Hypothesis 5, regarding the interrelation of expressive and subjective responding, by examining the correlations between facial activity and emotion self-reports.

Method

Participants. A sample of 40 female undergraduates from a large Dutch university participated in this experiment. None of them participated in Study 1. The data of three participants were excluded from analyses, one due to a technical malfunction with the hidden camera and another two because they reported in the debriefing that they had suspected being filmed. The remaining 37 participants ranged in age from 18 to 47 years ($M = 22.22$, $SD = 5.83$). All participants received either credit toward their psychology courses or 7 euros as compensation.

Stimuli and apparatus. The stimuli were identical to those used in Study 1. Similar to the procedure in Study 1, the sound clips were controlled for volume and were again randomly presented in emotion-specific blocks, via computer, through an audio/microphone headset.

Measures.

Facial activity. The same action units targeted in Study 1 were again examined in Study 2 (anger: AU 4; disgust: AUs 9/10; happiness: AU 12; sadness: AU 15). A certified FACS coder again scored participants' facial reactions, blind to which stimuli were being presented in each block.

Self-reported emotions. To assess changes in subjective emotions, we adapted a questionnaire from Philippot, Chapelle, and Blairy (1994), also used by Hess and Blairy (2001). Participants reported on a number of bodily sensations and discrete emotions that they were feeling at that moment. By presenting both emotion- and body-related items under the cover of an "experimental stress" measure, we aimed to reduce participants' focus on the experiment's true purpose (Hess & Blairy, 2001). Participants indicated their subjective feelings on 11-point scales (cf. Flack, 2006; Hatfield et al., 1995), ranging from 0 (*not at all*) to 10 (*very strongly*). To measure the respective emotions, the following items were used: "I feel irritated"; "I feel disgusted"; "I feel cheerful"; "I feel sad, depressed." Examples of the items that measured bodily states are "I have a headache" and "I have stiff muscles." The items were presented randomly, both in a baseline measure and after each block of stimuli.

Procedure. The cover story was similar to that used in Study 1, except that participants were merely asked to provide judgments of the sounds for the purposes of improving the Internet telephone software. Participants were also told it would be helpful in analyzing their perceptions of the sound patterns if they gave periodic reports of their "experimental stress," as the stress they experienced in the laboratory could potentially affect their judgments. Participants were asked to report on these items as accurately as possible, ostensibly in order to control for their individual differences in the statistical analyses. At this point, participants completed a baseline administration of the subjective questionnaire, followed by the block of neutral vocalizations, and then the remaining angry, disgusted, happy, and sad stimulus blocks in random order. Participants heard each sound clip twice, in close succession. Participants rated the recordings after every sound block on the affective dimensions of activation and valence (e.g., Russell & Barrett, 1999),[5] followed by an administration of the subjective well-being questionnaire. Between each of the stimulus blocks, participants took 1-min breaks during which they performed an unrelated, affectively neutral puzzle task. Upon completion of all sound blocks, participants provided demographic information and were probed for their ideas about the goals of the study. Participants were then debriefed and given the opportunity to withdraw their video footage from further analysis.

Results

Strategy of analyses. Raw means and standard deviations of the frequencies for each action unit in each stimulus block can be seen in Table 2. Each of the four predicted facial patterns were analyzed in separate, five-level RM-ANOVAs, with emotion block (neutral, anger, disgust, joy, and sadness) as the within-subjects factor. Participants were dropped from the RM analyses if the action unit being studied was obscured in any of the video footage (e.g., if a participant moved out of frame or if the participant's hands covered part of the face). Table 2 also displays the descriptive data for participants' emotion self-reports in each sound block. Similar analyses were performed for these data. In the analysis of emotion self-reports, we included baseline scores as an additional level in the RM-ANOVAs (six levels in total) in order to ascertain whether hearing neutral voices also increased emotion experiences. As the sphericity assumption was violated in all analyses of facial actions and self-reported emotions, these results were inter-

[5] The patterns of participants' ratings of arousal and valence (made on 7-point Likert scales) were highly similar to those reported in prior studies of facial and vocal expression. The RM-ANOVA for ratings of arousal (1 = *calm*, 7 = *excited*) revealed a main effect of emotion, $F(4, 144) = 144.24$, $p < .001$, $\eta_p^2 = .80$. Anger vocalizations were rated highest ($M = 6.27$, $SD = 0.80$), followed by happiness ($M = 5.95$, $SD = 0.71$), disgust ($M = 4.95$, $SD = 0.97$), sadness ($M = 4.54$, $SD = 1.19$), and neutral sounds ($M = 2.03$, $SD = 0.96$), respectively. All planned contrasts were significant at $p < .02$, except for the comparison of disgust and sadness ($p = .06$). The RM-ANOVA for ratings of valence (1 = *very negative*, 7 = *very positive*) also revealed a main effect of emotion, $F(4, 144) = 265.89$, $p < .001$, $\eta_p^2 = .88$. Vocalizations of happiness ($M = 6.43$, $SD = 0.90$) were rated as most positive, followed by neutral ($M = 4.30$, $SD = 1.05$), sadness ($M = 1.84$, $SD = 0.83$), disgust ($M = 1.57$, $SD = 0.99$), and anger sounds ($M = 1.30$, $SD = 0.57$), respectively. With the exceptions of comparisons between anger and disgust ($p = .15$) and between disgust and sadness ($p = .16$), all contrasts were significant at $p < .001$. Further details of these data are available upon request.

Table 2
Descriptive Statistics of Facial Actions and Self-Reported Emotions in Each Stimulus Block (Study 2)

	Facial action unit frequency								Self-reported emotion intensity							
	AU 4		AU 9/10		AU 12		AU 15		Anger		Disgust		Happiness		Sadness	
Stimulus block	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Baseline									1.24	1.53	0.30	0.62	6.57	1.68	1.08	1.34
Neutral	0.28	0.74	0.03	0.19	0.50	0.82	0.13	0.35	1.00	1.47	0.41	0.86	6.49	1.91	0.76	1.23
Anger	**1.17**	1.40	0.41	0.68	0.53	0.73	0.27	0.45	**3.11**	2.91	1.70	2.30	5.38	2.11	1.49	1.85
Disgust	1.08	1.27	**1.28**	1.22	0.53	0.78	0.50	0.82	2.08	2.38	**3.11**	2.86	5.70	2.21	1.27	1.56
Happiness	0.25	0.50	0.38	0.56	**1.93**	1.41	0.30	0.60	0.92	1.28	0.38	0.64	**7.14**	1.69	0.89	1.41
Sadness	0.61	1.05	0.52	0.95	0.77	0.90	**0.73**	1.20	1.89	2.27	0.84	1.76	5.32	2.10	**2.27**	2.62

Note. Action unit (AU) frequency scores ranged from 0 (*no AU activity for any sounds in a given emotion block*) to 4 (*AU activity for each sound*). Emotion intensity scores ranges from 0 (*not at all*) to 10 (*very strongly*). Values in bold signify the emotion stimulus block in which respective scores were predicted to be highest.

preted on the basis of Greenhouse–Geisser corrections (indexed by ε). Four pairwise tests were performed for each facial action RM-ANOVA, and five tests for the emotion RM-ANOVAs (including baseline), comparing scores within the concordant stimulus block to the scores for every other measurement point. Using a procedure similar to that in Study 1, we assessed the correlations between facial actions and emotion self-reports for each relevant stimulus block (e.g., AU 9/10 activity and self-reported disgust when hearing disgust sounds).

Self-reported emotions[6] and facial actions.

Anger and AU 4 (brow lowerer). The RM-ANOVA performed on anger self-reports revealed a main effect of emotion block, $F(5, 180) = 13.62$, $p < .001$, $\eta_p^2 = .27$, $\varepsilon = .56$. Pairwise comparisons revealed that participants reported higher levels of anger after listening to anger sounds compared with all other emotions (all *p*s $< .01$). One participant's AU 4 scores were omitted from the RM analysis of facial actions because the relevant portion of the face was obscured in the anger stimulus block. An RM-ANOVA was thus carried out with the remaining 36 participants. The analysis revealed a main effect of emotion stimulus block, $F(4, 140) = 8.62$, $p < .001$, $\eta_p^2 = .20$, $\varepsilon = .79$. Pairwise comparisons revealed that, as expected, participants frowned more frequently in response to growling sounds, compared with the neutral, happy, and sad sounds (all *p*s $< .004$). There were no significant differences in the frequency of AU 4 activity between the anger and disgust stimulus blocks ($p = .74$). Within the block of anger sounds, AU 4 frequency was significantly correlated with self-reported anger ($r = .40$, $n = 36$, $p = .02$).

Disgust and AU 9/10 (nose wrinkler/upper lip raiser). The RM-ANOVA for reported disgust showed a main effect of emotion, $F(5, 180) = 25.63$, $p < .001$, $\eta_p^2 = .42$, $\varepsilon = .37$. Pairwise comparisons revealed that participants reported higher levels of disgust after listening to the disgust sounds, compared with all other stimulus blocks (all *p*s $< .001$). Scores for eight participants' AU 9/10 activity were omitted from the RM analysis of facial actions because one or both of these action units were obscured in at least one of the five stimulus blocks (although none in the disgust block). An RM-ANOVA was carried out with the remaining 29 participants. The analysis revealed a main effect of emotion, $F(4, 112) = 11.55$, $p < .001$, $\eta_p^2 = .29$, $\varepsilon = .70$. In accordance with the hypotheses, pairwise comparisons revealed that participants grimaced more frequently in response to disgust stimuli compared with all other stimulus blocks (all *p*s $< .003$). Within the block of disgust sounds, AU 9/10 frequency showed a trend toward a positive correlation with self-reported disgust ($r = .29$, $n = 37$, $p = .09$).

Happiness and AU 12 (lip corner puller). The RM-ANOVA for happiness self-reports revealed a main effect of emotion, $F(5, 180) = 16.22$, $p < .001$, $\eta_p^2 = .31$, $\varepsilon = .55$. Pairwise comparisons revealed that participants reported higher levels of happiness after listening to laughtercompared with all other emotion blocks (all *p*s $< .013$). Seven participants' AU 12 frequency scores were omitted from the RM analysis of facial actions because this action unit was obscured in at least one of the five stimulus blocks (two in the happiness stimulus block). An RM-ANOVA was thus carried out with the remaining 30 participants. The analysis revealed a main effect of emotion stimulus block, $F(4, 116) = 16.01$, $p < .001$, $\eta_p^2 = .36$, $\varepsilon = .68$. Pairwise comparisons revealed that, as expected, participants smiled more frequently to sounds of laughter compared with all other stimulus blocks (all *p*s $< .001$). Within the block of happiness sounds, AU 12 frequency was significantly correlated with self-reported happiness ($r = .36$, $n = 35$, $p = .03$).

Sadness and AU 15 (lip corner depressor). The RM-ANOVA for reported sadness showed a main effect of emotion, $F(5, 180) = 9.08$, $p < .001$, $\eta_p^2 = .20$, $\varepsilon = .43$. Pairwise comparisons revealed that participants reported higher levels of sadness after listening to crying compared with all other emotion

[6] During the postexperimental debriefing, participants were probed as to their suspicions regarding the purpose of the study. Roughly half of participants indicated a suspicion that the sound clips were intended to influence their own emotions (56%). We then compared these individuals with those who indicated no such suspicion in a series of univariate ANOVAs that examined emotion self-reports and facial actions in the concordant sound blocks (e.g., reports of disgust and AU 9/10 in the disgust block). No significant differences were noted for anger self-reports, $F(1, 35) = 1.38$, $p = .25$, or AU 4, $F(1, 34) = 0.13$, $p = .72$; disgust, $F(1, 35) = 0.71$, $p = .41$, or AUs 9/10, $F(1, 35) = 0.04$, $p = .85$; happiness, $F(1, 35) = 1.03$, $p = .32$ or AU 12, $F(1, 33) = 0.80$, $p = .38$; sadness, $F(1, 35) = 0.11$, $p = .74$, or AU 15, $F(1, 32) = 0.45$, $p = .51$. Thus, suspicions about the purposes of the experiment did not seem to influence participants' responses in a meaningful way.

blocks ($ps < .009$). Seven participants' AU 15 frequency scores were omitted from the RM analysis of facial actions because this action unit was obscured in at least one of the five stimulus blocks (three in the sadness stimulus block). An RM-ANOVA was thus carried out with the remaining 30 participants. The analysis revealed a main effect of emotion stimulus block, $F(4, 116) = 3.54$, $p = .03$, $\eta_p^2 = .11$, $\varepsilon = .61$. Pairwise comparisons revealed that participants enacted this behavior more frequently in response to sounds of crying compared with the neutral ($p = .01$) and anger ($p = .03$) blocks. There were no significant differences compared with the disgust block ($p = .35$) and only a trend toward a difference with the happiness block ($p = .07$). Within the block of sadness sounds, AU 15 frequency was not significantly correlated with self-reported sadness ($r = -.15$, $n = 34$, $p = .39$).

Discussion

In Study 2, we examined whether hearing emotion vocalizations activated related facial movements in absence of instructions for participants to actually vocalize. We also investigated whether the sounds affected listeners' self-reported emotions, and whether significant correlations existed between the predicted patterns of facial and subjective responses. Our hypotheses were largely supported by the results.

Replicating the results of Study 1, most of the predicted facial patterns were observed again, supporting Hypothesis 1 and countering the possibility that these behaviors were solely a function of an overt goal to reproduce the sounds. It is also clear from a comparison of listening scores in Studies 1 and 2, however, that the frequencies of corresponding actions were lower in Study 2. The higher scores in Study 1 could be interpreted as participants' more active simulation processes in advance of reproducing the sounds.

Some overlaps were also apparent in the AUs observed between different stimulus blocks. For example, no significant differences in AU 15 activity were observed between the sadness block, where this activity was predicted to be highest, and the disgust block, for which no predictions were made. This observation is in line with the facial prototypes reported by Ekman and Friesen (1978), however, which specify that while AU 15 is present in the majority of prototypical sadness configurations, it is also present to some extent in the prototypes listed for disgust. Thus, AU 15 cannot be considered a facial action that is completely unique to sadness. The equivalent AU 4 frequency between the anger and disgust stimuli was further noteworthy, as this also occurred in the Study 1 vocalizing task. There are morphological similarities between anger and disgust faces (Ekman et al., 1978; Rosenberg & Ekman, 1995); AU 4 and AU 9 muscles, in particular, are connected to one another. Strong AU 9 activity can thus also produce a lowering of the inner eyebrows. A final finding concerning overlapping facial activity was the pattern for AU 4, which again was elevated for all negative emotions, suggesting more general connections with negative valence.

We expected that nonverbal vocalizations of discrete emotions would activate listeners' convergent, subjective emotional states (Hypothesis 4) beyond the more general valence and activation effects demonstrated in prior research (e.g., Bradley & Lang, 2000; Dimberg, 1990; Verona et al., 2004). This hypothesis was supported for each of the discrete emotion vocalizations; anger vocalizations evoked stronger feelings of irritation in listeners than other sounds, disgust sounds evoked stronger disgust, and so on. These results further specify the pattern of valence and activation ratings reported across multiple studies of facial and vocal expressions. Relatively high scores of self-reported disgust in the anger block were also present, as were elevated levels of self-reported irritation in the disgust block. These "bleed-over" effects have previously been observed following facial feedback manipulations (e.g., Duclos et al., 1989; Flack, 2006), and findings from other studies have suggested that these two emotions often co-occur (Fischer & Roseman, 2007). Thus, the stimuli appeared to activate both concordant emotions and, to some extent, other closely related states.

Taken together, the first two studies support the notion that processing nonverbal emotion vocalizations involves simulations of both facial behaviors and subjective states. Evidence for a connection between these two responses, in terms of the pattern of correlations, was somewhat mixed. Fairly substantial associations were found between self-reports and the facial actions targeted for happiness and anger (although not as strongly as those observed for other forms of positive and negative auditory stimuli, cf. Bradley & Lang, 2000). This relation was not as straightforward for disgust, which showed only a trend, nor for sadness, which showed no indication of a positive association. One plausible interpretation of these results concerns the prevalence of the action units within the listed facial prototypes for their respective emotions (Ekman, 2007; Ekman et al., 2002). While AUs 12 and 4 are considered to be actions critical to the respective configurations of happiness and anger, there is somewhat more variability in the prototypes for the other two emotions. Specifically, the fact that *either* AU 9 or AU 10 is represented in the possible prototypical configurations for disgust, but both were conjunctively coded in this research, could have weakened the overall correlational result. Further, in contrast to the other actions studied, AU 15 is not consistently identified in every prototype for sadness and thus may be more subject to individual differences. While AU 15 is certainly a characteristic component of sadness, it is also not considered critical for generating subjective feelings through facial feedback (Duclos et al., 1989; Ekman, 2007; Flack, 2006).

In general, the correlation patterns noted in this study suggest that facial actions considered more central to the prototypical expression of certain emotions also show stronger associations with related subjective feelings, whereas other combinations are more independent from self-reports (see also Hess & Blairy, 2001). However, these correlations do not clarify whether these facial behaviors actually influenced how listeners processed or responded to the vocalizations, as would be predicted by an embodiment perspective. We examined these issues in two subsequent studies (Studies 3 and 4); in both of these studies, we used methods to unobtrusively disrupt participants' ability to produce matching facial expressions (e.g., Niedenthal et al., 2001, 2009; Strack et al., 1988).

Study 3

The first two studies provided evidence that individuals spontaneously adopt congruent facial expressions when exposed to nonverbal emotion vocalizations, and that these responses are linked to individuals' use of similar facial muscles in their own vocalizing. A case for interpreting these findings in terms of cross-channel simulation would be further bolstered by demonstrating that these matching facial expressions actually play a role in listeners' processing of those sounds. Thus, in Study 3, we examined whether participants' ability to match their faces to an initial emotion sound (e.g., smiling when hearing laughter) facilitated a focus on that first stimulus and interfered with the processing of subsequently emerging sounds (e.g., crying) that were incongruent with the facial behavior.

In formulating the predictions and procedure for this experiment, we drew inspiration from two lines of prior literature. The first line concerns facilitation and interference effects, respectively, that occur when individuals are presented with an emotion-congruent or incongruent facial-vocal stimulus pairing and are then asked to label the emotion conveyed either by the facial or vocal stimulus. Under such paradigms, it has been repeatedly found that audiovisual combinations conveying the same emotion are labeled more quickly and accurately, while pairings conveying different emotions impair speed and accuracy (e.g., De Gelder et al. 2002; De Gelder & Vroomen, 2000; Dolan et al., 2001; Massaro & Egan, 1996).

The second line of research concerns studies showing that inhibiting participants' own facial expressions limits the processing of visually presented emotional faces (Effron et al., 2006; Niedenthal et al., 2001; Oberman et al., 2007; Stel & Van Knippenberg, 2008). In one study (Niedenthal et al., 2001, Study 2), researchers showed participants films of a model's face as it "morphed" along a continuum between happiness and sadness. Respondents moved a sliding bar back and forth to identify the point at which they first detected the offset of the initial expression and the onset of the second. Facial imitation was inhibited for half of the sample. Respondents who could not continually adjust their own facial muscles as they moved the slider also detected the expressive change later on the continuum. In another study (Effron et al., 2006), participants were shown pictures of angry and happy facial expressions at different presentation lengths and were instructed to estimate the duration of the stimuli. Half of participants' facial responses were unimpaired, and these individuals tended to overestimate the duration of the presentation of the faces. Both these results offer evidence that interfering with participants' own facial expressions disrupted their ability to engage in deeper processing of the facial stimuli. Similarly, we expected that blocking participants' spontaneous facial simulations of vocal expressions would interfere with processing of the auditory stimulus.

We operationalized emotion processing in terms of the extent to which participants focused more strongly on an initial vocalization, even as it actually faded away and a subsequent, contrasting vocalization became more prominent. To test this prediction, we developed an auditory version of the procedure created by Niedenthal and colleagues (2001). In this novel task, we cross-faded recordings of laughing and crying produced by the same actor, so that one stimulus decreased in volume while the second increased in volume. This created a period of overlap between the two sounds. Participants' task was to identify the point at which the predominant emotion shifted from the first sound to the second. During this task, we inhibited spontaneous facial responses for half of the sample.

Despite certain similarities between this task and the morphing task of Niedenthal and colleagues, there are also important distinctions. The prior research explained the faster detection of facial expression change among participants with uninhibited faces in terms of their ability to microadjust their own facial muscles as they moved the slider back and forth between the two emotions. In contrast, the time-locked and dynamically unfolding nature of our vocal stimuli did not permit participants this fine-tuned control over the recordings. Allowing participants to "rewind" or slow down the recordings would fundamentally alter the acoustic features of the sounds. The vocalizations were instead presented in a "ballistic" fashion, playing at a fixed speed from beginning to end.

In light of these characteristics of our auditory task, we expected that participants who could match their faces to the initial vocalization would be slower to detect the point at which the second expression became dominant. We reasoned that the increased processing fluency created by facial matching of the initial vocalization would promote a selective focus on this first sound at the expense of the second, incongruent sound. Smiling when hearing laughter, for example, may lead participants to generate a richer and more meaningful representation of the sound, which interferes with processing of sounds incongruent with the ongoing simulation. As a result, people may be slowed in their detection of an emerging, facially incongruent crying vocalization. In contrast, listeners whose facial expressions are inhibited should not show this preferential focus. In short, we predicted that participants who could move their faces would detect the transition from laughing to crying, and vice-versa, more slowly than participants whose faces were inhibited from matching the initial sound.

Method

Participants. A sample of 53 female undergraduates from a large Dutch university participated in this study. Three participants were excluded because they did not correctly follow the directions for responding to the sounds. Five additional participants were excluded, all from the facial inhibition condition: Two did not comply completely with the facial inhibition manipulation, and another three correctly guessed the purpose of this manipulation in the debriefing. The age of the remaining 45 participants (25 in the uninhibited condition, 20 in the inhibited condition) ranged from 18 to 32 years ($M = 20.51$, $SD = 2.81$). All participants received either credit toward their psychology courses or 7 euros as compensation.

Stimuli and apparatus. Stimuli consisted of 10 audio recordings of laughter and 10 audio recordings of crying. All sound samples were 11,500 ms in length. Stimuli were produced by the same 10 actors (five men and five women), with each actor contributing one of each type of recording. These recordings included extended versions of the same laughter and crying stimuli used in Studies 1 and 2. Additional stimuli were utilized from existing sets (Hawk et al., 2009), in order to acquire a more extensive set of sounds for use in repeated trials. The sounds of the same actor were combined into one recording, which produced two different versions. In one version, the volumes of these stimuli were adjusted so that initial laughing sounds gradually faded away and the crying sounds gradually became more prominent. In a second version, this order was reversed. Thus, the final stimulus set consisted of 20 recordings (of 10 men and 10 women), with half of the stimuli transitioning from laughter to crying and the other half transitioning from crying to laughter. Figure 2 displays the time course of these mixed recordings. All stimuli began with 500 ms of silence to allow for computer buffering. The first sound then began at full volume and gradually diminished. The second sound became audible (at a low volume) 3,000 ms after the first sound and gradually became louder. The two sounds were equal in volume at the midpoint of the recording, and the first sound ceased being audible at 3,000 ms before the end of the recording. As in the earlier studies, all stimuli were presented via computer through an audio headset.

Measures. The main variable of interest was participants' response latency in accurately detecting the shift from the first emotion to the second. We defined accurate responses as any that occurred after the midpoint between the two sounds (see Figure 2). To obtain participants' detection speeds, we calculated the number of milliseconds that occurred after this midpoint, but before they logged their responses. Separate mean reaction time scores were then computed for the two types of stimuli (laughter-to-crying and crying-to-laughter). Only accurate responses were included in these calculations, which represented 92.89% of all responses. The percentage of omitted responses did not differ between the laughter-to-crying (7.33%) and crying-to-laughter (6.89%) stimuli. Participants also completed a version of the experimental stress questionnaire for the measure of subjective emotion. The primary items of interest were self-reported cheerfulness and sadness, scored on a 7-point scale (1 = *not at all*, 7 = *very strongly*). We also included the item *relaxed* to index participants' self-reported physiological arousal and two general mood items—one positively worded and the other negatively worded. The negative item was recoded to index positive mood, and the two items were then averaged. We constructed similar mean scores for the perceived difficulty of the task, measured on a 7-point scale with the items "I found this task to be very difficult" (1 = *disagree*, 7 = *agree*) and "I found this task to be very easy" (reversed).

Procedure. Upon providing informed consent, participants were escorted to individual cubicles and instructed to put on the headphones. The experiment ostensibly concerned divided attention, focusing on how combining a physical and a perceptual task altered performance. Participants were told that they would hear a series of recordings, each of which contained both laughing and crying sounds. The nature of the stimuli was further explained to them via a graphical depiction similar to Figure 2 (but without the time indices; participants were never explicitly told the length of the stimuli). Participants were instructed to push the space bar on the computer keyboard with their dominant hand, precisely at the moment that they perceived the shift from one emotion to the next. Although prior studies have demonstrated that results from similar procedures involving faces are not affected by instructions to detect onset versus offset of expression (Niedenthal et al., 2001), we avoided this potential issue in the present research by providing all instructions in terms of "change,"without explicitly mentioning onset or offset. Participants practiced this task with four recordings not included in the actual experiment (two laughing-to-crying and two crying-to-laughing stimuli, randomly presented). Participants were allowed to repeat this practice as many times as they wished.

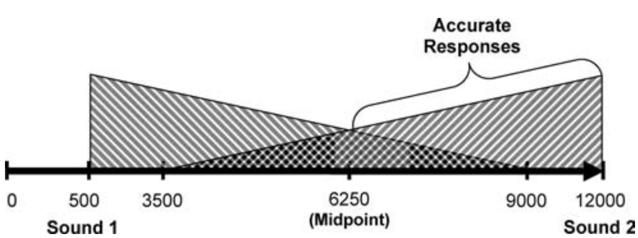

Figure 2. Graphical depiction of the auditory cross-faded stimuli in Study 3.

When participants indicated that they understood this procedure, the experimenter explained their physical task. In the uninhibited condition, participants were instructed to hold a pen in their nondominant hand and squeeze with a gentle but steady pressure during the response trials (see Figure 3a). In the inhibited condition, participants were instructed to hold the end of the pen in between their teeth and also to wrap their lips gently around the pen (see Figure 3b; Strack et al., 1988; see also Foroni & Semin, 2011). Thus, we ensured that all participants were exposed to a simple physical task requiring a minimal amount of concentration and muscular tension. Participants were told they could keep the pen afterward. Participants then engaged in the 20 trials. Compliance with the respective pen tasks was monitored via a visible, wall-mounted video camera. Following the auditory trials, participants completed the experimental stress measure and were probed for suspicion regarding the nature of the pen task.

Results

Checks. Participants in the two experimental conditions reported the response task to be equally difficult ($M_{\text{uninhibit}}$ = 4.20, SD = 1.52; M_{inhibit} = 3.85, SD = 1.33), $F(1, 43) = 0.66$, $p = .42$. The two conditions also showed no differences in the emotions reported after the reaction time task; positive mood ($M_{\text{uninhibit}}$ = 4.74, SD = 1.23; M_{inhibit} = 4.47, SD = 1.21), $F(1, 43) = 0.52$, $p = .48$; relaxation ($M_{\text{uninhibit}}$ = 3.72, SD = 1.72; M_{inhibit} = 4.15, SD = 1.53), $F(1, 43) = 0.76$, $p = .39$; cheerfulness ($M_{\text{uninhibit}}$ = 3.92, SD = 1.44; M_{inhibit} = 3.40, SD = 1.23), $F(1, 43) = 1.64$, $p = .21$; sadness ($M_{\text{uninhibit}}$ = 2.76, SD = 1.48; M_{inhibit} = 3.10, SD = 1.33), $F(1, 43) = 0.64$, $p = .43$. Thus, participants in the two conditions reported similar subjective experiences of emotion and task difficulty following the experimental task.

Response latencies. We conducted a 2 (stimulus: laughter-to-crying vs. crying-to-laughter) × 2 (inhibition: uninhibited vs. inhibited) mixed-model ANOVA, with stimulus type as a within-subjects factor and inhibition task as a between-subjects factor. In line with predictions, a main effect of experimental condition was observed, $F(1, 43) = 4.47$, $p = .04$, $\eta_p^2 = .09$. As expected, uninhibited participants, whose faces were allowed to move freely (M = 1,670.72 ms, SD = 520.40), were slower to respond than inhibited participants (M = 1,399.00 ms, SD = 270.46). A main effect of stimulus type was also observed, $F(1, 43) = 16.62$, $p < .001$, $\eta_p^2 = .28$, in which the responses to the crying-to-laughter stimuli (M = 1,419.71 ms, SD = 451.88) were faster than responses to the laughter-to-crying stimuli (M = 1,680.19 ms, SD = 527.14). No interaction existed, $F(1, 43) = 2.36$, $p = .13$. Thus, participants whose faces were inhibited from matching the first sound played in each recording were quicker to detect the point at which the second sound became dominant over the first.

We then performed similar analyses with various self-report measures (positive mood, relaxation, cheerfulness, and sadness) entered as covariates. Separate analyses of covariance

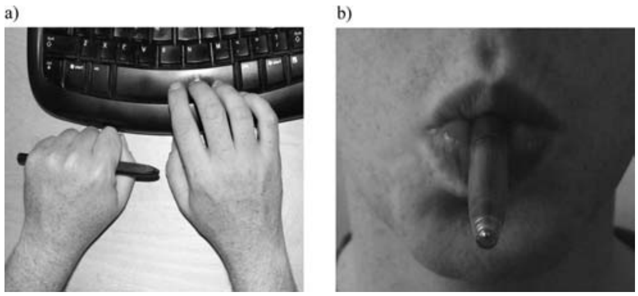

Figure 3. Study 3 control (a) and facial inhibition (b) manipulations. The Study 3 facial inhibition task was inspired by a similar task reported in Strack et al. (1988)

(ANCOVAs) were conducted for each subjective measure. No main effects existed for any of these covariates (all *F*s $\leq$ 2.40, all *p*s $\geq$ .13). Most important, the main effect of the facial manipulation remained for all ANCOVAs (all *F*s $\geq$ 4.03, all *p*s $<$ .05). No significant interactions existed between the covariates and the other factors. Thus, the effects of the inhibition manipulation appeared to be independent of participants' subjective reports.

Finally, we conducted a similar 2 $\times$ 2 mixed-model ANOVA on accuracy rates to ensure that the shorter response latencies found for the inhibited condition did not also come at the expense of accurate responding With consideration to the 20 stimuli used in the experiment, this test revealed no significant differences in the number of correct responses between the inhibited ($M_{\text{total}} = 18.40$, $SD = 1.90$; $M_{\text{laugh–cry}} = 9.15$, $SD = 1.14$; $M_{\text{cry–laugh}} = 9.25$, $SD = 0.97$) and uninhibited conditions ($M_{\text{total}} = 18.72$, $SD = 1.62$; $M_{\text{laugh-cry}} = 9.36$, $SD = 1.22$; $M_{\text{cry–laugh}} = 9.36$, $SD = 0.78$), $F(1, 43) = 0.37$, $p = .55$. Additionally, no differences were found between the laughter-to-crying stimuli ($M = 9.27$, $SD = 1.18$) and the crying-to-laughter stimuli ($M = 9.31$, $SD = 0.85$), $F(1, 43) = 0.09$, $p = .76$, nor was there an interaction. Thus, the differences between conditions did not seem to result from a speed–accuracy tradeoff.

Discussion

In Study 3, we presented participants with an initial emotion sound that gradually transitioned to a categorically different sound (either from laughing to crying, or the reverse). Supporting Hypothesis 6, participants who could spontaneously match their faces to the initial emotion vocalization were slower to respond to the shift between emotions, as compared with participants whose facial muscles were inhibited. We interpreted this finding as further support for a simulation account of the cross-channel emotion matching observed in Studies 1 and 2. Specifically, the ability to adopt a congruent facial expression in response to an emotion vocalization facilitated a stronger focus on the first sound at the expense of an emerging, facially incongruent vocalization. Conversely, those who could not match their faces to the initial sound were faster in detecting the objective point of change. To our knowledge, this is the first evidence that congruent facial behavior promotes the processing of emotional expressions communicated through a different nonverbal channel.

It is important to note that this finding underscores the notion that facial simulations can enhance the processing of congruent social information. When individuals are presented with two contrasting emotion vocalizations, it stands to reason that the enhanced processing fluency fostered by spontaneous facial simulation of a first sound should also promote a stronger focus on that stimulus at the expense of the other, incongruent sound. While similar results have been demonstrated in examinations of the various effects of congruent versus incongruent facial-vocal stimulus pairs (e.g., De Gelder et al. 2002; De Gelder & Vroomen, 2000; Dolan et al., 2001; Hietanen et al, 2004; Massaro & Egan, 1996; Pell, 2005), this is the first study on cross-channel processing to actually involve the manipulation of observers' own bodily responses. Together with these prior studies, the current results suggest that the facial matching of others' vocal expressions promotes processing of congruent vocal stimuli and interferes with the processing of incongruent sounds.

Respondents across conditions were also faster to detect the change from crying to laughter than the reverse. One explanation for this result may be that laughter vocalizations were rated by Study 2 participants as higher in arousal than the crying sounds (see Footnote 2). Prior research has shown that facial expressions that communicate higher arousal also lead observers to overestimate their duration of presentation (Effron et al., 2006). It should also be noted that similar effects were observed in research concerning transitions between facial expressions of happiness and sadness (Niedenthal et al., 2001), suggesting that the effect is attributable to a quality of the expressions that exists independent of channel. Another possibility in this regard, however, concerns valence, for which there was also a substantial difference in ratings by Study 2 participants. Individuals show behavioral preference for pleasant sounds when they are perceived as approaching (in terms of increasing volume), as opposed to when they are withdrawing (in terms of decreasing volume; Tajadura-Jiménez, Väljamäe, Asutay, & Västfjäll, 2010). In the present study, an approaching pleasant stimulus (laughter) may have elicited faster responses than an approaching negative stimulus (crying), and/or the reverse effect could exist for receding sounds (see also Davis, Gross, & Ochsner, 2011). Further research should be conducted to consider these possibilities more fully, and to confirm whether the effect is indeed robust to different channels of emotion communication.

It is also noteworthy that facial inhibition did not diminish participants' subjective emotional responses. Although the mean scores for both subjective emotion and more general arousal and valence responses were generally higher in the uninhibited condition, no effects were significant. Covariate analyses seemed to further support that individuals' response latencies were independent of any relevant subjective responses. Similar results in prior research have been interpreted as evidence that the inhibition manipulation had a direct effect that was not further mediated by an emotional response (see Niedenthal et al., 2001, Study 2). This may suggest that the results were driven, at least in part, by simulation of facial motor behaviors instead of resulting from differential emotional reactions between conditions.

This is the first evidence that manipulating listeners' own facial responses can modulate their processing of emotion vocalizations, which supports our account of cross-channel simulation. The question of whether disrupting these spontaneous facial actions also has implications for emotional responding to the sounds is still an important one, however. Methodological aspects of this experiment, particularly the repeated switching between vocalizations and the single emotion measure at the end of the study, complicated the assessment of participants' more immediate emotional responses. Thus, this study was not ideal for addressing the question of whether interfering with participants' facial matching of emotion vocalizations also diminishes concordant subjective feelings. We examined this issue explicitly in Study 4, focusing on whether disrupting spontaneous facial responding to disgust vocalizations affected the extent to which listeners experienced a congruent subjective state.

Study 4

In a final study, participants heard disgust vocalizations, and half engaged in a pen-holding manipulation that interfered with disgust-related facial actions (cf. Niedenthal et al., 2009, Study 3). If our account of cross-channel simulation is correct, inhibiting such facial behavior may also disrupt the subjective experience of disgust (Hypothesis 7), whereas as a strict emotion "by-products" account would not suggest any particular role for the face in promoting emotional responding to expressions in another nonverbal channel.

Although the enhancing effects of adopting facial expressions have been shown for feelings of happiness, sadness, disgust, fear, and anger (e.g., Duclos et al., 1989; Flack, 2006; Larsen et al., 1992; Strack et al., 1988), the consequences of facial inhibition for subjective emotions have been most reliably demonstrated for positive states such as amusement (e.g., Foroni & Semin, 2009, 2011; Strack et al., 1988; but see Davis et al., 2009, 2010). In particular, we are not aware of research using an unobtrusive inhibition manipulation to examine discrete feelings of disgust (cf. Davis et al., 2010), making this emotion particularly interesting. We also focused on this emotion for methodological reasons; our pilot tests suggested that the manipulation chosen for interfering with the disgust-related AUs 9/10 (see Procedure) did not block other AUs to an equal extent. Thus, this manipulation would likely not have equal effects upon responses to other emotions presented in a within-participants design, and using different facial manipulations in a between-participants design could create methodological confounds. In summary, we examined the previously unstudied connection between facial simulation of disgust vocalizations and changes in associated subjective feelings. This was done under the guise of a memory and reaction time test, after which we measured participants' self-reported feelings of disgust.

Method

Participants. Participants were 48 undergraduate students (85.5% female) at a large Dutch university. From this initial sample, one participant was excluded for not following the pen instructions as they were given, and six were excluded because they suspected the goal of the facial inhibition manipulation. The remaining 41 participants were randomly assigned to either the control condition or the facial inhibition condition.

Stimuli and apparatus. The stimuli were the same neutral and disgusted sound clips used in Studies 1 and 2. Similar to Studies 1 and 2, the stimuli were controlled for volume and were again presented, via computer, through an audio headset.

Measures. We again used an adapted version of the experimental stress questionnaire for the measure of subjective emotion.

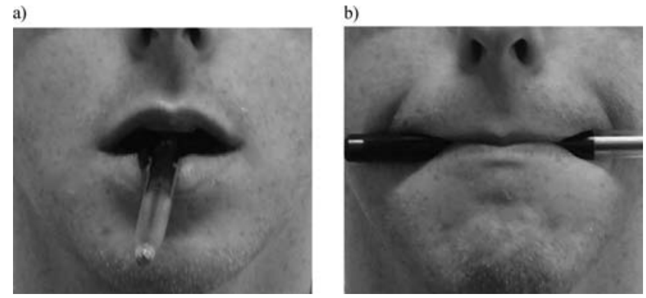

Figure 4. Study 4 control (a) and facial inhibition (b) manipulations. The Study 4 task was inspired by a similar manipulation reported in Niedenthal et al. (2001, 2009).

The primary item of concern for this experiment was self-reported *disgust*, scored on an 11-point scale from 0 (*not at all*) to 10 (*very strongly*). The list also included, among other items, the previously used terms *irritated*, *cheerful*, *sad*, and *amused*, as well as an item indexing general arousal (*relaxed*) and two items (*generally positive* and *generally negative* (reversed)) that were averaged to form a mean score of positive mood. After the experiment, participants also rated the general comfort of their pen-holding task on a scale from 1 (*not at all uncomfortable*) to 7 (*very uncomfortable*). To rule out alternative explanations, the experimenter asked the participants also to rate on 7-point scales (1 = *not at all*, 7 = *a great deal*) the extent to which they found the memory task difficult, the extent to which they were distracted from this task by the disgust sounds, and the extent to which they concentrated on the emotions communicated by the sound clips during the memory task.

Procedure. Upon providing informed consent, participants were escorted to individual cubicles and instructed to put on the headphones. The experimenter claimed to be doing a study on memory and the ability to concentrate on several things at one time. As part of this cover story, participants were told that they would see a series of numbers on the screen that would quickly disappear as a background sound would begin to play. The numbers would then reappear on the screen, but in some cases, one of the digits would be different (e.g., a 17 could change to a 37 or a 14). Participants' task was to indicate as quickly and accurately as possible, by means of a key press, whether the number had changed or stayed the same. To introduce the pen-holding task into the cover story, the experimenter explained that it was extremely important to the study that they mentally rehearsed the number while they listened to the background sound, but that it would damage the results if they rehearsed the number by either repeating it out loud or "mouthing" the number silently to themselves. The experimenter explained that in order to prevent these types of rehearsal, participants would be asked to hold a pen in their mouths.

Two sets of pen-hold instructions were provided, depending on the experimental condition. Because prior studies have connected expressions and experiences of disgust to bad tastes and oral irritation (e.g., Rozin, Lowery, & Ebert, 1994), we thought it wise to have participants in both conditions hold the same object with their mouths. Participants in the control condition thus held the end of the pen between their front teeth, but were told that they could keep their mouth relaxed (see Figure 4a). Participants in the inhibition condition were asked to hold the pen horizontally between both their teeth and lips, while lightly pressing their lips together (see Figure 4b). In this way, AU 9/10 muscles could move normally in one condition, but not in the other. Participants in both conditions were also instructed to keep their tongues underneath the pen to further "prevent repetition of the numbers," and also to avoid biting or pushing down in an uncomfortable way. The experimenter modeled how to hold the pen for participants and confirmed that they could do this correctly. Compliance with the pen task was further checked in postexperimental debriefing.

After the experimenter left the cubicle, participants began with the memory task. In each trial, a two-digit number appeared on the screen for 5 s, and the number was then replaced by a cross-fixation point that remained for an additional 5 s. During this time, participants heard the sound clips. The number then reappeared on the screen, and participants indicated via a key press whether the number had stayed the same or had changed. One digit in the number changed in 50% of the trials, and this was balanced equally between changes to the first or the second digit. There were 16 trials in total; the first four trials were identified as practice trials, in which participants heard only a short electronic beep. The next four trials contained the neutral vocalizations and were intended to habituate participants to hearing human voices before being exposed to the disgust sounds. The subsequent eight trials contained the disgust vocalizations (each sound played in two separate trials). Within the respective stimulus blocks, each vocalization was presented in a completely random order. Participants then completed postmeasures, including the emotions self-report scale, manipulation checks, and demographic data. Participants were allowed to remove the pens from their mouths when completing these measures. Upon completion of the experiment, participants were probed for their thoughts about the nature of the pen manipulation and their ideas about the purposes of the study.

Results

Checks. The rated discomfort of participants' respective pen-holding tasks was equivalent, $F(1, 39) = 0.14$, $p = .72$. Participants in the inhibition condition ($M = 4.95$, $SD = 1.35$) rated their pen-holding task to be equally uncomfortable as those in the control condition ($M = 5.14$, $SD = 1.86$). Participants in the inhibition condition also rated the memory task to be equally difficult, compared with participants in the control condition ($M_{\text{inhibit}} = 1.89$, $SD = 0.99$; $M_{\text{control}} = 2.00$, $SD = 1.27$), $F(1, 39) = 0.09$, $p = .77$. The groups also did not differ in the extent to which they reported being distracted by the sound clips ($M_{\text{inhibit}} = 2.95$, $SD = 1.75$; $M_{\text{control}} = 3.32$, $SD = 1.94$), $F(1, 39) = 0.41$, $p = .53$, nor in the extent to which they concentrated on the emotions communicated by the sounds ($M_{\text{inhibit}} = 2.47$, $SD = 2.01$; $M_{\text{control}} = 2.18$, $SD = 1.62$), $F(1, 39) = 0.27$, $p = .61$. The two experimental groups thus seemed to be equivalent with respect to variables that could potentially influence their self-reported emotions.

Self-reported emotion. Means and standard deviations of the emotion self-reports are shown in Table 3. Participants in the two conditions differed in their self-reported disgust, $F(1, 39) = 7.08$, $p = .01$, $\eta_p^2 = .15$. Participants in the control condition ($M = 3.00$, $SD = 2.71$), whose AU 9/10 muscles could move freely, reported stronger feelings of disgust after the experiment than did participants in the inhibition condition ($M = 1.16$, $SD = 1.43$), whose AU 9/10 movements were impaired by the pen task. Inhibiting AU 9/10 activity during the experiment thus decreased participants' self-reported feelings of disgust. Similar analyses performed on the other arousal, mood, and specific emotion items in the questionnaire yielded no additional significant effects (all ps $> .14$). Thus, the effect appeared to be restricted to the specific emotion for which the associated facial muscle was most inhibited by the manipulation.

Discussion

In Study 4, we examined whether interfering with facial responses to disgust vocalizations would diminish participants' concordant subjective feelings. We reasoned that if these facial expressions reflected only a motor activation with no affective connotation or were strictly by-products of directly induced general affect (e.g., Owren et al., 2005), then inhibiting participants' facial muscles would not diminish discrete self-reported feelings. Conversely, if inhibiting these facial muscles reduced the intensity of discrete self-reported emotions linked with the vocalization, this would suggest that such interference complicates pattern completion by disturbing the retrieval of relevant subjective states.

The data supported our expectations. In line with Hypothesis 7, participants in the inhibition condition reported significantly less disgust in comparison to participants whose task allowed for natural AU 9/10 movement. Other emotion reports did not differ between conditions, suggesting that the inhibition manipulation had rather specific effects instead of lowering positive/negative affect or emotional responding more generally (cf. Owren et al., 2005). To our knowledge, this is the first study to show that manipulating participants' facial matching of emotional expressions communicated through a different nonverbal channel also affects their related feelings. Additionally, this difference in subjective experience was independent of other aspects of the experiment, including the comfort of the pen tasks, concentration on the emotion communicated by the sounds, or the perceived difficulty of the cover task.

While previous work suggests that the within-channel matching of facial expression promotes the activation of congruent emo-

Table 3
Effects of Facial Inhibition on Subjective Emotional Reactions to Disgust Vocalizations (Study 4)

	Condition			
	Inhibited		Control	
Reaction	*M*	*SD*	*M*	*SD*
Relaxed	7.58_a	1.12	7.00_a	1.54
Positive mood	8.05_a	1.38	8.00_a	1.30
Irritated	1.05_a	1.62	1.91_a	2.33
Disgusted	1.16_a	1.43	3.00_b	2.71
Happy	7.26_a	1.70	7.14_a	1.32
Amused	6.53_a	1.47	5.91_a	2.20
Sad	1.42_a	1.71	0.77_a	1.07

Note. Different subscripts across columns denote significantly different values at $p < .05$.

tional states, this study extends literature on emotional embodiment by suggesting that similar effects occur through facial reenactments of emotion vocalizations. Additionally, we focused on the relatively neglected emotion of disgust, for which facial inhibition effects upon subjective feelings have not been demonstrated previously (but see Niedenthal et al., 2009, for evidence regarding effects of inhibition upon disgust-related semantic processing). The results of this experiment offer additional evidence that the facial matching of emotion vocalizations was neither mere motor response nor a by-product of directly induced affect. Instead, these facial responses appear to modulate the activation of concordant subjective responses to emotion sounds. These results are in line with the notion that cross-channel simulations of an observed expression function to complete a larger pattern of affective inferences.

General Discussion

In the present research, we adopted an embodied emotion perspective to examine whether observers' matching of another's emotional expressions is restricted to the same channel of nonverbal communication. We observed discrete facial and subjective reactions to nonverbal emotion vocalizations and gathered evidence that the observed facial responses can be considered *cross-channel simulations* of the auditory stimuli. In Study 1, hearing and producing such vocalizations elicited concordant facial behavior (Hypotheses 1 and 2), and the facial behaviors between these tasks generally showed positive correlations (Hypothesis 3), suggesting involvement of the same motor representations. We additionally showed in Studies 2 and 4 that vocalizations can activate discrete and concordant emotions in listeners that extend beyond general positive and negative responses (Hypothesis 4; cf. Bradley & Lang, 2000; Dimberg, 1990) and found expected correlations between facial action and subjective reports for at least two emotions (anger, happiness, and, to some extent, disgust; mixed support for Hypothesis 5). Finally, in Studies 3 and 4, disrupting facial matching of emotion sounds diminished both selective focus on congruent vocalizations (Hypothesis 6) and the activation of concordant emotions (Hypothesis 7). The results suggest that spontaneous facial matching facilitates affective processing and responding to vocalizations.

Theoretical Contribution and Implications

Embodied emotion accounts. Embodiment theories propose that emotion information is processed through partial simulations of perceptual, motor, and affective experiences (e.g., Barsalou et al., 2003; Niedenthal, 2007). Prior studies have shown discrete matching of facial and vocal signals within the respective nonverbal channels, but we demonstrated that exposure to emotion messages communicated through one channel (the voice) may also prompt relevant actions in another (the face). Thus, nonverbal emotion matching need not be specific to the expressive channel in which an emotion message is initially communicated. This suggests flexibility in the activation of the motoric and affective systems involved in emotion understanding and interpersonal emotion transfer (e.g., Hatfield, Cacioppo, & Rapson, 1992, 1994; Hoffman, 1984, 2008; Preston & De Waal, 2002). Earlier studies showed that vocal stimuli stimulate related motor activity at the neural level (e.g., Arnott et al., 2009), but Studies 3 and 4 implicate cross-channel simulation in how listeners actually process and respond to others' expressions. This cross-channel simulation may have adaptive value; the attention-eliciting and on/off nature of vocalization may not be as advantageous for facilitating online processing, compared with the relatively covert and analog facial channel. Our results elaborate upon the adaptive nature of pattern completion, which is a central aspect of embodiment theories (e.g., Barsalou et al., 2003). Further, apart from neuroimaging studies (e.g., Carr et al., 2003; Leslie et al., 2004; Van der Gaag et al., 2007), there has been little research into parallels between expressing an emotion and encountering another's similar expression. We interpret the correlations between facial actions during vocal processing and vocal production in Study 1 as evidence that the two activities engage the motor and affective systems in similar ways.

We also offer novel results on the extent to which vocalizations of emotions result in listeners' discrete emotional responding. Many studies have examined facial and emotional reactions to auditory stimuli that cannot be interpreted beyond general valence and arousal effects (e.g., Bradley & Lang, 2000; Dimberg, 1990; Hietanen et al., 1998; Magnée et al., 2007; Neumann & Strack, 2000; Verona et al., 2004). Our results suggest that vocalizations can also activate more emotion-specific patterns (Studies 1 and 2). Further, interfering with emotion-specific facial responses diminishes discrete subjective responses, while leaving more general affective reactions and unrelated emotional states unaffected (Study 4).

On the other hand, frequencies of AU 4 activity in Studies 1 and 2 revealed an underlying valence component, as this action was more frequent across negative emotion stimuli than neutral or positive stimuli. Participants' self-reports of each negative emotion also tended to be higher following the negative emotion sounds. Thus, while we demonstrated fairly discrete facial responses, they may be at least partially founded on valence (e.g., Barrett & Russell, 1999; Russell & Barrett, 1999). For AU 4, in particular, elevated scores across negative stimuli suggest that researchers utilizing FACS or facial EMG should be cautious in assuming that AU 4 reflects any specific emotion.

Strengths and limitations. There are limitations to this research that should be considered. First and foremost, the results do not establish a stable causal order between the observed cross-channel facial responses and participants' subjective emotions. As suggested in other research implicating embodiment processes (e.g., Davis et al., 2009, 2010; Effron et al., 2006), facial inhibition (i.e., Studies 3 and 4) could attenuate direct or appraisal-mediated induction of emotion. Other research suggests the opposite causal direction, as activating emotional states impairs mimicry of incompatible facial expressions (e.g., Moody, McIntosh, Mann, & Weisser, 2007; Niedenthal et al., 2001), and still other literature implicates parallel activation (e.g., Barsalou, 1999; Blairy et al., 1999; Hess & Blairy, 2001; Oosterwijk et al., 2009) that may also involve bidirectional links (Van der Gaag et al. 2007). Even when observing facial mimicry of subliminally presented faces, Dimberg and colleagues (2000) acknowledged the possibility of preliminary affective activation, further emphasizing the difficulty and complexity of this issue. Of greater importance for our research is that either interpretation suggests a role for facial expressions in how individuals process and respond to vocal stimuli. However, the finding that the facial inhibition effect in Study 3 was independent from a number of subjective reports is particularly noteworthy evidence that differences in processing were not solely an effect of emotional reactivity to the sounds (see Niedenthal et al., 2001, for a similar interpretation). Regardless of whether facial actions precede or follow emotional states, the results of Studies 3 and 4 are first evidence that interfering with facial matching disrupts natural engagement with emotion vocalizations.

Several methodological issues should also be mentioned. In earlier studies on facial responses to vocalizations (e.g., Hietanen et al., 1998; Magnée et al., 2007; Verona et al., 2004), obtrusive measurement (e.g., fEMG) was used, and no distinction was made between valenced and discrete responding. Our FACS coding of hidden camera footage allowed for an unobtrusive examination of a broader range of facial actions but came at a price of decreased sensitivity. The intensity scoring system of FACS allows for less fine-grained assessment of activity, compared with fEMG. Our choice to use a frequency-based measure is a common one among observational studies of nonverbal responding (e.g., Bavelas, Black, Lemery, & Mullett, 1986; Chartrand & Bargh, 1999; Provine, 1992). We regard fEMG as a better indicator of intensity, however, and such techniques should continue to be used in future studies.

Additionally, this is the first research using vocal stimuli to show activation of discrete facial and emotional responses. The within-participants presentation of rather explicit stimuli (cf. Wild et al., 2001) in Studies 1 and 2 could have highlighted the contrasts between emotions, as could the judgments that formed part of the cover story (cf., Hess, Philippot, & Blairy, 1998; Niedenthal et al., 2009). According to posthoc tests in Study 2, however, experimental demand did not affect self-reports, and no participants were aware of being filmed. Nevertheless, the artificial nature of the tasks makes it impossible to rule out demand effects completely, and between-participants designs may be useful in future studies.

We utilized acted vocal portrayals, in order to more easily maintain an equivalent duration and clarity for each emotional stimulus. While modeled expressions are by far the norm in research on emotion expression, spontaneous and natural vocalizations may not be as intense, prolonged, or differentiated as our stimuli (e.g., Owren et al., 2005), and their production may be influenced by selective social and environmental pressures (Krumhuber & Scherer, 2011; Scherer, 1994) in ways that we could not investigate in this artificial and isolated setting. Using more naturalistic stimuli represents an area for further elaboration.

The involvement of facial action when producing emotion vocalizations also means that facial responses in Studies 1 and 2 could represent a sequential process that began with facial action but did not reach its full (vocalized) potential (e.g., Scherer, 1994), due to active inhibition (Dijksterhuis & Bargh, 2001). The facial responses could also be a sign of vocal mimicry occurring in an abridged form, which had subsequent vocal feedback effects upon subjective states (e.g., Flack, 2006; Hatfield et al., 1995). We cannot think of why the inhibition tasks in Studies 3 and 4 would affect the vocal chords, but if disturbing the initiation of sequential or covert action patterns had subsequent consequences for subjective states, this would be fully in line with a simulation perspective (Barsalou et al., 2003; Niedenthal, 2007). Further demonstrating that *adopting* certain expressions intensifies cognitive or subjective responding, using paradigms such as the directed facial action task (e.g., Ekman, 2007; see also Duclos et al., 1989, and Flack, 2006) can make an additional case that congruent facial action facilitates emotion vocalization processing.

We used predominantly female participants, and it is relevant that females show heightened responsiveness when exposed to emotional facial expressions (e.g., Dimberg & Lundqvist, 1990; Wild et al., 2001). Other studies, however, have found no gender differences among those high in trait empathy (e.g., Sonnby-Borgström, 2002), suggesting a tendency for females to be generally more empathic than males (e.g., Doherty, Orimoto, Singelis, Hatfield, & Hebb, 1995). Future studies should include mixed-gender samples.

Implications for further research. We have largely interpreted our results in terms of the same processes used to explain automatic mimicry of emotional expressions (Barsalou et al., 2003; Dimberg et al., 2000; Neumann & Strack, 2000; Niedenthal, 2007). Examining the automaticity of cross-channel responses represents an important extension of the present research. The attention-eliciting nature of vocalizations (Guilford & Dawkins, 1991; Hawk et al., 2009; Owren et al., 2005) suggests that exposure to such expressions is typically quite conscious, however. This makes overt presentation a reasonable starting point for investigating effects on others' emotions. Studies examining similar cross-over effects between other channels, such as from face to voice, would be useful for demonstrating that there is a broader flexibility in emotion simulation (see, e.g., Magnée et al., 2007, for evidence of posture-to-face responses) or, alternatively, that the face plays an especially prominent role in online embodied emotional processing (see, e.g., Niedenthal et al., 2010). However, it is important to consider natural co-activation between channels. If vocal expressions depend more on facial action than the reverse, for example, then asymmetrical dependencies may influence the strength of certain effects.

It would be further interesting to examine a more diverse range of discrete emotional responding, such as fear responses to anger vocalizations (see, e.g., Esteves, Dimberg, & Öhman, 1994; Lundqvist & Dimberg, 1995; Moody et al., 2007), which would be predicted by affect induction and social-functional theories. The lack of social context or presence of additional stimuli likely smoothed the way for the transfer of a congruent emotion (e.g., Dijksterhuis & Bargh, 2001), but this could likely be altered by a psychological state of the observer (e.g., social anxiety; Fox, Russo, & Dutton, 2002) or the social relationships involved (e.g., Dimberg & Öhman, 1996; Lanzetta & Englis, 1989; Moody et al., 2007; Owren et al., 2005; Van Kleef, De Dreu, & Manstead, 2010). This is an important area for further investigation, as is whether matching nonverbal responses might still precede divergent reactions (e.g., Barsalou et al., 2003).

Our specific focus on whether the face is involved in the processing and interpersonal transfer of emotion communicated through a different nonverbal channel (the voice) precluded consideration of other interesting issues. For example, more information is needed on how these responses compare with those induced by nonhuman, context-embedded sounds (cf. Bradley & Lang, 2000; Dimberg, 1990). Future studies should examine the differences between responses to a wide variety of human and nonhuman acoustic stimuli. It is interesting that comparing pictures of smiling faces with similarly positive nonfacial stimuli still results in stronger fEMG responses to faces (Dimberg & Karlsson, 1997), which may suggest the additional activation of motor systems.

Similarly, our finding of associations between actions when hearing and repeating emotion vocalizations offers evidence implicating motor representations of the sounds (cf. Arnott et al., 2009).

Conclusion

Our research suggests that listening to vocalizations of emotion activates the same facial behaviors and subjective states involved in one's own production of similar sounds, and that cross-channel facial simulations of vocal stimuli are involved in processing these sounds and concordant emotional experiences. While our results might also generalize to nonemotional sounds, such as yawning (Arnott et al., 2009), we suggest that emotion expressions are special because they contain important and stable social messages (Fischer & Manstead, 2008; Hawk et al., 2009; Keltner & Haidt, 1999; Van Kleef, 2009). In addition to understanding and sharing others' feelings, showing others that we are affected by their emotions can be highly important to many forms of social interaction (e.g., Bavelas et al., 1986). Further, the subjective states activated by others' expressions may have social benefits of their own, beyond issues of nonverbal signaling. Actually feeling pale reflections of others' emotions may further strengthen interpersonal bonds, ensure adaptive reactions to emotionally charged situations, and increase our concern for others' welfare (Batson, Turk, Shaw, & Klein, 1995; Van Kleef et al., 2008). It stands to reason that these social functions of empathic responding are supported by a system that allows flexibility in the relations between how individuals initially express an emotion, on the one hand, and how they represent that state and show their solidarity with the expresser, on the other hand. By "facing the noise," we can both signal our understanding of others' feelings and share their emotions more intensely.

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