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Emotional prosody rarely affects the spatial distribution of visual attention

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Emotional manipulations have been demonstrated to produce leftward shifts in perceptual asymmetries. However, much of this research has used linguistic tasks to assess perceptual asymmetry and there are therefore two interpretations of the leftward shift. It may reflect a leftward shift in the spatial distribution of attention as a consequence of emotional activation of the right hemisphere; alternatively it may reflect emotional facilitation of right hemisphere linguistic processing. The current study used two non-linguistic attention tasks to determine whether emotional prosody influences the spatial distribution of visual attention. In a dual-task paradigm participants listened to semantically neutral sentences in neutral, happy or sad prosodies while completing a target discrimination task (Experiment 1) and a target detection task (Experiments 2 and 3). There was only one condition in one experiment that induced perceptual asymmetries that interacted with emotional prosody, suggesting that task-irrelevant emotional prosody only rarely directs attention. Instead a more likely cause of the leftward perceptual shift for comprehension of emotional speech is facilitation of right hemisphere linguistic processing.

Keywords: Prosody; Emotion; Laterality; Attention; Language; Speech.

Emotional manipulations, particularly involving negative or withdrawal-related emotions, are known to activate the right hemisphere (Borod, 1992; Borod et al., 1998; Mitchell, Elliott, Barry, Cruttenden, & Woodruff, 2003; Ross, Thompson, & Yenkosky, 1997) and produce leftward shifts on perceptual asymmetry tasks (Alfano & Cimino, 2008; Asbjörnsen, Hugdahl, & Bryden, 1992; Compton, Heller, Banich, Palmieri, & Miller, 2000; Gadea, Gómez, González-Bono, Espert, & Salvador, 2005; Gruzlier & Phelan, 1991;

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Van Strien & Boon, 1997; Van Strien & Heijt, 1995; Van Strien & Morpurgo, 1992). This effect can be observed through manipulation of the emotional state of the individual (e.g., Gruzlier & Phelan, 1991) or through the processing of emotional information (e.g., Van Strien & Morpurgo, 1992). A key source of emotional information is a speaker's tone of voice, or emotional prosody. The goal of the present research was to determine whether processing of prosodically emotional speech might similarly influence perceptual asymmetry, and to explore the mechanism through which such an effect might arise.

Previous research suggests a leftward shift in perceptual asymmetry associated with semantic processing of emotional speech. Grimshaw, Kwasny, Covell, and Johnson (2003) found that the typical right ear advantage (REA) for language processing, assessed by a dichotic listening task, was eliminated when speech was spoken in a sad tone of voice. This effect was further found to be specific to sad, but not happy or angry, speech (Grimshaw, Séguin & Godfrey, 2009). There are two possible mechanisms through which emotional activation of the right hemisphere could produce such an effect. First, emotional prosody could activate the right hemisphere, causing a leftward shift in the spatial distribution of attention (Kinsbourne, 1970; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990), thereby enhancing performance at the left ear. Alternatively, emotional prosody could activate the right hemisphere and thereby facilitate right hemisphere language processing.

Grimshaw et al. (2003, 2009) interpreted their findings in terms of prosodic facilitation of right hemisphere language processing. However, given their research design, specifically the use of a linguistic dichotic listening task, it is impossible to distinguish between an attentional and a linguistic explanation of their results. To dissociate the two interpretations it is necessary to evaluate the effect of incidental emotional prosody on a non-linguistic attention task. This is most effectively accomplished using a cross-modal dual-task paradigm in which the effects of emotional prosody on the distribution of visuospatial attention are examined. Thompson, Malloy, and Le Blanc (2009) have recently used this approach, and report evidence in favour of the attentional explanation. Participants listened for comprehension to speeches that were spoken in either neutral prosody or emotionally consistent prosody while simultaneously monitoring the image of a face for the rapid presentation of a target dot. When the speeches were spoken in neutral prosody, target detection was more accurate on the right side of the face than the left. However, when the speeches were spoken with emotional prosody, target detection was more accurate on the left side of the face than the right. This shift occurred even though the emotional prosody was incidental to the language comprehension task. Thompson et al. (2009)

interpret this finding as a leftward visuospatial attentional bias related to right hemisphere activation by the emotional prosody.

Alternative explanations for Thompson et al.'s (2009) results are possible. Notably, the target detection task was superimposed on the image of a face. Therefore the attentional effects might reflect how people attend to faces, or how face perception and speech perception interact (Grandjean et al., 2005; Lansing & McConkie, 1999; Thompson, Malmberg, Goodell, & Boring, 2004). Support for this interpretation comes from another finding from Thompson et al. (2009); prosodically emotional speech not only caused a leftward shift in attention, but also caused a shift from the mouth to the eyes, which clearly does not reflect hemispheric influences.

We present here three experiments that used a dual-task methodology similar to that reported by Thompson et al. (2009), but with no facial component in the attention tasks. Specifically, participants listened to semantically neutral sentences while discriminating between two visual targets (Experiment 1) or detecting a specified target (Experiments 2 and 3). We wanted to keep several components of our task consistent with the design of the Grimshaw et al. (2003, 2009) dichotic studies. Thus the prosody of the sentences was blocked and task-irrelevant. Targets could appear in either the left or right hemifield. If emotional prosody causes a leftward attentional shift, then target processing in the left hemifield should be better when comprehending prosodically emotional speech than when comprehending prosodically neutral speech.

The experiments further examined possible differences between the effects of happy and sad emotional prosody. Grimshaw et al. (2009) found a shift in the REA for linguistic processing of sad speech, but not happy or angry speech. Such a finding is consistent with theories that the right hemisphere is particularly involved in the processing of withdrawal-related emotions such as sadness, while the left hemisphere is involved in the processing of approach-related emotions such as happiness or anger (Davidson, 1992, 1993; Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Harmon-Jones, 2003; Harmon-Jones & Allen, 1998; Harmon-Jones & Sigelman, 2001; Heller, 1993). To this end, participants listened to either prosodically happy or prosodically sad speech in the emotional speech conditions.

EXPERIMENT 1

Participants in Experiment 1 completed a target discrimination task adapted from Okon-Singer, Tzelgov, and Henik (2007) either on its own, or while simultaneously listening to semantically neutral sentences spoken in either a neutral voice or a prosodically emotional voice. For the attention task, four letters were presented on the screen, one in each quadrant. One of the letters was always an O or a Q, and participants were required to indicate which one was present. Okon-Singer et al. found this task to be sensitive to attentional manipulations. Although one could argue that letter discrimination is a linguistic task, such tasks are weakly (if at all) lateralised (Belger & Banich, 1998). Dual-task blocks were followed by a recognition memory test to ensure that participants were attending to the sentences. For the prosodically emotional block, half the participants heard a sad voice and half heard a happy voice.

Method

Participants

Participants were 69 undergraduate students (54 females, 15 males; mean age 19.09 years) who received course credit for their participation. All had normal or corrected-to-normal vision, had no hearing deficits, reported having English as their first language, and were right handed (as assessed by the Waterloo Handedness Questionnaire–Revised; Elias, Bryden, & Bulman-Fleming, 1998).

Stimuli and apparatus

Both the auditory and visual stimuli were presented using a Dell PC computer running Psychology Software Tools' E-Prime Suite version 1.1 (Schneider, Eschman, & Zuccolotto, 2002). Visual stimuli appeared on a 31cm $\times$ 22cm Dell CRT monitor with a vertical refresh rate of 60 Hz. Auditory stimuli were presented with Manhattan noise-cancelling stereo headphones with circumaural cushions.

The stimuli for the language comprehension task were 64 sentences spoken in a New Zealand accent by a female actress (e.g., *Trains run on train tracks*; *Here are the keys for the office*). Each sentence was semantically neutral (as determined in a separate ratings study not reported here) and was spoken in neutral, happy, and sad prosodies (giving a total of 192 tokens). The digital stimuli were recorded with a Neumann U87 microphone, at 16 bits and 44100 Hz, using the software Protools version 7, controlled by a Macintosh G5 computer. All sentences were equated at a peak amplitude of 75 dB. They ranged from 1.10 seconds to 4.46 seconds in length.

The stimuli for the recognition memory task were 64 words, one taken from each of the sentences. The selected word was unique in the set of sentences. For each of the 64 words a distractor word was chosen that was matched to the presented word for length and for frequency.

The stimuli for the visual attention task were the capital letters O, Q, C, R, and U; the target letters were O and Q. The letters were in black Arial size 20 font presented on a white background. On each trial, one target letter and three distractors were presented in each of the four quadrants, in locations that were three degrees above and below, and three degrees to the left and right of the centre of the screen.

Procedure

In order to reduce carryover effects, prosodic emotion was manipulated between participants. Participants were randomly assigned to either the happy prosody condition or the sad prosody condition. They were positioned 60 cm from the screen using a chin rest. The experiment consisted of three blocks of 32 trials each, one in which the letter discrimination task was completed alone (single-block), and two dual-task blocks; one block in which the letter discrimination task was completed while listening to semantically neutral sentences in a neutral prosody (neutral-prosody block), and one in which the letter discrimination task was completed while listening to semantically neutral sentences in a happy or sad prosody (emotional-prosody block). Block order was fixed in order to eliminate any emotional carry over to the neutral-prosody block. Participants did the single-block first, followed by the neutral-prosody block, and then the emotional-prosody block. The 64 sentences were split into two lists of 32 sentences for counterbalancing purposes. Participants heard one list in neutral prosody and the other list in emotional prosody.

Attention task. The attention task was a two-target letter discrimination task, and was the same for the single and dual-task blocks. One of the four presented letters was always one of the targets; O or Q. In each block of 32 trials there were 16 in which the target was O (8 left hemifield, 8 right hemifield) and 16 in which the target was Q (8 left, 8 right). Target displays were presented for 250 ms. Participants were instructed to press the 1 key on the number pad with their right index finger if an O was present, and to press the 2 key with their right middle finger if a Q was present. Participants were instructed to respond as quickly and as accurately as possible. Accuracy and response time were recorded using E-Prime and the computer's internal timer.

For the dual-task blocks, a trial consisted of the 250-ms target display presented during a binaurally presented sentence. The onset of the visual display was unpredictable and randomly varied between 500, 550, 600, or 650 ms before the end of the auditory sentence. Participants were told to listen carefully to the sentences because they would later be tested on their content. The single-task block was preceded by 24 practice trials; the first dual-task block was preceded by 8 practice trials.

Recognition memory task. At the end of each dual-task block a recognition memory test was completed in order to check that participants were listening and attending to the sentences. Participants were presented with 16 words (8 presented words and 8 foils) and asked to indicate with a key press (y or n) whether or not they had heard the word previously.

Results and discussion

Accuracy was tabulated for each participant on the target discrimination and recognition memory tasks. For the recognition memory task, accuracy was converted to a d' measure of sensitivity or ability to discriminate between target words and foils. For the attention task, accuracy was similarly converted to a d' measure of sensitivity to discriminate between the O and Q targets.

For the attention task response time analysis, an outlier procedure was performed such that trials in which the response time was less than 200 ms (anticipatory responses) or greater than 3 standard deviations above a participant's mean were excluded from the analysis. See Tables 1 and 2 for recognition memory and target discrimination task performance.

A total of 21 participants were removed from the final analyses because they either had recognition memory d' of less than 1 (7 participants); or had poor performance on the attention task (12 participants); or English was not their first language (1 participant); or did not respond to any of the trials on one block (1 participant). The final 48 participants were 38 females and 10 males (mean age 18.20 years) of whom 24 heard happy prosody (20 female, 4 male) and 24 heard sad prosody (18 female, 6 male).

Recognition memory task performance

The d' values were analysed in a 2 (block: neutral prosody, emotional prosody) × 2 (emotion: happy, sad) mixed ANOVA, with block as a within-participants variable and emotion as a between-participants variable. See Table 1 for the hit and false alarm rates. There was no significant difference between the neutral prosody ($M = 1.78$) and the emotional prosody ($M = 1.65$) recognition memory blocks, $F(1, 46) = 1.082$, $MSE = 0.341$, $p = .304$, or any interaction between block and emotion, $F(1, 46) = 0.252$,

TABLE 1
Hit and false alarm rates for the recognition memory task in the neutral and emotional prosody blocks in Experiments 1 and 2

	Neutral prosody		*Emotional prosody*	
	Hits	*False alarms*	*Hits*	*False alarms*
Experiment 1	5.88	1.08	5.44	0.98
Experiment 2	6.15	0.57	5.13	0.68

Maximum possible hits and false alarms are 8 in each condition.

MSE = 0.341, *p* = 0.618; suggesting that emotional prosody had no effect on either attention to or encoding of the sentences.

Attention task: Accuracy analysis

The *d′* values were analysed in a 3 (block: single, neutral-prosody, emotional-prosody) × 2 (hemifield: left, right) × 2 (emotion: happy, sad) mixed ANOVA. See Table 2 for summary data. There was a significant main effect of block, $F(2, 92) = 9.469$, $MSE = 0.199$, $p < .001$. *Post hoc* paired *t*-tests indicated that performance was worse in the single-task block than in either the neutral-prosody dual-task block, $t(47) = 3.476$, $p = .001$ or the emotional-prosody dual-task block, $t(47) = 3.900$, $p < .001$. Importantly, there was no difference between performance in the two dual-task blocks, $t(47) = 0.477$, $p = .635$. In terms of the hypotheses there was no block type × hemifield interaction, $F(2, 92) = 0.321$, $MSE = 0.141$, $p = .647$, nor was there a block × hemifield × emotion interaction, $F(2, 92) = 2.216$, $MSE = 0.321$, $p = .115$, suggesting that comprehending prosodically emotional sentences does not affect the spatial distribution of attention.

Attention task: Response time analysis

The response times were analysed in a 3 (block: single, neutral-prosody, emotional-prosody) × 2 (hemifield: left, right) × 2 (emotion: happy, sad) mixed ANOVA. See Table 2 for summary data. There was a significant main effect of block, $F(2, 92) = 13.353$, $MSE = 9862$, $p < .001$. *Post hoc* paired

TABLE 2
Performance (d′ and response time) on the target discrimination task in Experiment 1

Emotion	*Block*	*Left* *M (SD)*	*Right* *M (SD)*	*Total* *M (SD)*
d′				
Happy	Single-task	2.15 (.58)	1.88 (.74)	2.01 (.46)
	Neutral Prosody	2.21 (.77)	2.37 (.65)	2.29 (.52)
	Emotional Prosody	2.35 (.61)	2.20 (.60)	2.27 (.41)
Sad	Single-task	2.01 (.65)	2.04 (.57)	2.03 (.47)
	Neutral Prosody	2.32 (.45)	2.09 (.64)	2.21 (.38)
	Emotional Prosody	2.39 (.40)	2.17 (.69)	2.28 (.38)
RT				
Happy	Single-task	732 (107)	722 (90)	727 (92)
	Neutral Prosody	791 (112)	768 (92)	779 (97)
	Emotional Prosody	811 (93)	804 (92)	808 (74)
Sad	Single-task	765 (161)	750 (146)	757 (749)
	Neutral Prosody	826 (120)	810 (135)	818 (122)
	Emotional Prosody	823 (146)	808 (142)	816 (134)

t-tests indicated that performance was faster in the single-task block than in either the neutral-prosody dual-task block, $t(47) = -4.245$, $p < .001$ or the emotional-prosody dual-task block, $t(47) = -4.376$, $p < .001$. This difference is in the opposite direction of the accuracy analyses; faster but worse performance for the single-task block, which may be suggestive of a speed–accuracy trade-off. However, again there was no difference between performance in the two dual-task blocks, $t(47) = 0.979$, $p = .332$. In terms of the hypotheses there was no block type × hemifield interaction, $F(2, 92) = 0.222$, $MSE = 2162$, $p = .802$, nor was there a block × hemifield × emotion interaction, $F(2, 92) = 0.211$, $MSE = 0.2162$, $p = .810$, again suggesting that comprehending prosodically emotional sentences does not affect the spatial distribution of attention.

Overall, the findings indicate that the spatial distribution of attention was not influenced by the simultaneous processing of either neutral or emotionally prosodic sentences. There was a speed–accuracy trade-off between the single- and dual-task blocks; performance was faster but less accurate on the single-task block. Although this complicates interpretation of the dual-task manipulation, overall performance on the target discrimination task was equivalent in the two dual-task conditions, making direct comparisons between them clearly interpretable. Experiment 1 therefore finds no differences between the attentional effects of neutral and emotional incidental prosody.

EXPERIMENT 2

It is possible that the null effects observed in Experiment 1 were due to the difficult nature of the target discrimination task. This concern plus the presence of a speed–accuracy trade-off led us to conduct Experiment 2 with a similar dual-task methodology but with a simple go/no-go target detection task. The target was defined as a conjunction of features, a red X among a set of distractors that were green Xs and red Os. Conjunction searches of this type are known to require attentional resources (Treisman & Gelade, 1980), and response time provides a sensitive measure of attentional processing.

Method

Participants

Participants were 61 undergraduate students (49 female, 12 male; mean age 22.05 years). All had normal or corrected-to-normal vision, had no hearing deficits, and were right-handed (as assessed by the Waterloo Handedness Questionnaire–Revised; Elias et al., 1998).

Stimuli and apparatus

Both the auditory and visual stimuli were presented using a Dell PC running Psychology Software Tools' E-Prime Suite version 1.1 (Schneider et al., 2002). Visual stimuli appeared on a 34 cm × 27 cm Dell flat-screen monitor with a vertical refresh rate of 60 Hz. Auditory stimuli were presented with stereo headphones with foam cushions. Participants set the volume level to a personally appropriate level themselves before the experiment.

The stimuli for the language comprehension and recognition memory tasks were the same as in Experiment 1. The attention task was a simple go/no-go target detection task. The distractors were the capital letters O and X coloured red and green, respectively. The target was a red X. The letters were in Arial size 20 font presented on a white background. A target array consisted of 13 letters with three presented along the vertical mid line, and five in each hemifield. See Figure 1 for an example target array. The target appeared in only six of these locations (*Left* and *Right* horizontal visual angle = 5.77 degrees, vertical visual angle = 0 degrees; *Upper Left, Upper Right, Lower Left*, and *Lower Right* horizontal = 3.47 degrees, vertical = 3.42 degrees). Within each block the target appeared 15 times in the left hemifield (5 times in each possible target location) and 15 times in the right hemifield. Participants were instructed to respond as quickly as possible by pressing the space bar once they had detected the target. Each

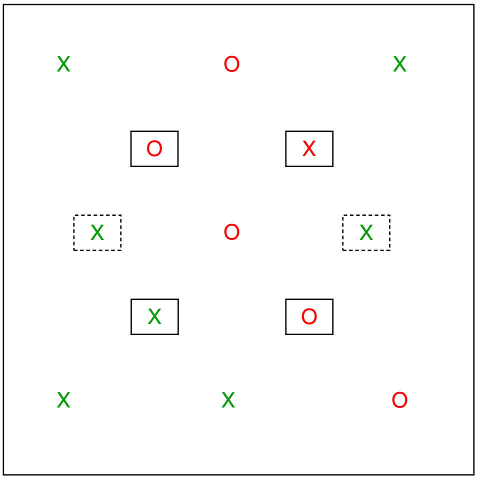

Figure 1. Example stimulus array from Experiment 2. A similar array was used in Experiment 3, but with non-familiar symbols (see Figure 2). The boxes indicate positions where the target could appear; they were not present in the actual presentation. Solid boxes indicate target positions in Experiments 2 and 3. Dashed boxes indicate additional target positions used in Experiment 2.

block of 32 trials included 2 catch trials in which no target was present and on which participants were instructed not to respond. Response time was recorded using E-Prime and the computer's internal timer.

Procedure

Participants completed the experiment in groups of no more than 20 people, while seated at individual carrels. They were seated at an approximate distance of 60 cm. They were randomly assigned to either the happy prosody condition or the sad prosody condition. Blocks of 32 trials were presented in the same order as Experiment 1; single-task block, then neutral prosody block, then emotional prosody block.

Results and discussion

Accuracy on the recognition memory task was calculated for each condition, and converted to the sensitivity measure d'. On the target detection task, participants who responded on more than one of the six catch trials were eliminated, resulting in a sample of 47 participants (9 men and 38 women, mean age 22.34 years), of whom 26 heard happy prosody (21 female, 5 male) and 21 heard sad prosody (17 female, 4 male). For the remaining participants, responses faster than 200 ms were eliminated as anticipatory (two trials across all participants), and a median RT was calculated for each block.

Performance on the recognition memory task was analysed in a 2 (block: neutral-prosody, emotional-prosody) $\times$ 2 (emotion: happy, sad) mixed ANOVA. See Table 1 for the hit and false alarm rates. There was a main effect of block, $F(1, 45) = 14.782$, $MSE = 0.312$, $p < .001$. Memory was better for words from sentences spoken in neutral prosody ($M = 2.09$) than for words from sentences spoken in emotional prosody ($M = 1.66$).

Response times on the target detection task were analysed in a 3 (block: single, neutral-prosody, emotional-prosody) $\times$ 2 (hemifield: left, right) 2 (emotion: happy, sad) mixed model ANOVA. See Table 3 for summary data. There was a main effect of block, $F(2, 90) = 5.640$, $MSE = 98681$,

TABLE 3
Response times (ms) on the target detection task in Experiment 2

Emotion	*Block*	*Left M (SD)*	*Right M (SD)*	*Total M (SD)*
Happy	Single-task	593 (81)	600 (91)	596 (74)
	Neutral Prosody	611 (96)	613 (101)	612 (92)
	Emotional Prosody	627 (98)	615 (93)	621 (92)
Sad	Single-task	606 (133)	593 (94)	600 (112)
	Neutral Prosody	630 (135)	634 (138)	632 (133)
	Emotional Prosody	668 (162)	666 (190)	667 (173)

$p = .005$. Responses were fastest in the single-task block, slowest in the emotional-prosody block, and intermediate in the neutral-prosody block. *Post hoc* paired *t*-tests indicated that only the single-task block and emotional-prosody block differed significantly, $t(46) = 2.713$, $p = .009$. Importantly, there was no block × hemifield interaction, $F(2, 90) = 0.256$, $MSE = 2242$, $p = .775$, nor a block × hemifield × emotion interaction, $F(2, 90) = 0.623$, $MSE = 2242$, $p = .538$, indicating that the prosody of the sentences had no effect on the spatial distribution of visual attention.

In the lack of significant interactions with hemifield, Experiment 2 showed essentially identical results to Experiment 1 with respect to the spatial distribution of attention.

EXPERIMENT 3

As a final exploration of the emotional modulation of the spatial distribution of visual attention, a third experiment was conducted with several changes from Experiment 2. First, in order to ensure the primacy of the language task, participants were probed with a comprehension question after every sentence. Second, in order to rule out any linguistic processing of the stimuli in the visual attention task, instead of the letters X and O two unfamiliar symbols from the Doulos SIL font were used. See Figure 2 for the symbols. Third, the order of the neutral-prosodic and emotional-prosodic blocks was counterbalanced. Fourth, a fixation cross was added at the beginning of each trial to ensure that the participant's attention was first focused on the centre of the screen.

Method

Participants

Participants were 50 undergraduate students (39 female, 11 male; mean age 19.38 years). All had normal or corrected-to-normal vision, had no hearing deficits, and were right-handed (as assessed by the Waterloo Handedness Questionnaire–Revised; Elias et al., 1998).

Stimuli and apparatus

Both the auditory and visual stimuli were presented using a Dell PC running Psychology Software Tools' E-Prime Suite version 1.1 (Schneider

Figure 2. Symbols used in Experiment 3.

et al., 2002). Visual stimuli appeared on a 31cm × 23cm Dell CRT monitor with a vertical refresh rate of 60 Hz. Auditory stimuli were presented with Manhattan noise-cancelling stereo headphones with circumaural cushions.

The auditory stimuli for the language comprehension tasks were 22 of the sentences used in Experiment 1. The attention task was a simple go/no-go target detection task. The symbols were 27 × 27 pixels in size, coloured green and red, presented on a white background. A target array consisted of 13 symbols with 3 presented along the vertical mid line, and 5 in each hemifield; these are the same locations used in Experiment 2. The target appeared in only four of these locations (*Upper Left, Upper Right, Lower Left*, and *Lower Right* horizontal = 3.47 degrees, vertical = 3.42 degrees). Within each block the target appeared 10 times in the left hemifield (five times in each possible target location) and 10 times in the right hemifield. Participants were instructed to respond as quickly as possible once they had detected the target. Each block of 22 trials included 2 catch trials, on which participants were instructed not to respond. Response time was recorded using E-Prime and the computer's internal timer.

The stimuli for the new language comprehension task were simple one- to three-word questions based on Bransford and Franks (1971), which required the participant to extract the meaning of the sentence. For example after listening to "*The parcel arrived on Monday*", participants were asked "*What did?*"; the correct response is *the parcel.*

Procedure

In order to reduce carryover effects, prosodic emotion was manipulated between participants. Participants were randomly assigned to either the happy prosody condition or the sad prosody condition. They were positioned 60 cm from the screen using a chin rest. The experiment consisted of two blocks of 22 trials each (the single block was removed and the number of trials reduced because of time constraints), one in which the target detection task was completed while listening to semantically neutral sentences in a neutral prosody (neutral-prosody block), and one in which the letter discrimination task was completed while listening to semantically neutral sentences in a happy or sad prosody (emotional-prosody block). Block order was counterbalanced.

Participants were instructed that the language comprehension task was their primary task, and were told to listen carefully to the sentences because they would be tested on their content.

The attention task was the same as in Experiment 2. Participants were instructed to press the 0 key on the number pad (which was positioned centrally in front of the participants) when the target was detected as quickly as possible. If the target was not presented (on a catch trial), they were instructed not to respond.

A trial consisted of a visual target display (up to 4000 ms) presented during a binaurally presented sentence. The onset of the target display was unpredictable and randomly varied between 500, 550, 600, or 650ms before the end of the auditory sentence. Before the target display a fixation cross was displayed, this also varied in length (450, 500, 550, or 600 ms) so that participants could not use the fixation as a cue to the onset of the visual display. The memory prompt was presented 1000 ms after response to the target. On a catch trial, the memory prompt was presented 4000 ms after onset of the visual display. Participants typed their responses. After a 2000-ms ISI, the next trial began. The experimental blocks were preceded by five language task practice trials, five attention task practice trials, and two dual-task practice trials.

Results and discussion

Responses for the language task for each participant were coded for accuracy. All participants responded appropriately on all questions. This is to be expected as the task was relatively easy; participants only had a short delay (1 second) over which to remember the sentence before the question was presented. We included this task check only to ensure that participants were listening to and processing the sentences.

On the target detection task, participants who responded on more than one of the four catch trials were eliminated, resulting in a sample of 48 participants (38 women and 10 men, mean age 19.40 years), of whom 24 heard happy prosody (21 women, 3 men) and 24 heard sad prosody (17 women, 7 men). For the remaining participants, responses faster than 200 ms were eliminated as anticipatory (two trials across all participants), and a median RT was calculated for each block.

Response times on the target detection task were analysed in a 2 (block: neutral-prosody, emotional-prosody) $\times$ 2 (hemifield: left, right) $\times$ 2 (emotion: happy, sad) mixed ANOVA. See Table 4 for summary data. The only significant effect was a main effect of hemifield, $F(1, 46) = 6.945$,

TABLE 4
Response times (ms) on the target detection task in Experiment 3

Emotion	*Block*	*Left M (SD)*	*Right M (SD)*	*Total M (SD)*
Happy	Neutral Prosody	693 (196)	681 (179)	716 (240)
	Emotional Prosody	688 (178)	673 (170)	681 (184)
Sad	Neutral Prosody	740 (278)	681 (193)	693 (193)
	Emotional Prosody	698 (211)	696 (243)	684 (208)

$MSE = 3340$, $p = .011$, indicating that participants were faster to respond to right hemifield targets ($M = 683$, $SD = 187$) than to left hemifield targets ($M = 705$, $SD = 204$). The changed nature of the linguistic task seems to have engaged more left hemisphere processing, resulting in a perceptual shift to the right hemifield. Such a pattern suggests that the target detection task is sensitive to perceptual shifts. Importantly, there was no block × hemifield interaction, $F(1, 46) = 2.163$, $MSE = 4141$, $p = .148$, nor a block × hemifield × emotion interaction, $F(1, 46) = 2.675$, $MSE = 4141$, $p = .109$, indicating that the prosody of the sentences had no effect on the spatial distribution of visual attention.

However, when order of the blocks was included as a between-participants variable the picture was different. As in the previous ANOVA there was a main effect of hemifield, indicating again that participants were faster to respond to right hemifield targets, $F(1, 44) = 7.489$, $MSE = 3098$, $p = .009$. Additionally, there was a block × order interaction, $F(1, 44) = 19.169$, $MSE = 10440$, $p < .001$. Paired samples t-tests indicated that participants responded faster in their second block than the first: Neutral-first condition (neutral-prosody block: $M = 743$, $SD = 222$, emotional-prosody block: $M = 668$, $SD = 204$), $t(23) = –3.042$, $p = .006$); Emotional-first (neutral-prosody block: $M = 654$, $SD = 190$, emotional-prosody block: $M = 709$, $SD = 189$), $t(23) = 3.366$, $p = .003$.

There was also a significant block × hemifield × emotional prosody × order interaction, $F(1, 44) = 5.704$, $MSE = 3743$, $p = .021$. In order to interpret this four-way interaction, follow-up block × hemifield repeated-measures ANOVAs were calculated for each of the four order × emotional prosody conditions. These follow-up ANOVAs revealed that the four-way interaction was driven by a significant block × hemifield interaction in the sad-prosody/neutral-first condition, $F(1, 11) = 5.559$, $MSE = 7669$, $p = .038$ (see Figure 3). Follow up paired-samples t-tests show that in the sad-prosody/neutral-first condition there is a significant right hemifield ($M = 759$, $SD = 222$) versus left hemifield ($M = 847$, $SD = 329$) advantage for the neutral-prosody block, $t(11) = 2.508$, $p = .029$; however, there was a non-significant left hemifield ($M = 691$, $SD = 251$) versus right hemifield ($M = 722$, $SD = 298$) advantage for the emotional-prosody block, $t(11) = –1.442$, $p = .177$. The right hemifield advantage was attenuated in the sad-prosody block. This interaction suggests that in the sad-prosody/neutral-first condition, comprehension of prosodically emotional sentences activated the right hemisphere and resulted in a perceptual shift to the left hemifield. However, the block × hemifield interactions were non-significant in all other conditions.

An examination of the participant characteristics suggested a possible reason for the block × hemifield interaction being present only in the sad-prosody/neutral-first condition. In the other three conditions the majority of

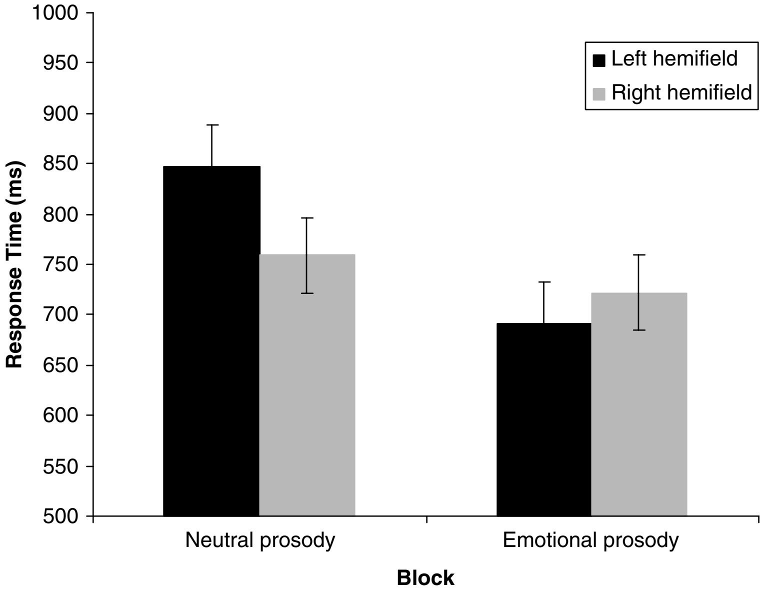

Figure 3. Response time to detect the target in Experiment 3 as a function of block and hemifield in the neutral-first/sad-prosody condition.

the participants were female, whereas in the sad-prosody/neutral-first condition 6 of the 12 participants were male. However, visual inspection of the data revealed the same pattern in male participants as in female participants. Thus sex differences are unlikely to be responsible for the effect.

GENERAL DISCUSSION

Experiments 1, 2, and 3 explored the influence of task-irrelevant emotional prosody on the spatial distribution of attention. Experiment 1 (using a target discrimination task) and Experiment 2 (using a target detection task) both show that incidental emotional prosody has no effect on the spatial distribution of visual attention. Participants were equally as sensitive/quick to discriminate/detect targets in the left and right side of space when comprehending prosodically neutral sentences and prosodically happy and sad sentences. This repeated effect implies that the presence of task-irrelevant emotional prosody does not direct attention to the left side of space.

However in Experiment 3 (using a target detection task) perceptual asymmetries were observed. First, there was an overall shift to the right hemifield, perhaps reflective of greater left hemisphere activity induced by the additional linguistic processing required by the more demanding linguistic task. This is evidence that the linguistic task is appropriate for inducing perceptual shifts. Second, in one condition (sad-prosody/neutral-block first) a pattern of results consistent with an attentional explanation emerged. Participants in this condition were faster to respond to targets in the right hemifield when processing neutral sentences, but non-significantly faster to respond to targets in the left hemifield when processing sad sentences. Importantly, this pattern was only present in one of the four conditions and furthermore this pattern is only present in one of three experiments.

In the visual language domain, Ferry and Nicholls (1997) also reported no evidence of emotional modulation of the spatial distribution of visual attention with a non-linguistic attention task. They presented positive and negative words at fixation, followed by a lateralised gap detection task. After the gap detection task participants were required to use the word in a sentence (to ensure comprehension). Processing of emotional words did not result in a shift of attention to the left hemifield. We concur with Ferry and Nicholls that attention-orienting effects of emotion seem to be very circumstance-driven and idiosyncratic.

Our findings contrast with Thompson et al. (2009) who reported that comprehending prosodically emotional speeches resulted in a leftward shift of visuospatial attention for a dot detection task. However, there are a number of procedural differences between the current study and Thompson et al. that could account for the discrepancy. First, the Thompson et al. dot detection task was superimposed on a picture of a face. It is possible that this induced a face-specific mode of processing and may reflect the integration of facial and speech processing. In conjunction with the leftward shift of attention while listening to emotional prosody, participants shifted their attention from the mouth to the eyes. Previous research by Thompson and colleagues (2004) suggests that attentional shifts to the eyes are associated with the emotional expressiveness of the speaker. The shift to the eyes is not amenable to a simple hemispheric attentional explanation.

Alternatively, differences between studies might reflect differences in the type of attention examined. All three of the experiments presented here assessed the momentary spatial distribution of attentional resources. In contrast, Thompson et al. (2009) examined sustained differences in vigilance across space. In their experiment participants were cued to the location (left cheek, right cheek, eyes, mouth) where the dot might appear during a 20-second interval. Thus the task measures a participant's ability to attend to a location over a long period. The tasks used in the present study required attention to be divided over visual space, much like the dichotic listening tasks used by Grimshaw et al. (2003, 2009) required attention to be divided across both ears. The vigilance task used by Thompson et al. (2009) may therefore be more analogous to dichotic listening tasks that require focused attention on one ear (e.g., Hugdahl & Andersson, 1986). Vigilance is a highly controlled attentional process and may rely more heavily on frontal networks (Marklund et al., 2007; Stuss, 2006) than the more automatic orienting functions of attention that are associated with posterior networks (Posner, 1980; Stuss, 2006). It is possible that emotional prosody exerts more of an effect on the frontal attentional networks, and would therefore produce larger attentional effects on vigilance tasks.

Consistent with a frontal activation explanation, the speeches used by Thompson et al. (2009) may have particularly activated frontal regions associated with emotional experience (Davidson, 1992; Heller, 1993). The speeches were semantically emotional in nature (e.g., *Women's Rights Are Human Rights*; Clinton, 1995). In contrast to the semantically neutral sentences presented here (and the semantically neutral words used by Grimshaw et al., 2003, 2009), the speeches used by Thompson et al. may have been particularly more effective at inducing a congruent mood when spoken in consistent emotional prosody. Their findings may therefore reflect the effect of mood, and not emotional prosody specifically, on the spatial distribution of visual attention. Effects of emotion on perceptual asymmetries are more consistently found in mood induction studies (e.g., Gruzlier & Phelan, 1991; Van Strien & Boon, 1997) than in studies that examine the concurrent processing of emotional information (e.g., Ferry & Nicholls, 1997).

Findings presented here suggest that the reduced REA for linguistic processing observed in the Grimshaw et al. (2003, 2009) dichotic studies are probably not due to modulation of the spatial distribution of attention but rather to emotional prosodic facilitation of right hemisphere linguistic processing. Consistent with this claim, a similar shift in the REA was not observed for non-words in Grimshaw et al. (2003). If the effect were spatially induced, one would expect it to apply to the processing of all left ear stimuli. That the leftward shift seems to be specific to lexical stimuli suggests that it reflects emotional prosodic activation of right hemisphere language processing.

So far, two studies (the current paper and Thompson et al., 2009) have examined changes in the distribution of spatial attention induced by incidental emotional prosody. The literature on perceptual shifts induced by processing emotional semantics and mood induction is much larger, and robustly suggests that the presentation of emotional words and negative mood induction both result in a leftward perceptual shift. However, all of these studies used lateralised linguistic tasks to assess the perceptual shift (e.g., Alfano & Cimino, 2008, letter trigram reporting; Compton et al., 2000, colour naming; Gadea et al., 2005, consonant-vowel dichotic listening task; Gruzlier & Phelan, 1991, vowel detection; Van Strien & Boon, 1997, letter trigram reporting; Van Strien & Heijt, 1995, physical-identity letter matching and nominal-identity letter matching; Van Strien & Morpurgo, 1992, lexical decision). Notably, Ferry and Nicholls (1997) and the present study have used non-linguistic attention tasks, and found much less robust effects. Our findings suggest further investigation into the factors that do (and do not) produce attentional shifts is warranted. Such factors could include the emotional and/or cognitive load of the primary task, the nature of the attentional task, or situational and/or individual difference variables..

In conclusion, the current study, by virtue of the use of two non-linguistic attention tasks, is uniquely suited to explore the contribution of the spatial distribution of attention to perceptual asymmetries induced by emotional prosody. The rarity of emotional-prosodic related perceptual shifts suggests that perceptual asymmetries induced by task-irrelevant emotional prosody are not mainly due to asymmetries in the spatial distribution of attention. As most of the studies that have assessed emotion-induced perceptual asymmetries have employed a linguistic attention task, an alternative mechanism for such perceptual asymmetries is facilitation of right hemisphere language processing.

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