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Research Report

Does the sight of physical threat induce a tactile processing bias? Modality-specific attentional facilitation induced by viewing threatening pictures

Stefaan Van Damme[a,*], *Alberto Gallace*[b], *Charles Spence*[c], *Geert Crombez*[a], *G. Lorimer Moseley*[c]

[a]*Ghent University, Department of Experimental–Clinical and Health Psychology, Henri Dunantlaan 2, 9000 Ghent, Belgium*
[b]*University of Milano-Bicocca, Italy*
[c]*University of Oxford, UK*

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ABSTRACT

Threatening stimuli are thought to bias spatial attention toward the location from which the threat is presented. Although this effect is well-established in the visual domain, little is known regarding whether tactile attention is similarly affected by threatening pictures. We hypothesised that tactile attention might be more affected by cues implying physical threat to a person's bodily tissues than by cues implying general threat. In the present study, participants made temporal order judgments (TOJs) concerning which of a pair of tactile (or auditory) stimuli, one presented to either hand, at a range of inter-stimulus intervals, had been presented first. A picture (showing physical threat, general threat, or no threat) was presented in front of one or the other hand shortly before the tactile stimuli. The results revealed that *tactile* attention was biased toward the side on which the picture was presented, and that this effect was significantly larger for physical threat pictures than for general threat or neutral pictures. By contrast, the bias in *auditory* attention toward the side of the picture was significantly larger for general threat pictures than for physical threat pictures or neutral pictures. These findings therefore demonstrate a modality-specific effect of physically threatening cues on the processing of tactile stimuli, and of generally threatening cues on auditory information processing. These results demonstrate that the processing of tactile information from the body part closest to the threatening stimulus is prioritized over tactile information from elsewhere on the body.

1. Introduction

It has been argued that an important function of the attention system relates to the facilitated processing of threatening stimuli (Bar-Haim et al., 2007). One mechanism by which threatening information is prioritized is by the preferential orienting of spatial attention toward the location of the threat. This integration of affective and spatial information is clearly adaptive because it allows for the swift localisation of the threat and the initiation of appropriate protective behaviours

* *Corresponding author*. Fax: +32 9 264 64 89.
E-mail address: Stefaan.Vandamme@UGent.be (S. Van Damme).

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(Crawford and Cacioppo, 2002). For example, in escaping an attacking predator, one is advantaged by attending to the predator's location relative to oneself.

The preferential allocation of visuospatial attention toward the location of threatening stimuli has been demonstrated in several different experimental paradigms such as, for example, the visual search task (e.g., Öhman et al., 2001), the visual probe task (e.g., Mogg et al., 2004), and the visual cuing paradigm (e.g., Koster et al., 2006). More specific for the case of physical threat, research has shown that visual attention is biased toward the location of words that are typically related to illness and physical symptoms (Asmundson et al., 2005; Keogh et al., 2001), toward pictures that show painful events (Roelofs et al., 2005), and toward pain (Van Damme et al., 2007) and cues that signal impending pain (Van Damme et al., 2004). Such studies have substantially increased our knowledge of the effect of threatening stimuli on attentional modulation within the visual domain. However, somewhat surprisingly, the effect of threatening stimuli on the distribution of spatial attention within other sensory modalities, such as, for instance, the tactile and/or auditory domains remains unclear.

A large body of empirical research has demonstrated crossmodal interactions between visual, auditory, and tactile stimuli in the control of spatial attention (see Spence and Driver, 2004, and Spence and Gallace, 2007, for reviews). On that basis, and from an evolutionary perspective, visual stimuli implying some kind of threat to a particular part of the body might also be expected to result in a shift of tactile attention toward the processing of information from that specific body part. There is some empirical support for this view. For example, when the participants had to make speeded discrimination responses between high versus low frequency tactile stimuli presented on one or the other hand, their responses were found to be significantly faster when the stimuli were preceded by a picture implying threat (snake or spider) at that hand than when they were preceded by a neutral picture (flower or mushroom) (Poliakoff et al., 2007). However, there are two important limitations with this study: First, it is unclear on the basis of Poliakoff et al.'s results whether the tactile processing bias should be attributed to the fact that the pictures implied bodily damage to the hand, or to the pictures' general negative valence. Second, it is also unclear whether this bias is specific to the processing of somatosensory stimuli, or whether instead, it also extends to affect the processing of stimuli presented in other sensory modalities as well.

Therefore, in the present study, we investigated the impact of the presentation of threatening pictures on spatial attention using an unspeeded temporal order judgment (TOJ) task that provides a particularly sensitive measure of the latency of perceptual processing (see Spence et al., 2001). In the TOJ task, pairs of tactile stimuli are presented, one to either hand, and the participants are instructed to try to determine which hand they perceive to have been stimulated first. If a given pair of stimuli happen to have been preceded by a visual stimulus (i.e., a picture) located in front of one of their hands, then the tactile stimulus delivered to that hand can be presented later relative to the tactile stimulus presented to the other hand, in order for the two stimuli to be perceived as occurring simultaneously (see Shore et al., 2001; Spence et al., 2004; Zackon et al., 1999). We hypothesised: (i) that pictures implying threat would bias tactile attention to their location more than neutral pictures, and (ii) that the magnitude of this bias would be larger when the pictures imply threat to the hand (such as a picture showing a knife in the hand) than when they imply a general threat (e.g., an exploding truck). To verify the modality-specific nature of this effect, we also replicated the experimental protocol but now presented pairs of auditory stimuli, via loudspeakers one placed next to each hand.

2. Results

2.1. TOJ data

The proportion of correct responses at each SOA was converted into a corresponding *z*-score using a standardized normal distribution. The best-fitting straight line was computed for each participant and the derived slope and intercept values were used to compute the point of subjective simultaneity (PSS) and the just noticeable difference (JND) values for the subsequent statistical analyses (see Table 1). The PSS refers to the point at which observers report the two events (right hand first and left hand first) equally often (likely equivalent to the SOA at which participants perceive the two stimuli as occurring at the same time). We recoded the PSS data so that a positive value indicates that the stimulus contralateral to the cue had to be presented first in order for both stimuli to be perceived as simultaneous. Thus, the PSS provides information concerning biases in spatial attention resulting from the presentation of the pictures. The JND indicates the interval needed to achieve 75% correct performance, and as such provides a standardized measure of the sensitivity of participants' temporal perception.

Two repeated measures analysis of variance (ANOVA), with the factors of Cue Type (physical threat, general threat, or neutral control), and Target Modality (tactile or auditory) were performed on the PSS and JND data. Greenhouse–Geisser corrections (with corrected degrees of freedom) were reported if the sphericity assumption was violated (Mauchly's Test of Sphericity; $p<.05$). Cohen's d was calculated to determine whether expected differences had a small (0.20), medium (0.50), or large (0.80) effect size (Cohen, 1988).

Table 1 – Parameters of the functions [Z-point-errors = SOA × slope + intercept] used to calculate the PSS and JND values in the present study

	Tactile TOJ		Auditory TOJ	
	Slope	Intercept	Slope	Intercept
Physical threat	0.007698125	−0.486030868	0.008015352	−0.445996389
General threat	0.006744895	−0.342201878	0.006100653	−0.430580757
Control	0.009027287	−0.229911130	0.008127268	−0.436733812

The slope and intercept are reported for the tactile and auditory tasks and for each experimental condition.

2.1.1. PSS data

A main effect of Cue Type ($F(2,24)=9.97$, $p=.001$) revealed that the tactile and auditory PSSs were differentially affected as a function of the type of picture that was presented (see Fig. 1). That is, the PSS was larger when the picture was physically threatening ($M=68$ ms, SD=35) than when it was neutral ($M=42$ ms, SD=14) [$F(1,12)=11.66$, $p=.005$], and larger when the picture was generally threatening ($M=67$ ms, SD=30) than when it was neutral [$F(1,12)=14.53$, $p=.002$]. There was, however, no PSS difference between the physical and general threat pictures ($F<1$). There was no main effect of Target Modality ($F(1,12)=1.22$, $p=.291$), meaning that, on average, the PSS was similar for the auditory and tactile TOJs.

The significant interaction between Cue Type and Target Modality ($F(1.3, 15.2)=7.25$, $p=.012$) indicated that the different types of picture had a different effect on tactile and auditory TOJs (see Fig. 1). Post-hoc tests revealed that for the *tactile* TOJs, the PSS was larger for physical threat pictures than for either general threat ($F(1,12)=6.44$, $p=.026$, $d=.55$), or neutral pictures ($F(1,12)=12.32$, $p=.004$, $d=1.07$). The tactile PSS was also larger for general threat pictures than for neutral pictures ($F(1,12)=17.14$, $p=.001$, $d=.92$). By contrast, in terms of the *auditory* TOJs, the PSS was significantly larger for general threat than for the physical threat ($F(1,12)=5.60$, $p=.036$, $d=.86$) or neutral pictures ($F(1,12)=8.20$, $p=.014$, $d=.98$). For the auditory TOJs, there was no difference in PSS between physical threat and neutral pictures ($F(1,12)=.01$, $p=.927$, $d=.05$).

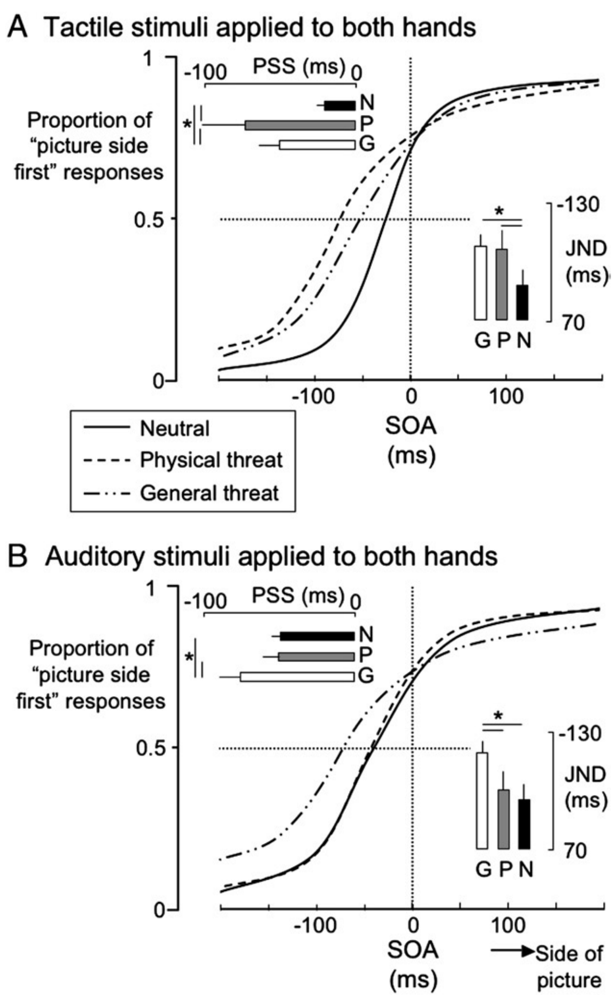

Fig. 1 – Tactile and auditory temporal order judgment (TOJ) data. Fitted curves for cumulative data from 13 participants for tactile and auditory TOJs (A and B, respectively). Data are plotted as a proportion of responses that coincided with the side on which the picture was presented (*y*-axis), as a function of stimulus onset asynchrony (SOA, *x*-axis), for trials in which a neutral picture was shown (solid line), a physically threatening picture was shown (broken line), or a generally threatening picture was shown (uneven broken line). Top left bar graph in each panel shows mean and standard error point for subjective simultaneity (PSS) for neutral (N, black bar), physically threatening (P, grey bar) and generally threatening (G, white bar) pictures. Bottom right bar graph in each panel shows mean and standard error for the just noticeable difference (JND) for each picture type. Asterisk denotes significance at $\alpha=.05$.

2.2. JND data

A main effect of Cue Type ($F(1.4, 16.7)=6.14$, $p=.017$) revealed that there was a differential effect of the type of picture on the tactile and auditory JNDs (Fig. 1). That is, the JND was larger following the presentation of general threat pictures ($M=114$ ms, SD=27) than following the presentation of neutral ($M=92$ ms, SD=35), $F(1,12)=10.24$, $p=.008$), and physical threat pictures ($M=97$ ms, SD=29), $F(1,12)=16.57$, $p=.002$), but there was no difference between physical threat and neutral pictures ($F<1$). There was no main effect of Target Modality ($F(1,12)<1$, n.s.), nor any interaction between Cue Type and Target Modality ($F(1,12)=2.17$, $p=.136$).

3. Discussion

We hypothesised that viewing threatening pictures would have a greater effect on the spatial distribution of a person's tactile attention if those pictures implied physical threat to a particular body part (such as a knife piercing someone's hand) than if they implied a more general threat (as implied, for example, by the picture of an explosion). Our data showed that when participants made TOJs regarding which of two tactile stimuli had been presented first, the PSS was significantly larger when a picture showing physical threat was presented prior to the tactile stimuli than when a general threat picture, or neutral picture, preceded it. The opposite was true for auditory TOJs, that is, the PSS was larger when a general threat picture preceded the auditory stimuli than when a physical threat picture, or neutral picture, preceded them. Thus, the modulation of spatial attentional processing was modality-specific in nature.

By investigating tactile as well as auditory information processing, we have been able to establish that the attentional modulation elicited by physical threat stimuli is more sophisticated than was previously thought (Brown et al., 2007; Poliakoff et al., 2007). That is, when the threatening stimulus implies the threat of physical harm to a particular part of the body, rather than to the person as a whole, then tactile attention is biased toward tactile input from that part of the body over tactile input from other parts of the body (the opposite hand in the present study). The current data also suggest that physical threat shifts attention to tactile rather than auditory information. This would make sense because the tactile modality is probably most relevant in terms of eliciting an efficient response to bodily threat.

The results of the research outlined here show that the crossmodal links in spatial attention that have been documented recently using relatively simple 'beeps and flashes' (see De Gelder and Bertelson, 2003; Spence and Driver, 2004; Spence and Gallace, 2007), can be modulated by the threat value of any visual stimuli that are presented. From a functional perspective, such a modulation would have clear adaptive value. In particular, it would presumably allow for the rapid (and preferential) processing of potentially relevant stimuli and could also facilitate the initiation of behavioural responses to potentially harmful stimuli. Our findings also indicate that biases in attentional processing are not limited to the visual modality but may also extend to the tactile modality in certain situations (see also Poliakoff et al., 2007).

Until now, threat-related attentional biases have almost exclusively been examined within the visual modality (see Bar-Haim et al., 2007, for a review). However, the persistence of clinical states such as fibromyalgia (McDermid et al., 1996), panic disorder (Kroeze and van den Hout, 2000) and chronic pain (Crombez et al., 2005), has been attributed to vigilance toward internal bodily sensations, rather than toward external stimuli. Such attributions have relied on the assumption that attention to bodily sensations is modulated by perceived threat. In order to test this assumption, a number of attempts have been made to extend typical visual attention paradigms to the tactile modality. For instance, Van Damme et al. (2002) instructed healthy individuals to make speeded modality discrimination responses between innocuous electrocutaneous stimuli and auditory stimuli. Each stimulus was preceded by a non-predictive visual cue (the word 'pain' or 'tone'). Interestingly, the pain cue resulted in faster responses to electrical stimuli than to auditory stimuli, and this effect was more pronounced in those participants who reported a higher level of catastrophic thoughts about pain (see Sullivan et al., 2001, for a review on catastrophic thinking and pain).

In another study, participants made speeded discriminations between tactile and visual stimuli that were preceded by body-relevant or body-irrelevant pictures that could be either threatening or neutral (Brown et al., 2007). Responses to tactile stimuli were consistently faster than responses to visual stimuli, and this effect was most pronounced when threatening body-related pictures were shown in individuals with a tendency to experience somatoform symptoms.

The current study extends these previous findings in two ways: First, our results demonstrate that presenting visual stimuli that imply threat to a particular body part results in the prioritization of the processing of tactile information presented at that specific body part over tactile information presented elsewhere. Second, our findings show that the prioritization of tactile attention by physical threat pictures was modality-specific, as the processing of auditory information was not affected by this experimental manipulation. In this sense, the current work lays the platform from which we can more thoroughly investigate tactile processing in clinical groups in which somatosensory vigilance is believed to play an important role. Future studies should also investigate the effects of individual difference variables that are thought to mediate vigilance toward threatening somatic cues such as catastrophic thought processes about pain (Sullivan et al., 2001).

It is not clear why general threat pictures have a stronger effect than physical threat pictures on auditory processing. One potential explanation is that some of the general threat pictures used in the current study might be associated with specific sounds (e.g., exploding jet, guns). It is also notable that the general threat pictures involve threats that are more distant in time and space (such as pictures of boat or plane accidents). Similarly, the relative size of general threat pictures depicts events that may be perceived as being further away from the hand than the events shown in the physical threat pictures. This might explain the difference between tactile and auditory results. That is, while the tactile system has to deal with stimuli that are in close proximity of the body, the auditory and the visual systems have to make forecasts on the basis of distal stimuli (see Gregory, 1967).

Several issues should be considered when interpreting the results of the current study. First, we used a small non-clinical sample: to extrapolate directly to patients would be problematic. To investigate this issue in patients, consideration needs to be given to the location, characteristics and context of the stimuli, and of the threatening pictures. Perhaps stimuli within the somatosensory domain would better modulate tactile attention. However, it is worth noting that the IAPS does not contain many pictures that imply physical threat or harm *specifically* to the hands. Furthermore, some of the pictures used in the current study imply threat to the participants' hand (e.g., biting snake), while other pictures show threat to another person's hand (e.g., meat slicer). It is not clear whether this difference could affect the findings. Future studies should perhaps therefore consider using a more coherent category by adding pictures selected from other sources. Second, the modulation of tactile processing by physical threat pictures was demonstrated for the PSS but not for the JND measure, which only increased for the general threat pictures. This increased accuracy in tactile TOJs following the presentation of general threat pictures is difficult to interpret, as the JND is usually insensitive to spatial cuing manipulations (e.g., Shore et al., 2005; Spence et al., 2001). Further research is needed to clarify the nature of the mechanisms underlying these differential effects. Third, we did not measure state or trait anxiety, both of which might be expected to modulate attention (Bar-Haim et al., 2007). However, it should be noted that it is questionable whether information about the anxiety level of participants would have added much value in terms of the key findings presented here, because there is no reason to assume that anxiety would have differential effects on tactile and auditory processing.

One might also wonder about the possible neural substrates of the effects that are reported here. The fact that physical threat pictures enhanced tactile processing (more than auditory processing) at the location of the threat might imply that visual stimuli pre-activated the somatic representation of the body part closest to the threatening stimulus. This might suggest an effect on area S1 where somatotopic maps of the surface of the body have been documented (e.g., Nakamura et al., 1998; Narici et al., 1991; Penfield and Rasmussen, 1950). A study by Lloyd et al. (2006) is also worth mentioning here. They found that when participants watched a rubber hand (placed over their real hand) being touched by a probe, activity in the posterior parietal cortex increased when the probe was sharp (implying bodily damage) relative to blunt (neutral). Of particular interest here was the fact that the effect only emerged when the rubber hand was in a spatially congruent position with respect to the real hand. Lloyd et al.'s results suggest that the posterior parietal cortex, known to be involved in the integration of visuospatial and somatosensory information, also plays a role in the visuospatial encoding of physical threat, even in the absence of real tactile input. By contrast, the effect of general threat images on auditory processing might be due to spatial (and therefore amodal/multisensory) representations, and likely involve the temporo–parietal-junctions of the right brain hemisphere (e.g., Vallar, 2001). However, before any conclusions can be drawn, further studies need to be performed. In particular, behavioural studies will have to discriminate the spatial frames of reference (or representations) responsible for the modality-specific prioritization effects by disentangling spatial and somatosensory representations (i.e., by asking participant to assume particular postures, for example by crossing their hands; e.g., see Shore et al., 2002). Brain imaging studies could provide insights regarding the brain areas that sustain the prioritization of auditory and tactile information following visual threat pictures.

In summary, the current findings clearly demonstrate the existence of modality-specific effects of the presentation of threatening visual images on tactile attention. Pictures that implied a general threat to the whole person had no effect on tactile processing but a large effect on auditory processing, whereas pictures that implied a physical threat to the body part closest to the picture, had a large effect on tactile processing. These findings substantiate previous assertions (e.g., Spence and Gallace, 2007) and corroborate popular theories of clinical states such as chronic pain (e.g., Crombez et al., 2005).

4. Experimental procedures

4.1. *Participants*

Thirteen healthy volunteers (6 female and 7 male; mean age of 29 years, ranging from 21 to 38 years) took part in this study. All of the participants had normal or corrected-to-normal vision and normal hearing. The experimental session lasted for approximately 1 h. All of the participants gave informed consent to participate in the study. The study was approved by the University of Oxford Ethics Committee and conformed to the Declaration of Helsinki.

4.2. *Task and materials*

The task and stimulus presentation were controlled by a 466 MHz processor computer, using an in-house software program written in Matlab (The Mathworks Inc. Nattick, MA, USA). The participants sat in front of a 15 in monitor, their hands placed behind the lower corners of the monitor.

4.2.1. *Tactile TOJs*

The tactile stimuli (10 ms duration; 290 Hz) were generated by a TE-22 signal generator and were presented via bone conduction vibrators (Part no. VBW32, Audiological Engineering Corp. Somerville, MA, USA; vibrating surface 1.6 cm×2.4 cm) mounted into the upper surface of a foam cube. The participants held one foam cube in either hand such that their index finger rested on top of the vibrator. Two tactile stimuli were presented in each trial, one delivered to either index finger. The stimulus onset asynchronies (SOA) between the two stimuli were +120, +60, +30, +15, or +5 ms (negative values indicate that the left hand was stimulated first) and were randomized between trials.

4.2.2. *Auditory TOJs*

The auditory stimuli (10 ms tone; 290 Hz) were generated by the same generator and presented at 70 dB (A), as measured from the participants' ear position, via loudspeaker cones placed

Table 2 – Number, description, and valence/arousal ratings of IAPS pictures in different cue categories

Cue category	IAPS number	Picture description	Valence	Arousal
Physical threat	1120	Snake (apparently intending to bite)	3.79	6.93
	1300	Pit bull (apparently intending to bite)	3.55	6.79
	1930	Shark (showing teeth)	3.79	6.42
	6300	Knife (hold by a hand)	2.59	6.61
	7361	Meat slicer (with hand close to knife)	3.10	5.09
			3.36	**6.37**
General threat	2120	Angry face	3.34	5.18
	5940	Lava (coming down on a road)	4.23	6.29
	6830	Guns	2.82	6.21
	9600	Ship (sinking)	2.48	6.46
	9622	Jet (exploding)	3.10	6.26
			3.19	**6.00**
Neutral control	1450	Gannet	6.37	2.83
	1670	Cow	5.82	3.33
	2500	Man	6.16	3.61
	2580	Chess	5.71	2.79
	5020	Flower	6.32	2.63
	5390	Boat	5.59	2.88
	5530	Mushroom	5.38	2.87
	7090	Book	5.19	2.61
	7140	Bus	5.50	2.92
	7490	Window	5.52	2.42
			5.76	**2.89**

Mean valence and arousal per category are highlighted in bold.
[a] Valence and arousal ratings are taken from Lang et al. (1999). We tested for differences between categories using independent samples *t*-tests. Physical threat pictures as well as general threat pictures are significantly more unpleasant and arousing than the neutral control pictures (all $p<.001$). As intended, there was no difference in unpleasantness or arousal between the physical and general threat pictures ($p>.10$).

immediately behind the bottom corners of the screen at the same spatial location as the tactile stimuli were presented. On each trial, two tones were presented, one from either loudspeaker. The SOA between the two stimuli was the same as in the tactile TOJ and was randomized between trials.

The inter-trial interval (ITI) was set at 1000 ms. The participants were instructed to keep the two foot-pedals, one placed under the toes of either foot, depressed, but to lift their toes off the pedal on the side on which the first stimulus was presented. The accuracy, rather than the speed, of participants' responses was emphasized. The participants were not given any feedback about their performance.

4.2.3. *Pictures preceding each pair of stimuli*

For both the auditory and tactile TOJ tasks, each trial (i.e., each pair of stimuli) was preceded by a picture, located at either the bottom left or right corner of the monitor. Images (512×384 pixels) from the International Affective Picture Set (IAPS; Lang et al., 1999) were used. Five physically threatening pictures implying risk of injury to the hand, five generally threatening pictures, and 10 neutral control pictures were selected based upon the ratings provided by Lang et al. (1999; see Table 2). We selected physically and generally threatening pictures that only differed in terms of their content[1], but not in terms of their valence and arousal. Pictures in both threat categories were more unpleasant and arousing than the neutral control pictures.

We used a randomized 2(side of picture)×3(category of picture) design such that the side on which the picture was presented was randomized, and the category from which the picture was selected was randomized and counterbalanced, across trials. The pictures were presented for 150 ms, 250 ms before the onset of the tactile or auditory stimuli (i.e., the cue-target SOA = 250 ms).

4.3. *Procedure*

The participants were tested individually in a dimly-lit room. First, they were instructed about the stimuli and the two TOJ tasks (i.e., tactile and auditory). The experiment consisted of four blocks: 2 blocks of 300 tactile TOJ trials and 2 blocks of 300 auditory TOJ trials. The first block was randomized to be a tactile or auditory block and subsequent auditory and tactile blocks were alternated.

[1] Additional ratings of the pictures were collected from an independent sample (N = 18 participants; 2 males and 16 females; mean age = 28.2, SD = 4.5). Participants were asked to rate each picture on the question "To what extent does this make you think about bodily damage?" on a Visual Analogue Scale (VAS). Ratings were significantly higher for both physical threat pictures (M = 6.79, SD = 1.61) and general threat pictures (M = 5.20, SD = 1.90) than for neutral pictures (M = 0.31, SD = 0.56) ($t(17) = 17.16$, $p < .001$, $d = 5.38$; $t(17) = 11.36$, $p < .001$, $d = 3.49$). Of particular interest, ratings were significantly higher for physical threat pictures than for general threat pictures ($t(17) = 4.02$, $p < .001$, $d = 0.90$), which provides support for our differentiation between the two threat categories. These ratings also show that the general threat pictures imply some physical threat. Because we had expected this, a second rating scale was included: "Does this make you think about damage to a particular body part or rather to the whole body?" Participants had to select a response from three possibilities: (1) particular body part, (2) whole body, (3) not applicable. For each participant, we calculated a specificity index (number of "specific body part" responses minus the number of "whole body" responses) separately for the different picture categories. A positive index means that more pictures were rated as implying bodily damage to a specific location whereas a negative index means that more pictures were rated as implying non-specific bodily damage. As expected, the specificity index was significantly larger for physical threat pictures (M = 2.33, SD = 2.14) than for general threat pictures (M = − 3.11, SD = 1.49), $t(17) = 10.75$, $p < .001$, $d = 2.95$). This indicates that the physical threat pictures were more likely to induce bodily threat to the cued hand than the general threat pictures.

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