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When a bang makes you run away: Spatial avoidance of threatening environmental sounds

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HIGHLIGHTS

► Attentional biases to emotional sounds were studied through the beep probe task.
► Left-presented negative and taboo nonverbal sounds elicited attentional avoidance.
► Left-presented taboo nonverbal sounds also initiated an IOR phenomenon.
► Taboo sounds elicited a freezing reaction, whatever their location.

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ABSTRACT

Environmental sounds can be powerful alarm signals. Hence, attentional orienting towards their location might occur extremely rapidly. Here, we used the beep probe task to investigate attentional biases to negative, positive and taboo sounds. While both left-presented negative and taboo sounds elicited attentional avoidance, taboo but not negative sounds triggered Inhibition of Return. Moreover, taboo sounds slowed participants' responses, whatever the sound and beep locations. Positive sounds had no effect. Interestingly, although spatial effects specific to taboo sounds were related to their disgusting nature, their non-spatial effects were linked to their shocking/surprising trait. This is the first evidence of emotional sounds' influence on spatial attentional orienting and of the involved emotional dimensions.

Consider an ordinary day and focus on its auditory qualities. Silence is rare: background noise is almost constant and, as Bradley and Lang [7] point out, you cannot "shut your ears" as you can close your eyes. Hopefully, you will not react to each sound you hear. Rather, only those relevant to your goals or personal concerns will attract your attention. However, despite concentrated on the paper you are writing, you will probably notice the screaming ambulance rushing down the street. Given their speed of transmission and relative insensibility to intervening stimuli, environmental sounds are very powerful alarm signals [21].

Emotional sounds have been found to capture attentional resources [e.g., 16,27]. Nevertheless, no study specifically investigated whether these sounds influence spatial orienting of attention, namely to what extent attentional resources are oriented to their location. Yet, identification of an auditory object relevant for survival or ecological adaptation might orient attention towards its location, putting the listener in a better position to process subsequent information from the same source. Consistently, we [4,5] reported preferential attentional orienting to the location of negative and taboo (i.e., shocking) spoken words. Also, cross-modal modulation of visual spatial attention by anger prosody has been reported [9].

It is thus established that the emotional content of auditory linguistic stimuli modulates spatial attentional orienting. The present study aimed at investigating whether this phenomenon also occurs for non-linguistic stimuli, namely emotional nonverbal environmental sounds. Since the conceptual processing of environmental sounds is comparable to that of words [24], similar attentional biases may occur for both types of stimuli.

Yet there are differences in the processing of words and environmental sounds. First, contrary to the arbitrary relationship that the sound pattern of words has to real-world objects or events, for many environmental sounds the mapping with meaning results from the physical properties of the object or event in question [28], which may lead to stronger attentional biases towards the emotional content of sounds. Second, several studies reported partially dissociated brain regions in the higher-order processing of verbal

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and nonverbal stimuli, including a greater involvement of the left and right hemisphere, respectively [e.g.,[15,26]]. Third, the spatial distribution of attention for verbal and nonverbal sounds could not follow the same rules. Kinsbourne [17] argued that the presentation of verbal (vs. nonverbal) material activate the left (vs. right) hemisphere preponderantly, leading to involuntary orientational biases to the right (vs. left) side of space. Furthermore, although there is a frontal position advantage in localizing both verbal and nonverbal stimuli due to sound attenuation by the pinna [29], only linguistic stimuli induce a frontal position advantage in identification (i.e., better recognition of inputs from the front than from the rear) due at least partly to the habit of looking at our interlocutors (e.g., [6]). Hence, laterality effects and the distribution of attention might modulate differently the spatial attentional biases associated with the emotional meaning of verbal and nonverbal sounds.

In this study, we used an auditory variant of the dot-probe task, the *beep probe task* [4,5], as it is well-suited to investigate the spatial attentional biases triggered by emotional sounds. Indeed, in the emotional pairs of this task, the simultaneous presentation of one neutral and one emotional sound, each one to one side, is followed by a monaural peripherally-presented beep. Reaction times to this probe as a function of its position and of the position of the emotional sound inform us about the allocation of attention when an emotional sound is presented.

Taboo, negative and positive emotional valences were contrasted to assess the impact of the negative (i.e., threatening) vs. positive valence of sounds, and of their shock value. Following results obtained with emotional spoken words [4,5], we predict (1) that threatening and shocking sounds influence one's attention to their location, with shorter RTs to probes presented at the same than at the opposite location as the threatening or shocking sound of the pair, and (2) a general, non-spatial slowing effect, delaying the processing of probes after shocking sounds, whatever their location. Here we predict that the spatial bias would occur only for left-, not right-presented emotional nonverbal sounds, reversing the laterality pattern observed with verbal stimuli [4,5]. In previous studies, we indeed observed attentional biases to negative and taboo spoken words only when these were right-presented. We argued that the use of verbal material would have activated the left hemisphere preponderantly [17], favoring the occurrence of spatial attentional biases when emotional words are presented in the contralateral (i.e., right) side of space. In the present study the use of nonverbal sounds would activate the right hemisphere preponderantly, inducing involuntary orientational biases to the left. Given the right hemisphere superiority for processing emotional material [e.g.,[12]], the emotional nature of the stimuli would even increase this laterality effect.

1. Method

1.1. Participants

Forty-six right-handed students of Université Libre de Bruxelles (35 women, mean age: 21.1, SD: 2.4) participated for course credits.

1.2. Material and apparatus

Stimuli consisted of 48 *emotional* pairs, in which one of the sounds was emotionally charged and the other was neutral, and 16 *neutral* pairs, consisting of two emotionally neutral sounds (e.g., scissors/tennis, see Supplementary material). The emotional pairs included 16 positive (e.g., laughter/sneeze), 16 negative (e.g., growling dog/farm animals) and 16 taboo pairs (e.g., diarrhea/grade crossing), defined as such because the emotional sound in the pair was positive, negative or taboo, according to our selection studies.

In a first selection study, 80 participants rated 390 sounds (from the *IADS-2* [8] or found on http://www.universal-soundbank.com) for familiarity on a five-points scale, ranging from (1) unfamiliar to (5) very familiar, as well as on one of four emotional scales (20 participants each): emotional valence, arousal, threat and shock values. Valence and arousal were assessed on seven-points scales, from (1) very negative/very quiet to (7) very positive/very exciting. Participants were asked to respond “4” when the sound was not emotional or not particularly arousing. Threat and shock values were rather estimated on five-points scales, from (1) not threatening/not shocking to (5) very threatening/very shocking, since the endpoints of these scales were not polarized.

In a second study, 40 participants had to press a keyboard spacebar once they recognized the sound, and to key in its meaning. Sounds were then selected so that emotional sounds of each category were matched on familiarity, arousal, percentage of correct recognition and recognition times to the neutral sounds associated with them in a pair ($F < 1$; $F(1,126) = 3.26$, $p > .07$; $F(1,126) = 1.14$, $p > .10$; $F < 1$). Also, to strengthen differences on the desired emotional characteristics between the sounds of a pair and to ensure that positive, negative and taboo pairs truly differ on the dimensions of interest, we applied a priori criteria considering the length of the scales (5 or 7 points). The two sounds of emotional pairs had to present at least a one-point scale emotional valence difference. Regarding shock value, they had to differ by more than 1.5 point in taboo pairs and less than 1.5 in positive and negative pairs. The threat difference in positive pairs had to be smaller than 1.5. A smaller maximal criterion (one point) was set for neutral pairs, whatever the scale, in order to minimize any difference between the neutral sounds constituting these pairs.

This resulted in taboo, negative and positive sounds differing in terms of emotional valence, shock and threat values, $F(2,47) = 872.093$, 351.496 and 31.804, all $p < .001$. Bonferroni adjusted post hoc comparisons ($\alpha = .0166$) revealed that taboo sounds were more shocking and negative than negative sounds, $p < .001$ and $p = .01$, with no threat value difference, $p > .10$. Both taboo and negative sounds were more shocking, negative and threatening than positive sounds, all $p < .001$.

In a post-selection study, 20 participants rated the selected sounds on six seven-points scales (1: not at all; 7: absolutely) depicting basic emotions: joy, surprise, fear, anger, disgust and sadness [10]. Taboo, negative and positive sounds differed in terms of how much they evoked these emotions, $F(2,47) = 365.774$, 5.589, 14.549, 24.426, 42.215, 14.159, all $p < .01$. In particular, Bonferroni adjusted post hoc comparisons ($\alpha = .0166$) revealed that taboo sounds were more disgusting and surprising than negative sounds, $p < .001$ and $p = .011$. Both negative and taboo sounds elicited increasing levels of anger, fear, sadness and disgust, but decreasing levels of joy, than positive sounds, all $p < .01$. Taboo but not negative sounds were more surprising than positive ones, $p < .03$ and $p > .50$.

Sounds were cleaned and normalized with the Protools Digidesign 6.2.2. software. Within each pair they were synchronized for onset and offset through short excisions. Mean duration was 1499 ms (SD: 115 ms). Each pair was presented through headphones, one sound in each ear, simultaneously, and followed by a 100-ms beep. Admittedly, processing sounds in this situation is different from processing sounds occurring in the real world. Some experiments were run in realistic conditions [13,25], but this was impossible here given the large diversity of the sounds we used. Using loudspeakers provides a rough approach to realistic conditions. Yet, in a previous study [3] we did not report any difference of headphones vs. loudspeakers presentation on the attentional effects of emotional spoken words. Hence headphones were preferred because (1) the distance between ears and the sound source