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# Babies in Traffic: Infant Vocalizations and Listener Sex Modulate Auditory Motion Perception

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Infant vocalizations and "looming sounds" are classes of environmental stimuli that are critically important to survival but can have dramatically different emotional valences. Here, we simultaneously presented listeners with a stationary infant vocalization and a 3D virtual looming tone for which listeners made auditory time-to-arrival judgments. Negatively valenced infant cries produced more cautious (anticipatory) estimates of auditory arrival time of the tone over a no-vocalization control. Positively valenced laughs had the opposite effect, and across all conditions, men showed smaller anticipatory biases than women. In Experiment 2, vocalization-matched vocoded noise stimuli did not influence concurrent auditory time-to-arrival estimates compared with a control condition. In Experiment 3, listeners estimated the egocentric distance of a looming tone that stopped before arriving. For distant stopping points, women estimated the stopping point as closer when the tone was presented with an infant cry than when it was presented with a laugh. For near stopping points, women showed no differential effect of vocalization type. Men did not show differential effects of vocalization type at either distance. Our results support the idea that both the sex of the listener and the emotional valence of infant vocalizations can influence auditory motion perception and can modulate motor responses to other behaviorally relevant environmental sounds. We also find support for previous work that shows sex differences in emotion processing are diminished under conditions of higher stress.

*Keywords:* auditory looming, emotion, infant vocalizations, sex differences

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When a sounding object approaches a listener, the auditory system goes on high alert. The looming sound elicits an array of physiological, behavioral, and affective responses that increase arousal, focus spatial attention, and prepare the motor system for action (Bach, Neuhoff, Perrig, & Seifritz, 2009; Bach et al., 2008; Seifritz et al., 2003; Seifritz et al., 2002). When asked to judge the arrival time of a looming sound, listeners typically perceive that the sound has arrived when it is still some distance away (Gordon & Rosenblum, 2005; Neuhoff, 1998, 2001; Neuhoff, Planisek, & Seifritz, 2009; Schiff & Oldak, 1990). Although technically a systematic "error," this anticipatory perceptual bias can provide slightly more time than expected to prepare for the actual arrival of the source and has been proposed as a behavioral adaptation that may provide listeners with a selective advantage (Haselton & Nettle, 2006; Neuhoff, 1998, 2001; Neuhoff et al., 2009).

Though looming sounds are processed with perceptual priority, they are by no means unique in alerting the auditory system. Infant vocalizations, for example, are also particularly salient environmental sounds. They capture parental attention and encourage care, which can increase the likelihood of survival and healthy attachment (Soltis, 2004). Like looming sounds, infant vocalizations also increase arousal, elicit affective responses, and prime the motor system for action (Giardino, Gonzalez, Steiner, & Fleming, 2008; Groh & Roisman, 2009; Montoya et al., 2012; Parsons, Young, Parsons, Stein, & Kringelbach, 2012; Seifritz et al., 2003).

The enhanced motor activation following the presentation of both looming sounds and infant vocalizations may be indicative of the environmental importance of these two classes of sounds. Both types of sounds can signal the need for an immediate motor response. Parsons et al. (2012) showed that compared with control sounds, listening to infant distress calls increased both speed and accuracy in a subsequent motor task. Similarly, Bach et al. (2008) showed that reaction times to auditory targets were significantly faster when the targets were preceded by looming (vs. receding) tones. Yet despite these similarities, there are likely differences in the putative goals of the motor activation that these sounds bring about. Looming sounds prime avoidance or interceptive behaviors. "Fight or flight" responses in this context can be beneficial (Bach et al., 2009). Alternatively, responses to infant vocalizations typically result in approach-oriented caregiving behavior (Montoya et al., 2012; Parsons et al., 2012; Zeskind & Collins, 1987).

There can also be differences in the valence of the emotional response that these sounds bring about in adult listeners. Looming sounds generally have a negative emotional valence (unless the sound source itself is positive; Bach et al., 2009; Tajadura-Jiménez, Valjamae, Asutay, & Vastfjall, 2010). They are perceived as more unpleasant, potent, arousing, intense, and more likely to signal a threat than are equivalent receding sounds (Bach et al.,

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2009). On the other hand, infant vocalizations can have either a negative or positive valence. Crying typically has a negative valence and can indicate distress, whereas laughter has a positive valence and can indicate contentment or joy (Riem et al., 2012; Swain, 2008).

There has been recent renewed interest in the effects of emotion on perception and cognition. Moreover, there is a large body of work that examines sex differences in the processing of emotional stimuli (for a review, see Kret & De Gelder, 2012). Though there are some conflicting findings in the area, most of the research suggests that women are better at recognizing emotional stimuli than men. However, a recent study suggests that this advantage may dissipate when emotional processing occurs under stressful conditions (DeDora, Carlson, & Mujica-Parodi, 2011). Regardless of sex, responses to emotional stimuli that are important for survival and well-being can be fundamentally different from responses to more mundane stimuli (for a review, see Brosch, Pourtois, & Sander, 2010). Some researchers have even suggested that "embodied emotion" provides a frame of reference in which all information processing takes place (Niedenthal, 2007; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005).

Given the potential importance of emotion in perceptual processing and the affect elicited by environmentally important sounds, we might expect that if exemplars from two classes of critically important sounds were heard simultaneously, affect could provide a means by which stationary infant vocalizations would influence auditory time-to-arrival judgments of an independent looming sound. In fact, analogous perceptual evidence for this position can be found in vision in which the emotional content of a looming object influences visual time-to-arrival estimates. Looming spiders and snakes, for example, are perceived to arrive sooner than looming butterflies and bunnies (Vagnoni, Lourenco, & Longo, 2012).

Here, we reasoned that differences in affect produced by infant laughs and cries might influence the perception of auditory time-to-arrival time of a looming tone in a similar manner. If negatively valenced infant cries increase the anticipatory looming bias (more cautious judgments), and positively valenced laughs decrease it relative to a no-vocalization control, then the emotional state induced in the listener is likely responsible for the effects. Alternatively, if infant laughs and cries both cause an increase in the anticipatory response to a looming tone compared with a condition in which no vocalization is present, then it would be difficult to conclude that the effect is due to the processing of emotion. A simpler explanation might be found in the attention-capturing nature of infant vocalizations.

Given previously demonstrated sex differences in emotional processing, we also hypothesized that laughs and cries might influence men and women differentially. Though the specifics are often of some debate, a considerable amount of work has shown a female advantage in processing emotion (Biele & Grabowska, 2006; Collignon et al., 2010; Donges, Kersting, & Suslow, 2012; Ethofer et al., 2007; Hampson, van Anders, & Mullin, 2006; Kret & De Gelder, 2012; Li, Yuan, & Lin, 2008). As such, we might expect an interaction between listener sex and the type of infant vocalization (laugh or cry) when listeners are tasked with predicting the arrival time of a concurrently sounding approaching tone.

In Experiment 1, we presented listeners with infant vocalizations while they judged the arrival time of a simultaneously heard looming tone. We found that infant cries produced negative affect and more cautious (anticipatory) estimates of arrival time over a no-vocalization control condition. Intensity-matched infant laughs had the opposite effect, producing positive affect and less cautious anticipatory judgments of the arrival time of the tone.

## Experiment 1

### Method

**Participants.** All 56 participants (28 female), aged 18 to 23 years, participated for course credit. They reported normal hearing and were not parents.

**Stimuli and apparatus.** A 3D virtual sound source with full spatial cues began 85 to 96m from the listener and approached at 15 m/s. The sound source was a 400-Hz square wave with a source intensity of 88 dB sound pressure level (SPL). The virtual listening point was situated 2 m from the straight-line trajectory of the source, with the listener facing perpendicular to the source's path (see Figure 1A). The source approached the listener from the side and passed in front of the listener. Half of the sounds approached from the left. Acoustic variables in the 3D simulation included absolute delay (to account for the speed of sound and the changing distance between the listener and the source), Doppler shift, atmospheric filtering, gain attenuation due to atmospheric spreading, ground reflection attenuation, and head-related transfer function from the MIT KEMAR data set (Gardner & Martin, 1995; see Neuhoff et al., 2009, for additional simulation details). The sounds

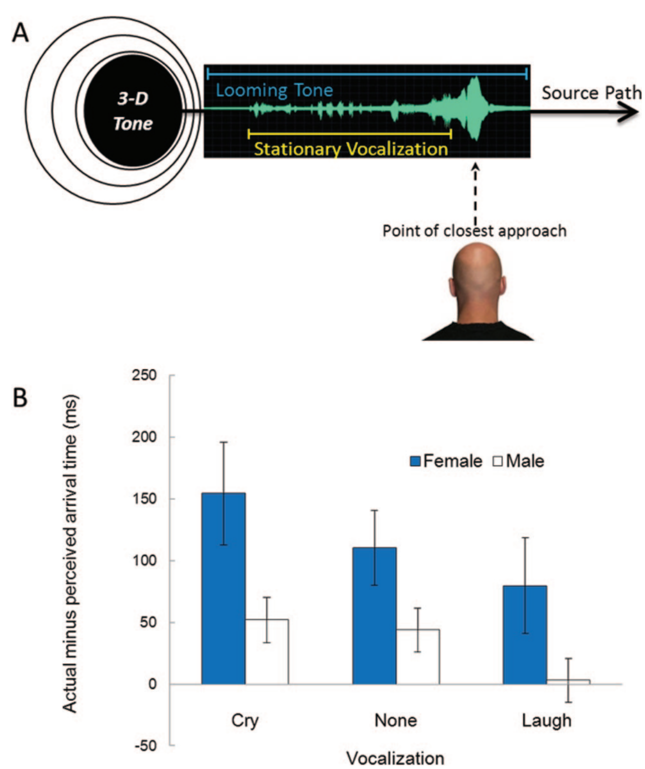


*Figure 1.* (A) Schematic diagram of stimulus presentation. (B) Mean anticipatory arrival time judgments by condition. Positive values indicate an anticipatory bias. Error bars represent ± 1 SEM.

were saved as wav files and presented by computer via Sennheiser HD Precision headphones.

Looming sounds were mixed at a signal-to-noise ratio of −13 dB with infant vocalizations from the International Affective Digitized Sounds database (Cry #261 and Laugh #110; Bradley & Lang, 1994). The vocalizations were matched in length by truncating the laugh to the duration of the cry (4.5 s) and then matched in total root mean square power by reducing the overall level of the laugh by 5.58 dB. We pretested the emotional content of the vocalizations with the Self-Assessment Manikin (Bradley & Lang, 1994). Thirty-two listeners (16 female) who were not involved in the subsequent experiments felt significantly more positive after hearing the laugh than the cry $t(31) = 13.94$, $p < .00001$, $d = 2.6$. There were no significant differences in arousal $t(31) = 1.35$, $p = .19$.

Experimental stimuli consisted of a stationary diotic vocalization that sounded during the approach of the 3D looming sound (see Figure 1A). Vocalizations began 5 s before the point of closest approach and ended 0.5 s prior to the point of closest approach. Control stimuli consisted of the looming tone without any vocalization. Sounds 1 through 3 in the online supplemental materials provide stimulus examples.

**Design and procedure.** Listeners heard six practice looming trials without vocalizations and were instructed to imagine that they were standing on the side of a road, facing it perpendicularly. They were told that they would hear a sound source approach and their task was to press a key when they heard the source pass directly in front of them. They were told to ignore any vocalizations and focus on the arrival time of the moving tone. At the beginning of each trial the words “Get Ready!” appeared for 1,500 ms, then disappeared when the sound stimulus began. Listeners heard six stimuli in each of the three vocalization conditions (laugh, cry, and no-vocalization) for a total of 18 completely randomized trials.

## Results and Discussion

Response times were averaged for each participant in each condition (see Figure 1B). The unit of analysis was the signed difference in milliseconds between the actual point of closest passage and the perceived point of closest passage. Positive scores indicated anticipatory responses (i.e., a looming bias), and negative scores indicated a response after the sound source had passed. We conducted a 2 (sex) × 3 (vocalization) mixed-design ANOVA. We found a main effect for vocalization indicating a greater anticipatory response to looming sounds in the presence of infant crying ($M = 103.2$ ms, $SD = 176.6$) than in the presence of infant laughing ($M = 41.5$ ms, $SD = 162.9$), $F(2, 108) = 12.82$, $p < .00001$, $\eta_p^2 = .19$. The mean anticipatory response in the no-vocalization control condition ($M = 77.0$ ms, $SD = 135.4$) fell between the means for the two vocalization conditions. We also found a main effect for sex indicating a greater anticipatory perception of arrival time for women than for men, $F(1, 54) = 4.42$, $p = .04$, $\eta_p^2 = .28$. The interaction between sex and vocalization type was not significant, $F(2, 108) = 1.14$, $p = .32$, $\eta_p^2 = .02$.

Our data in each condition exhibited a slight positive skew that ranged from 1.9 to 2.4 ($SE = .31$). Though ANOVA has been shown to be robust against violations of normality (Glass, Peckham, & Sanders, 1972; Harwell, Rubinstein, Hayes, & Olds 1992), we nonetheless conducted a nonparametric Friedman’s ANOVA by Ranks as a conservative measure. This analysis also showed a significant main effect, $\chi^2(2) = 25.32$, $p < .0001$. Bonferroni-corrected Friedman post hoc tests showed significant differences between cry and control, $\chi^2(1) = 5.79$, $p = .016$, laugh and control, $\chi^2(1) = 10.29$, $p = .001$, and laugh and cry conditions, $\chi^2(1) = 18.26$, $p = .00002$.

In Experiment 1, listeners exhibited the characteristic anticipatory bias in perceived arrival time, which would provide a margin of safety in perceiving the source’s approach. However, an infant’s laugh significantly reduced the anticipatory bias, resulting in less cautious judgments of arrival time. Conversely, an intensity-matched infant’s cry significantly increased the anticipatory bias, resulting in more cautious judgments of arrival time. The laugh and cry in Experiment 1 were matched for arousal and differed only on emotional valence. Previous work has shown that looming sounds themselves can create emotional responses, as measured by subsequent behavioral tasks, self-report, and psychophysiological measurements (Bach et al., 2008; Tajadura-Jiménez et al., 2010). Here we demonstrate the first evidence (to our knowledge) that the induction of different affective states in a listener can also influence judgments of auditory time-to-arrival.

Consistent with previous work, we found that females exhibited a greater anticipatory bias than males (Neuhoff et al., 2009). However, this sex difference may have more to do with sex differences in physical strength and the ability to deal with looming objects than with sex per se. In an embodied account of the perception of looming sounds, Neuhoff, Long, and Worthington, 2012 showed that the magnitude of the anticipatory auditory looming bias is correlated with strength and physical fitness (even when within-sex analyses were conducted). Thus, the average differences between men and women in strength and speed may in part account for the sex differences in perceived arrival time demonstrated here.

Previous work has also shown sex differences in response to infant vocalizations and differential responses to infant laughing and crying (Boukydis & Burgess, 1982; Sander, Frome, & Scheich, 2007; Seifritz et al., 2003). However, the sex difference shown in Experiment 1 is consistent only with previous sex differences in the perception of looming sounds that did not involve infant vocalizations (Neuhoff et al. 2009). Moreover, we found no interaction between sex and vocalization type. If indeed sex does interact with vocalization type, our method in Experiment 1 may not have been subtle enough to detect it. Looming sounds can be stressful stimuli, and stress has been shown to diminish sex differences in emotional processing. We return to this question in Experiment 3. In Experiment 2, we test a control for Experiment 1 and examine the effects of broadband noise that has been matched to the amplitude envelopes of the infant vocalizations used in Experiment 1.

# Experiment 2

Experiment 1 demonstrated the differential effects of positive and negative emotional infant vocalizations on the perception of a looming tone. Compared with a baseline condition in which no vocalization is present, laughs decrease the looming bias and cries increase it. However, the no-vocalization control condition leaves open the question of how other sounds might influence the perception of a looming complex tone. In Experiment 2, we presented listeners with noise-vocoded versions of the infant vocalizations while they judged the arrival time of a looming tone. These noise-laugh and noise-cry stimuli retained, respectively, the amplitude envelopes of the laugh and cry stimuli from Experiment 1. The only difference was that the spectra of the sounds in Experiment 2 were noise. Noise vocoding has been shown to diminish the emotional prosody of speech (Agrawal et al., 2012). Thus, in Experiment 2, we sought to employ stimuli equivalent to infant laughs and cries in level and amplitude envelope, but lacking the emotional quality provided by the spectral characteristics. That the positive and negative emotional vocalizations in Experiment 1 had opposite effects on time-to-arrival judgments is consistent with the idea that emotional valence is driving the effect. However, if the results of Experiment 1 were due, for example, to distraction or masking effects, then we might expect to find similar (perhaps even stronger) effects with broadband noise.

## Method

**Participants.** All 56 participants (28 female), aged 18 to 23 years, participated for course credit. They reported normal hearing and were not parents.

**Stimuli and apparatus.** The stimuli and apparatus were identical to those used in Experiment 1, with the exception of the infant vocalizations. We created one-channel white-noise vocoded versions of the vocalizations in Experiment 1 using the “vocoder” effect in the Audacity (version 1.3.13) digital editing program. This process yielded noise stimuli with amplitude envelopes identical to the laugh and cry stimuli used in Experiment 1 (see Figure 2). The noise stimuli were matched in level to the vocalizations from Experiment 1.

The 400-Hz looming square wave tones from Experiment 1 were mixed at a signal-to-noise ratio of $-13$ dB with the noise stimuli. Thus, experimental stimuli consisted of a stationary diotic vocoded noise stimulus that sounded during the approach of the 3D looming sound. As in Experiment 1, the vocoded noise began 5 s before the point of closest approach and ended 0.5 s prior to the point of closest approach. Control stimuli consisted of the looming tone without any vocalization. Sounds 4 through 6 in the online supplemental materials provide stimulus examples.

**Design and procedure.** The design and procedure were identical to those followed in Experiment 1.

## Results and Discussion

Response times were averaged for each participant in each condition. As in Experiment 1, the unit of analysis was the signed difference in milliseconds between the actual point of closest passage and the perceived point of closest passage. Positive scores indicated anticipatory responses (i.e., a looming bias), and negative scores indicated a response after the sound source had passed. The means and standard deviations for each condition are shown in Table 1. In contrast to Experiment 1, data in all conditions were normally distributed. We conducted a 2 (sex) × 3 (noise) mixed-design ANOVA with the Greenhouse-Geisser correction for violation of sphericity. We found that the two vocoded noise conditions (cry-noise: $M = 86.9$, $SD = 91.0$; laugh-noise: $M = 69.5$, $SD = 83.3$) did not significantly differ from the no-vocalization control condition ($M = 64.2$, $SD = 97.4$), nor did they differ from each other, $F$ (1.79, 108) 2.62, $p = .08$, $\eta_p^2 = .05$. The main effect for sex was not significant, $F(1, 54) = 1.87$, $p = .18$, $\eta_p^2 = .03$. The interaction between sex and vocalization type was also not significant, $F$ (1.79, 108) $= 1.65$, $p = .20$, $\eta_p^2 = .03$.

Taken together, the results of Experiments 1 and 2 suggest that positive and negative emotional states can differentially influence perceived auditory time-to-arrival. The differential effect of infant laughs and cries in Experiment 1 is not evident when the spectral information that conveys emotion is removed from the stimulus. These findings underscore the importance of emotion in perceptual processing (Niedenthal, 2007; Niedenthal et al., 2005).

Another difference between Experiments 1 and 2 was the distribution of response times. The data from Experiment 1 were positively skewed (for all three conditions, Kolmogorov–Smirnov tests were $p < .05$), indicating a number of participants with very large (cautious) anticipatory looming biases. However, the data from Experiment 2 were normally distributed in all conditions (all three Kolmogorov–Smirnov tests, $p > .10$). Between Experiments 1 and 2, the 95% confidence intervals for skew in the experimental conditions do not overlap. The positive skew in Experiment 1 represents very cautious responding on the part of a subset of the sample when emotional vocalizations are present. These distribu-

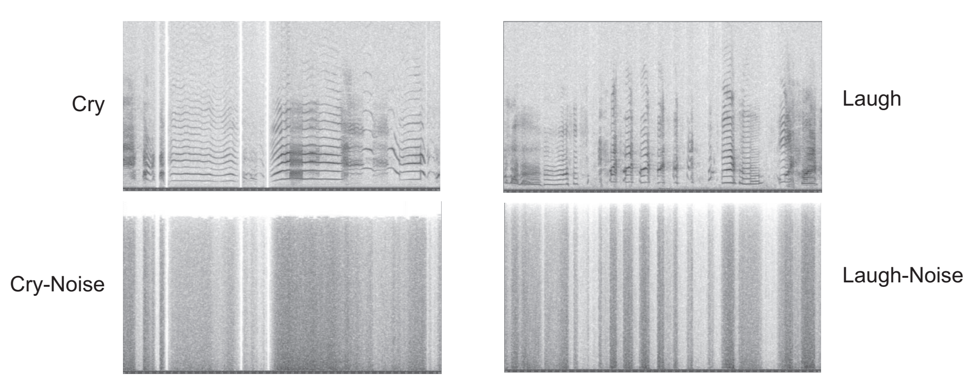


*Figure 2.* Spectrogram of infant laugh and cry stimuli used in Experiment 1 (top) and noise-vocoded laugh and cry stimuli used in Experiment 2 (bottom). All stimuli were 4.5 s in duration and sampled at 44.1 kHz. All were presented simultaneously with a 400-Hz virtual looming tone (see Method for details).

Table 1
*Mean Anticipatory Looming Bias in Milliseconds From Experiment 2 (With Standard Deviations in Parentheses)*

| | Vocalization condition | | |
|---|---|---|---|
| | Cry | Control | Laugh |
| Female ($n$ = 28) | 106.2 (86.7) | 84.3 (94.9) | 73.0 (87.6) |
| Male ($n$ = 28) | 67.6 (92.6) | 44.1 (97.4) | 66.2 (80.1) |

tional differences may indicate important individual differences that may interact with the saliency of emotional infant vocalizations and looming sounds. For example, in the context of novel emotional stimuli, previous work has identified a high-reactive phenotype in infants as young as 4 months that predicts responses to emotional stimuli nearly two decades later in adulthood (Schwartz et al., 2012).

The results of Experiment 2 suggest that, rather than distraction or masking effects, the emotional valences of the vocalizations in Experiment 1 are responsible for the perceived differences in auditory arrival time. Experiment 2 used broadband noise that was matched in level and amplitude envelopes to the vocalizations in Experiment 1. However, these sounds failed to produce effects that differed from a no-vocalization control condition.

## Experiment 3

Few studies have examined the interaction of listener sex with type of infant vocalization (laugh vs. cry). Seifritz et al. (2003) showed that men and women differ in their amygdala response to *both* infant laughs and cries. However, differential responding to different types of vocalizations (laughs vs. cries) occurred only between parents and nonparents. Independent of sex, parents showed stronger activation from crying, whereas nonparents showed stronger activation from laughing. This was a passive listening study without a behavioral component, so the results should be qualified somewhat with respect to implications for the current investigation. It should also be noted that listeners in Experiment 1 here were instructed to focus their attention on the looming tone rather than the emotional infant vocalization. Thus, it is possible that the diverted attention, the immediacy of a behavioral time-to-arrival judgment, and the increase in stress produced by a closely looming sound (Bach et al., 2009) obscured any potential interaction between sex and vocalization type.

In Experiment 1, we expected that the differential effects of emotional vocalizations on the perception of looming sounds would be greater for females than for males. Though the area is not without controversy, a good deal of work has shown a female advantage in the perception of emotion (Biele & Grabowska, 2006; Collignon et al., 2010; Donges et al., 2012; Ethofer et al., 2007; Hampson et al., 2006; Kret & De Gelder, 2012; Li et al., 2008). However, a recent study suggests that under conditions of stress, the female advantage in emotion processing disappears (DeDora et al., 2011). A quickly approaching sound is perceived as a stressful threat compared with equivalent control conditions (Bach et al., 2009). Thus, if we were to make our looming sounds less stressful, we might expect to find differential effects of laughs versus cries between men and women.

In Experiment 3, we examined the potential interaction of sex and vocalization type in a more subtle manner. We reduced the stressful nature of the looming tone by stopping it before it arrived. We presented listeners with looming sounds that were paired with infant vocalizations in a manner similar to that used in Experiment 1. However, in Experiment 3, the looming sounds stopped before reaching the listening point. After the sound stopped, listeners were asked to estimate the distance from the listening point to the source (in a method similar to that used by Neuhoff, Planisek, & Seifritz, 2009).

Close sources are louder than far sources, and louder sounds are more stressful (Burow, Day, & Campeau, 2005; Campeau, Dolan, Akil, & Watson, 2002). Moreover, 3D moving sounds that stop near a listener cause greater amygdala activation and greater skin conductance response than those that stop farther away. Subjectively, they are rated as more intense, arousing, and threatening (Bach et al., 2009). Thus, by manipulating stopping distance, we might be more likely to show an interaction between sex and vocalization type. As our laughs and cries were matched for arousal, any observed effects would likely be due to sex differences in the perception and evaluation of emotional valence.

### Method

**Participants.** All 20 participants (10 female), aged 18 to 23 years, participated for course credit. They reported normal hearing and were not parents.

**Stimuli and apparatus.** The looming sounds were adapted from those used in Experiment 1. A 3D virtual sound source with full spatial cues approached the listener and then stopped either at a near or far distance. In the far-approach condition, the source began 96 m from the listener and approached at 15 m/s. The source terminated its approach after 4.1 s at a virtual distance of 61.5 m from the point of closest passage. In the near-approach condition, the source began 63 m from the listener and terminated its approach after 4.1 s at a virtual distance of 1.5 m from the point of closest passage. The sound source was a 400-Hz square wave with a source intensity of 88 dB sound pressure level (SPL). The virtual listening point was situated 2 m from the straight-line trajectory of the source, with the listener facing perpendicular to the source's path (see Figure 1A). Half of the listeners heard sounds approach from the left. The other half heard sounds approach from the right. The sounds were saved as wav files and presented by computer via Sennheiser HD Precision headphones.

The laugh and cry vocalizations used in Experiment 1 were truncated to 2.1 s and matched in level. They were then mixed with the near-approach and far-approach looming tones. Because of the differences in distance from the listener, the far-approach sounds were lower in level than the near-approach sounds. The 400-Hz looming tones were mixed with the vocalizations at a signal-to-noise ratio of −12.5 dB for the far-approach sounds and −18 dB for the near-approach sounds. Thus, experimental stimuli consisted of a stationary 2.1-s vocalization that sounded during the 4.1-s approach of the 3D looming sound. The vocalizations began 1 s after the onset of the looming tone and ended 1 s prior to its termination. Sounds 7 through 10 in the online supplemental materials provide stimulus examples.

**Design and procedure.** Listeners were instructed to imagine that they were standing on the side of a road, facing it perpendicularly. They were told that they would hear a tone approach and then stop some distance from them and that their job was to estimate how far away the sound was when it stopped. After each stimulus was presented, a 100-mm computerized visual analog scale appeared on the computer screen. The left end of the scale was labeled "very near" and the right end was labeled "very far." Listeners were told to use the computer mouse to move a cursor to a spot on the scale that best described the location of the approaching sound when it stopped. There were no numbers or tick marks on the scale. We avoided using verbal estimates of distance because there are well-documented sex differences in the use of Euclidian metrics to describe distance (Dabbs et al., 1998; Galea & Kimura, 1993; MacFadden, Elias, & Saucier, 2003; Miller & Santoni, 1986; Ward, Newcombe, & Overton, 1986). Previous work has used this metric to examine sex differences in perception of looming sounds (Neuhoff, et al., 2009). Listeners were told to ignore any vocalizations and focus on the ending distance of the moving tone. Listeners first heard six practice trials at each distance without vocalizations, then 10 trials at each distance (near/far) and vocalization (laugh/cry), for a total of 40 trials.

## Results and Discussion

The unmarked numerical values for cursor position on the visual analogue scale indicated perceived distance range from 0 (*very near*) to 100 (*very far*). The 10 distance estimates for each participant in each of the four within-subjects conditions were averaged so that each participant contributed one data point to each condition. The data were analyzed with a 2 (distance) × 2 (vocalization type) × 2 (sex) mixed-design ANOVA. We found a main effect for distance indicating the participants perceived the terminal position of the near-approach stimuli ($M = 7.1$, $SD = 8.1$) as significantly closer than the far-approach stimuli ($M = 53.2$, $SD = 17.2$), $F(1, 18) = 209.6$, $p < .0001$, $\eta_p^2 = .92$. Separate paired $t$ tests for each sex showed that both males and females could significantly distinguish between near and far stimuli (females: $t[9] = 14.75$, $p < .0001$, $d = 6.67$; males: $t[9] = 9.45$, $p < .0001$, $d = 4.25$). We also found a significant main effect for sex that indicated females ($M = 22.4$, $SD = 3.8$) perceived the endpoint of the looming sounds to be closer than males did ($M = 37.9$, $SD = 9.4$). The main effect for vocalization type was not significant $F(1, 18) = 1.69$, $p = .22$, $\eta_p^2 = .08$.

However, there were several significant interactions. We found a significant interaction between sex and distance, $F(1, 18) = 8.42$, $p = .009$, $\eta_p^2 = .32$. Post hoc tests showed females perceived sounds to be significantly closer than males did at the far-approach distance, $t(18) = 4.6$, $p = .0002$, $d = 1.69$, but not at the near-approach distance, $t(18) = 1.8$, $p = .09$, $d = .85$ (see Table 2). Central to our hypothesis, we also found a significant Vocalization × Sex interaction, $F(1, 18) = 5.14$, $p = .036$, $\eta_p^2 = .22$. Females perceived looming trials accompanied by crying as significantly closer than trials accompanied by laughing, $t(18) = 2.6$, $p = .017$, $d = .50$. However, the difference between laughing and crying trials was not significant for males, $t(18) = .61$, $p = .54$.

Finally, we found a significant three-way interaction between distance, vocalization, and sex, $F(1, 18) = 5.7$, $p = .028$, $\eta_p^2 = .24$. To examine this interaction, we performed separate 2 (vocalization) × 2 (distance) repeated measure ANOVAs on the distance estimates of our male and female participants, respectively. For males, we found only a significant main effect for distance, $F(1, 9) = 89.26$, $p < .0001$, $\eta_p^2 = .91$. Males perceived near-approach trials ($M = 10.2$, $SD = 10.6$) as significantly closer than far-approach trials ($M = 65.5$, $SD = 15.3$). The main effect for vocalization was not significant, $F(1, 9) = .38$, $p = .55$, $\eta_p^2 = .04$. Similarly, the interaction between distance and vocalization was not significant, $F(1, 9) = 1.7$, $p = .23$, $\eta_p^2 = .16$. For females, we found a significant main effect for distance, $F(1, 9) = 217.78$, $p < .0001$, $\eta_p^2 = .96$. Females perceived near-approach trials ($M = 4.0$, $SD = 2.4$) as significantly closer than far-approach trials ($M = 40.9$, $SD = 7.4$). We also found a significant main effect for vocalization, $F(1, 9) = 8.64$, $p = .016$, $\eta_p^2 = .49$, indicating that females perceived looming trials accompanied by crying as significantly closer than trials accompanied by laughing (see Table 2). In support of our stress hypothesis, we also found a significant interaction between distance and vocalization type $F(1, 9) = 6.55$, $p = .03$, $\eta_p^2 = .42$. Post hoc tests showed that females perceived looming trials accompanied by cries as significantly closer than those accompanied by laughs at the far-approach distance $t(9) = 3.7$, $p = .0016$, $d = .45$, but not at the more stressful near-approach distance $t(9) = .55$, $p = .63$. Though the mean difference between the laugh and cry conditions at the far-approach distance is small, all 10 of our female participants perceived crying trials as closer than laughing trials (Sign test, $p = .002$).

Table 2
*Mean Egocentric Distance Estimates in Visual Analog Scale Units in Experiment 3 (With Standard Deviations in Parentheses)*

| | Vocalization and distance condition | | | |
|---|---|---|---|---|
| | Far cry | Far laugh | Near cry | Near laugh |
| Female ($n = 10$) | 39.19 (7.54) | 42.51 (7.36) | 3.74 (3.21) | 4.35 (2.49 |
| Male ($n = 10$) | 66.4 (16.1) | 64.6 (14.7) | 9.9 (10.3) | 10.6 (11.4) |

*Note*. Scores rage from 0 (*very near*) to 100 (*very far*).

## General Discussion

In vision, threatening looming stimuli are perceived to arrive sooner than those that are not threatening. Vagnoni et al. (2012) suggest that the "semantic content" of the looming object can influence perceived visual time-to-arrival. In Experiment 1, we showed that the induction of a positive or negative affective state by a stimulus unrelated to the looming sound can influence auditory time-to-arrival judgments. In other words, differences in the "semantic content" of the looming sound itself are not required. Rather, the important factor seems to be the induction of positive and negative affect, even if the affective sound is independent from the looming tone. Experiment 2 showed that noise stimuli with amplitude envelopes that matched the infant vocalizations but lacked the emotional quality of a vocalization do not similarly influence auditory time-to arrival estimates.

In Experiment 3, we used an egocentric distance estimation task to show that the valence of a concurrent emotional vocalization can interact with the sex of the listener when perceiving an unrelated looming sound. Consistent with previous research, females in Experiment 1 judged looming sounds as closer than males (Neuhoff et al., 2009; Schiff & Oldak, 1990). Previous work has also shown that louder sounds and closer sounds produce greater stress and a larger looming bias 25(Neuhoff, 1998, 2001; Szalma & Hancock, 2011). At far distances, when the looming sound was less stressful, females judged looming sounds accompanied by cries to be significantly closer than those accompanied by laughs. Males showed no effect of vocalization type. Moreover, when the looming sound was more stressful because it stopped very close to the listener, the effects of vocalization type for females disappeared. If women are more sensitive to emotions or process them more efficiently (Kret & De Gelder, 2012), we might expect the effects of emotional vocalizations to be more pronounced in women than in men. Experiment 3 provides support for this hypothesis, but only "when the stakes are low" and the looming source has stopped a good distance away. The interaction of sex, vocalization, type, and distance is consistent with findings that show the female advantage in processing emotion can be significantly diminished under conditions of stress (DeDora et al., 2011).

DeDora and colleagues (2011) asked participants to judge emotional faces as either angry or neutral. Under conditions of low stress, women showed a performance advantage. However, under high-stress conditions, men and women performed equally. Bach et al. (2009) showed that looming sounds are perceived as threatening and produce greater skin conductance responses than equivalent receding sounds. Sounds that approach a listener and then stop are likely less stressful than those that continue to approach and pass by very closely. Thus, the current results are consistent with a diminished sex difference in processing emotion under conditions of high versus low stress.

Our results do not speak to the specific mechanisms that underlie the female advantage in emotion processing. For example, it is unclear whether the women in our study perceived the vocalizations with greater emotional intensity, whether the men were simply better able to ignore the vocalizations, or whether a combination of other factors contributed to the interaction. Indeed, many of the current findings in the area of sex differences in emotion processing suggest that the "female advantage" is complex and even situation specific. Kret and De Gelder (2012) suggested that "there appears to be a female advantage when it comes to emotion recognition but due to conflicting results it is still not clear if this is true for all emotions in all situations and all expressers" (Kret & De Gelder, 2012, p. 1212).

However, the current findings, along with those of DeDora et al. (2011), may provide an explanation for failures to find differential effects of sex in processing infant laughs versus cries in neuroimaging studies (e.g., Seifritz, et al., 2003). The noise and confining nature of neuroimaging scanners can make them particularly stressful environments. Some patients even require sedatives to complete their scans. It may be that the stressful environment diminishes any advantage that women may have in processing differences in vocalization type.

Our results are consistent with embodied emotion views on the relationship between emotion and perception (Niedenthal, 2007; Niedenthal et al., 2005), and speak against the low-level attention-capturing characteristics of emotional sounds as a mechanism that underlies the effect. Emotional sounds certainly capture attention (Brosch et al., 2010), but Experiment 1 shows that laughs and cries move time-to-arrival estimates in *opposite* directions. Cries increase the looming bias above a no-vocalization control condition and laughs decrease it significantly below the control. As our sounds were matched in arousal, this makes attention-capturing explanations somewhat untenable.

Moreover, Experiment 2 shows that not just any sound can produce these effects. Sounds equivalent to infant vocalizations in level and amplitude envelope, but lacking the spectral structure that is critical to conveying emotion, fail to influence time-to-arrival estimates compared with a control condition. In the current work, we chose infant vocalizations because they have been shown to produce strong affective responses in adult listeners (Boukydis & Burgess, 1982; Giardino et al., 2008). However, it may be that other emotional sounds, or even visual stimuli, that induce positive and negative affect would similarly influence judgments of auditory spatial judgments. Positive and negative affect induced by positive and negative music, for example, has been shown to modulate acceptable interpersonal distance (or "personal space"; Tajadura-Jiménez, Pantelidou, Rebacz, Vastfjall, & Tsakiris, 2011). More general accounts of embodied emotion posit that affect provides a context in which all perceptual information is processed (Niedenthal, 2007). Our results are consistent with this idea.

## Conclusions

Our conclusions should be limited to the experimental conditions employed. However, we have taken a very conservative approach here. In particular, the use of multiple trials with looming sounds may actually underestimate the size of the effect in a more natural environment (e.g., if listeners habituate to looming sounds). Similarly, our use of randomized, rather than blocked, presentation of positively and negatively valenced stimuli may actually mute the effects of emotion on the perception of looming sounds. Finally, a visual "Get Ready!" warning prior to each trial may additionally contribute to underestimation of the size of the effects that might occur under more natural circumstances.

Looming sounds and infant vocalizations are both critically important from an evolutionary perspective. Both can influence motor behavior and elicit affective states in the listener (Bach et al., 2008, 2009; Parsons et al., 2012; Tajadura-Jiménez et al., 2010). Our results suggest that the perception of looming sounds can also be influenced by these same affective states. Specifically, the valence of emotional infant vocalizations and the sex of the listener can interact to modulate the perception of looming auditory motion.

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