RUNNING HEAD: Tactile Distance on the Back

Perception of Tactile Distance on the Back

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Abstract

The perceived distance between two touches is anisotropic on many parts of the body. Generally, tactile distances oriented across body width are perceived as larger than distances oriented along body length, though the magnitude of such biases differs substantially across the body. In this study, we investigated tactile distance perception on the back. Participants made verbal estimates of the perceived distance between pairs of touches oriented either across body width or along body length on: (1) the left hand, (2) the left upper back, and (3) the left lower back. There were clear tactile distance anisotropies on the hand and upper back, with distances oriented across body width overestimated relative to those along body length/height, consistent with previous results. On the lower back, however, an anisotropy in exactly the opposite direction was found. These results provide further evidence that tactile distance anisotropies vary systematically across the body, and suggest that the spatial representation of touch on the lower back may differ qualitatively from that on other regions of the body.

In one of the first systematic studies of the sense of touch, Weber (1834) found evidence for spatial anisotropy on the skin. As he moved the two points of a compass across his skin, if felt to him like the distance between them was bigger on more sensitive skin surfaces than on less sensitive surfaces, although he knew the that distance had not changed. This systematic relation between tactile sensitivity and perceived tactile distance has been replicated by subsequent research (Anema, Wolswijk, Ruis, & Dijkerman, 2008; Cholewiak, 1999; Fitt, 1917; Goudge, 1918; Miller, Longo, & Saygin, 2016; Taylor-Clarke, Jacobsen, & Haggard, 2004), and is now known as *Weber's illusion*. Other studies have reported analogous effects within single skin surfaces depending on the orientation of stimuli (Green, 1982; Longo & Haggard, 2011). For example, Longo and Haggard (2011), found that pairs of tactile distances oriented across the width of the hand dorsum were perceived as about 40% farther apart than identical pairs oriented along the length of the hand.

This pattern has been replicated by a number of subsequent studies (Calzolari, Azañón, Danvers, Vallar, & Longo, 2017; Canzoneri et al., 2013; Longo, 2017; Longo & Golubova, 2017; Longo & Morcom, 2016; Longo & Sadibolova, 2013; Miller, Longo, & Saygin, 2014, 2017; Tamè, Bumpus, Linkenauger, & Longo, 2017; Tamè, Tucciarelli, Sadibolova, Sereno, & Longo, 2021). While the majority of studies measuring anisotropy of tactile distance perception have measured perception on the hand, a number of studies have extended these findings to other parts of the body. In addition to the hand, there is evidence for tactile distance anisotropy on the forearm (Green, 1982; Le Cornu Knight, Longo, & Bremner, 2014), the thigh (Green, 1982; Tosi & Romano, 2020), the shin (Stone, Keizer, & Dijkerman, 2018), and the face (Fiori & Longo, 2018; Longo et al., 2020; Longo, Ghosh, & Yahya, 2015). Intriguingly, across each of these body parts, the direction of anisotropy is for distances oriented with body width to be judged as larger than those oriented with body length or height.

Despite the general consistency of the direction of anisotropy across many parts of the body, there are large variations in the magnitude of these biases. For example, anisotropy is smaller on the glabrous skin of the palm than on the hairy skin of the hand dorsum (Longo, 2020), and smaller on the forehead than on the hand (Longo et al., 2015). Indeed, on the belly there does not appear to be any anisotropy at all (Green, 1982; Longo, Lulciuc, & Sotakova, 2019; Marks et al., 1982). This suggests that despite the qualitative similarity in the nature of anisotropy across the body, this bias is not universal and differs depending on the particular characteristics of each skin region. Studies reporting anisotropy have predominantly used mechanical (pressure) stimuli, such as brass rods (Green, 1982), wooden sticks (Fiori & Longo, 2018; Longo & Haggard, 2011), von Frey hairs (Longo & Golubova, 2017), and air puffs (Tamè et al., 2021). Cholewiak (1999) used vibrotactile stimuli, and did replicate the basic pattern of Weber's illusion with perceived distance between touches related to sensitivity, but did not find evidence for anisotropy on the finger, palm, or thigh. It is therefore possible that anisotropy may differ depending on the mode of stimulation, though to our knowledge this has never been directly tested.

This study investigated tactile distance anisotropy on the back. Despite having relatively poor tactile sensitivity (Mancini et al., 2014; Weinstein, 1968), the back has been the focus of a substantial amount of research due in large part to its use as a surface for sensory-substitution devices (Bach-y-Rita, Collins, Saunders, White, & Scadden, 1969; Kristjánsson et al., 2016). Various systematic misperceptions of touch on the back have been reported, such as biases towards landmarks such as the spine (Cholewiak, Brill, & Schwab, 2004; van Erp, 2005), 'oblique' effects in which judgments or orientation are biased to the horizontal and vertical axes (Kappers, Bay, & Plaisier, 2020; Novich & Eagleman, 2015), and interactions between stimulus intensity and perceived direction of tactile apparent motion (Hoffmann, Brinkhuis, Unnthorsson, & Kristjánsson, 2019). There is some evidence, however, that anisotropy on the back may be different from the limbs. One study found that two-point discrimination thresholds were smaller vertically on the back than horizontally (Fuchs & Brown, 1984). Jones and colleagues (Jones, 2011; Jones, Kunkel, & Piateski, 2009) investigated pattern recognition from sequential displays of arrays of vibrotactile stimuli and found a clear anisotropy on the upper arm, with better pattern recognition when the sequence of stimuli progressed along the medio-lateral arm axis than along the proximo-distal axis. Critically, however, no such anisotropy was apparent for stimuli applied to the back. In contrast, Hoffmann and colleagues (Hoffmann, Valgeirsdóttir, Jóhannesson, Unnthorsson, & Kristjánsson, 2018) found higher accuracy of localization in the medio-lateral axis of the back. Thus, there is an unclear picture about the presence or absence of tactile anisotropy on the back.

To our knowledge, however, only one previous study has investigated tactile distance perception on the back. Plaisier, Sap, and Kappers (2020) applied vibrotactile stimuli to the lower back and found that distances along the vertical axis of the back were judged as farther apart than those across the horizontal axis. This anisotropy is notable as it is exactly opposite to that generally found on a range of other body parts, as described above. Indeed, as far as we are aware, this is the only study that has reported a tactile distance anisotropy in this direction on any skin surface. Plaisier and colleagues suggest that this may reflect the fact that vibrotactile stimuli activate different peripheral receptors than the pressure stimuli used in most previous studies of tactile distance perception. It is also possible, however, that anisotropy on the back is qualitatively different from other body parts.

The present study investigated tactile distance anisotropy on two locations on the back, a lower back location similar to that used in the recent study of Plaisier and colleagues (2020) and a location on the upper back. In addition, we also measured anisotropy on the hand dorsum in the same participants, allowing direct comparison of the back with a skin surface on which anisotropy is well-established. Participants made verbal estimates of the distance between pairs of touches oriented either with the width of the back or its length, similar to the procedures we have used in previous studies (e.g., Fiori & Longo, 2018; Longo & Golubova, 2017; Longo & Sadibolova, 2013). If the reverse anisotropy found by Plaisier and colleagues (2020) reflects differences between vibrotactile and pressure stimuli, then similar anisotropies would be expected on the hand and back. Conversely, the effect described by Plaisier and colleagues may reflect differences in the higher-level tactile organization of the back compared to other body parts, in which case anisotropy on the back may differ qualitatively from that on the hand.

Methods

Participants

Twenty women between 19 and 50 years of age (*M*: 30.8 years) participated. On average, participants were 70.5 kg (SD: 21.7 kg), 167 cm in height (SD: 9.0 cm), and had a mean BMI of 25.2 (SD: 7.0). All but two participants were right-handed as assessed by the Edinburgh Inventory (Oldfield, 1971) (M: 62.4, SD: 57.4). Participants gave written informed consent before participating. Procedures were approved by the Department of

Psychological Sciences Ethics Committee at Birkbeck, and were in accordance with the principles of the Declaration of Helsinki.

A weighted average of effect sizes from 15 previously-conducted experiments from our laboratory measuring tactile distance anisotropy on the hand (total N = 300) gave an average effect size of Cohen's *d* = 1.56. A power analysis using G*Power 3.1 (Faul, Erdfelder, Land, & Buchner, 2007) with alpha of 0.05 and power of 0.95 indicated that 8 participants were required. Our sample size of more than double this number is thus appropriately powered to detect potential anisotropy on the back.

Procedures

The stimuli were wooden sticks embedded in foamboard and set at different distances apart, similar to those used in several previous studies from our lab (Fiori & Longo, 2018; Longo et al., 2015; Longo & Golubova, 2017; Longo & Haggard, 2011; Longo & Morcom, 2016). The sticks were pointy, but not sharp, and tapered to a point of approximately 1mm diameter. Stimuli were applied manually by the experimenter with moderate pressure for approximately one second.

Across blocks, stimuli were applied to three different skin surfaces, the dorsum of the left hand, the left upper back, and the left lower back. For the hand blocks, participants lay their left hand palm-down on a table in front of them. Stimuli were applied approximately in the centre of the hand dorsum, with the exact locations stimulated randomly jittered from trial to trial. Participants were asked to turn their heads to the right to prevent visual feedback about stimulation. Stimuli on the back were applied directly on the skin, and participants were asked to remove their shirts. On the upper back, stimuli were presented over the centre of the scapula. On the lower back, stimuli were presented

3-5 cm laterally from the T10 and T11 vertebral spinous processes, the same location used by Mancini and colleagues (2014) to assess tactile acuity on the lower back. Notably, this location is also highly similar to that used by Plaisier and colleagues (2020) in their recent study. This location marks the boundary between the thoracic vertebrae with (T1-10) and without (T11-12) costal facets, making it comparatively easy to identify by feeling the spine. For each skin region, the centre of the specific area was marked with a washable eyeliner pen to allow locations to be consistent across trials. However, the exact location of stimulation was jittered slightly across trials in order to avoid skin soreness or sensitization.

On the hand, we used stimuli of 2, 3, and 4 cm, consistent with previous studies in out lab. Because of the poorer two-point discrimination threshold on the back (Mancini et al., 2014; Weinstein, 1968), larger stimuli are needed to ensure that participants don't perceive only one point. Informal pilot testing indicated that the stimulus sizes (3, 4.5, and 6 cm) we used in our recent study on the belly (Longo et al., 2019) were also suitable on the back, and so these were used.

The participant's task was to estimate the size of each tactile distance (in cm) using a verbal response, as in other studies using this paradigm (Fiori & Longo, 2018; Longo & Golubova, 2017; Longo et al., 2019; Longo & Sadibolova, 2013). Responses were unspeeded. Participants were instructed to respond as precisely as possible, and to consider giving decimal responses (e.g., "2.3 cm" rather than just "2 cm"). Participants were given the option of responding using inches if they preferred, but none did so. If they felt only a single touch, they were asked to respond by giving a distance of 0 cm.

There were 6 blocks of 36 trials each, two blocks on each skin surface. The first three blocks included one repetition of each of the three body parts, counterbalanced across participants according to a Latin square. The final three blocks included the same body parts in the reverse order. Each block included 12 repetitions of each of the three stimulus sizes, in random order.

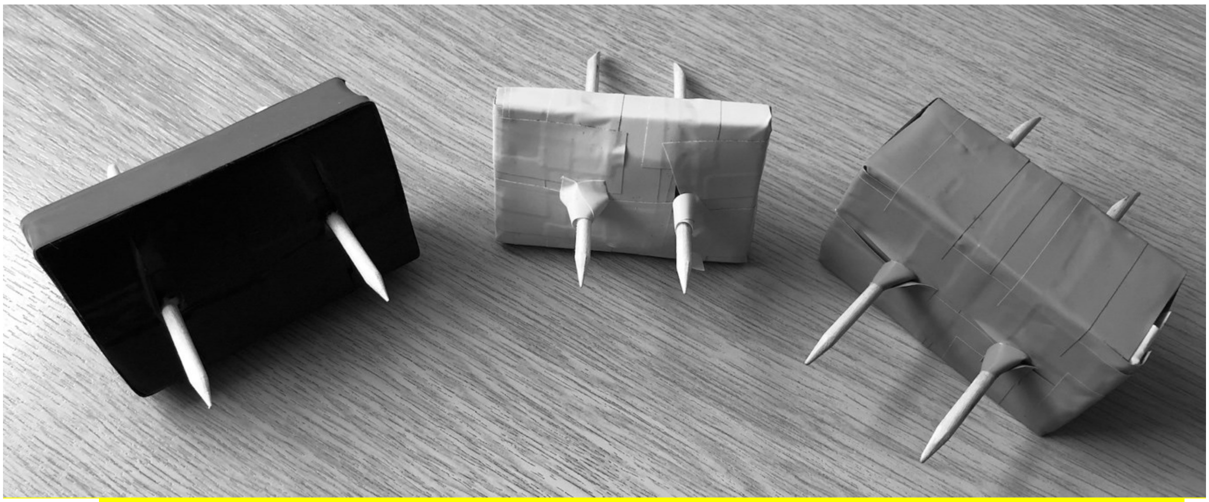

Figure 1: Examples of tactile distance stimuli used in the experiment. Each stimulus consisted of two sticks, embedded in foamboard at a specific distance.

Analysis

Analyses were similar to those used in our recent study measuring tactile distance anisotropy on the back (Longo et al., 2019). We first conducted separate analyses of variance (ANOVAs) on the hand and on the two locations on the back. Where Mauchley's test indicated a violation of the sphericity assumption, the Greenhouse-Geisser correction was applied.

Because different actual stimulus sizes were used on the hand and on the back, these data cannot be combined into a single factorial ANOVA including actual stimulus size as a factor. To directly compare body parts, we re-expressed each response as overestimation of actual distance as a percentage of actual distance. This allowed us to collapse across the different stimulus sizes, so that the three body parts could be included in a single ANOVA with body part (hand, upper back, lower back) and orientation (across, along) as factors.

Results

The results are shown in Figure 2. An ANOVA on the hand revealed a significant main effect of actual stimulus size, $F(1.24, 23.51) = 51.80$, $p < .0001$, $\eta_p^2 = .732$; judged size increased monotonically with actual size, showing that participants were able to perform the task. There was also a clear main effect of orientation, $F(1, 19) = 16.31$, $p < .001$, $\eta_p^2 = .462$, with distances oriented across the hand judged as larger than those along the hand, replicating the anisotropy found in previous research. There was a non-significant trend towards an interaction between size and orientation, $F(1.56, 29.61) = 2.72$, $p = .094$, $\eta_p^2 = .125$.

An ANOVA on the back revealed a significant main effect of actual stimulus size, $F(1.15, 69.89) = 53.42$, $p < .0001$, $\eta_p^2 = .738$, with judged size again increasing monotonically with actual size. This demonstrates that participants were able to differentiate the different stimuli and perform the task effectively. There was non-significant trend for a main effect of orientation, $F(1, 19) = 3.73$, $p = .069$, $\eta_p^2 = .164$, but this was modulated by a significant interaction of orientation and body part, $F(1, 19) = 13.23$, $p < .005$, $\eta_p^2 = .410$. There were no other significant effects.

To explore the significant interaction of orientation and body part, we conducted separate ANOVAs on the upper back and the lower back. On the upper back, there were significant main effects of actual stimulus size, $F(1.37, 26.00) = 40.55$, $p < .0001$, $\eta_p^2 = .681$, and of orientation, $F(1, 19) = 8.04$, $p < .02$, $\eta_p^2 = .297$. As on the hand, stimuli were judged as larger when oriented across the width of the upper back than when along its height. There was also a significant interaction of orientation and size, $F(2, 38) = 4.71$, $p < .02$, $\eta_p^2 = .199$. On the lower back, there were also significant main effects of actual size, $F(1.17, 22.45) = 52.87$, $p < .0001$, $\eta_p^2 = .736$, and of orientation, $F(1, 19) = 9.05$, $p < .01$, $\eta_p^2 = .323$. Critically, the effect of orientation on the lower back was opposite to that found on the hand and on the upper back, with tactile distances oriented along the height of the back judged as larger than those across its width.

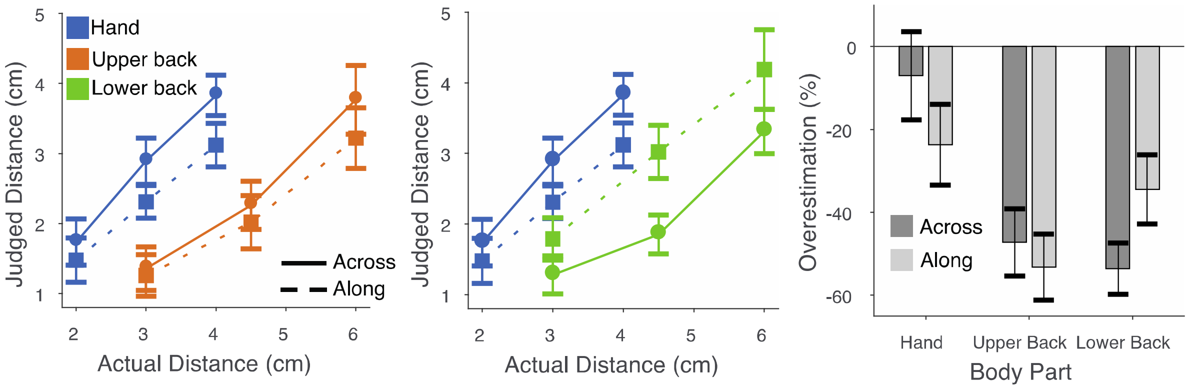

Figure 2: *Left panel*: Judged distance as a function of actual distance on the hand (blue) and upper back (orange). On both body parts, there was a clear anisotropy, with across distances judged as larger than along distances. *Centre panel*: the same data on the hand (blue) and the lower back (green). Identical data from the hand is shown on both plots for comparison. On the lower back, the anisotropy seen on the hand and upper back was reversed. Error bars are one standard error. *Right panel*: The same data expressed as overestimation as a percentage of actual stimulus size, and averaged across the different actual sizes. Positive numbers indicate overestimation, while negative numbers indicate underestimation.

Because the actual stimulus sizes used on the hand and on the back differed due to the different two-point discrimination thresholds on each skin region, we re-expressed each judgment in terms of over- or under-estimation as a percentage of actual size. These results are shown in Figure 1. We then conducted a 3 x 2 ANOVA with body part (hand, upper back, lower back) and orientation (across, along) as within-subject factors. There was a clear main effect of body part, $F(1.33, 25.25) = 21.49$, $p < .0001$, $\eta_p^2 = .531$. While there was underestimation of distance on all skin surfaces, this underestimation was smaller on the hand than on either the upper back, $t(19) = 6.99$, $p < .0001$, $d_z = 1.563$, or the lower back, $t(19) = 3.88$, $p < .001$, $d_z = 0.868$, consistent with the classic form of Weber's illusion. There was no difference overall between the upper and lower back, $t(19) = 1.49$, $p = .151$, $d_z = 0.334$. There was no main effect of orientation, $F(1, 19) = 0.20$, $p > .20$, $\eta_p^2 = .01$, but there was a clear interaction of orientation and body part, $F(2, 38) = 18.49$, $p < .0001$, $\eta_p^2 = .493$. Stimuli oriented with body width were judged as larger than those oriented with body length/height on both the hand (-7.05% vs. -23.70%), $t(19) = 3.87$, $p < .001$, $d_z = 0.866$, and the upper back (-47.26% vs. -53.20%), $t(19) = 2.62$, $p < .02$, $d_z = 0.586$. In contrast, an anisotropy in the opposite direction was apparent on the lower back (-53.63% vs. -34.47%), $t(19) = -3.36$, $p < .005$, $d_z = 0.751$.

Discussion

These results replicate the previously-reported tactile distance anisotropy on the hand dorsum, and extend the list of body parts on which such effects have been reported by showing that a similar anisotropy is present on the upper back. On both these body parts, tactile distances felt larger when oriented across body width than along body length/height. In contrast, our results indicate the presence of a reversed anisotropy (with along distances feeling bigger than across ones) on the lower back, consistent with the recent report of Plaisier and colleagues (2020).

Qualitatively similar anisotropies of tactile distance have been reported on a range of body parts beside the hand dorsum, including the palm (Fiori & Longo, 2018; Longo, 2020; Longo et al., 2015), the forearm (Green, 1982; Le Cornu Knight et al., 2014), the thigh (Green, 1982; Tosi & Romano, 2020), the shin (Stone et al., 2018), the face (Fiori & Longo, 2018; Longo et al., 2020, 2015), and the upper back (this study). While several studies have failed to find any anisotropy at all on the belly (Green, 1982; Longo et al., 2019; Marks et al., 1982), to our knowledge the lower back is the first body part in which a reversed anisotropy is present. Plaisier and colleauges (2020) suggested that this effect in their study might reflect their use of vibro-tactile stimuli, rather than the pressure stimuli used in most previous studies of tactile distance perception. The present results, however, replicate the basic pattern they reported on the lower back with pressure stimuli. This suggests that the spatial representation of the skin of the lower back may differ qualitatively from that of other regions of the body.

Absolute underestimation of tactile distance was found on all body parts, and was especially apparent on the two locations on the back. This difference between the hand and back is consistent with the classic form of Weber's illusion, in which perceived tactile distance across skin surfaces is proportional to their tactile sensitivity (e.g., Cholewiak, 1999; Weber, 1834). It is important to note, however, that there are other possible factors which could have contributed to this difference. Because the different two-point discrimination thresholds on the hand and back required that different absolute sizes of stimuli be used, overall differences between the surfaces could be due to factors such as logarithmic compression of the mental number line (Dehaene, 1999; Longo & Lourenco, 2007), which would result in greater underestimation of larger stimuli. Similarly, a tendency to bias responses towards the mean of all previous responses (Huttenlocher, Hedges, & Vevea, 2000) would also lead to apparent underestimation of conditions in which larger stimuli were applied. Critically, neither of these factors can account for the differences between orientations within a single skin surface, as these were exactly matched.

One important consideration in comparing anisotropy across body parts is how we determine what counts as 'the same' orientation on body parts with very different shapes and typical positions and postures, both with respect to each other and with respect to gravity. Intuitively, we have mapped the medio-lateral axis of the hand onto the medio-lateral axis of the torso, and the proximo-distal axis of the hand/arm onto the vertical axis of the torso. This intuition may, however, be misleading. The overall anterior-posterior limb axis is the most evolutionarily-ancient of the body axes (Kimelman & Martin, 2012), long predating the emergence of the limbs in tetrapods (Shubin, Tabin, & Carroll, 1997). Embryologically, the limbs form from the progressive elongation of small buds that form from the side of the torso after the overall anterior-posterior body axis of the torso is laid down (Towers & Tickle, 2009; Wolpert, Tickle, Martinez Arias, Lawrence, & Locke, 2019). The developmental emergence of the anterior-posterior (or, in humans, vertical) axis is thus qualitatively different from that of the proximo-distal limb axis, evolutionarily, embryologically, and genetically. While the significance of embryological considerations to the eventual neural organization of somatosensory representations is unclear, it is notable that the overall organization of the anterior-posterior axis of the torso (i.e., sacral->lumbar->thoracic->cervical) is mirrored in the high-level somatotopic organization of primary somatosensory cortex (Penfield & Boldrey, 1937; Sur, Merzenich, & Kaas, 1980). This suggests that we should be cautious in assuming that the vertical axis on the torso should necessarily correspond to the proximo-distal axis of the limbs.

Another potentially relevant factor is the organization of the dermatomes on different body parts (Foerster, 1933; Head, 1893; Keegan & Garrett, 1948; Sherrington, 1893), particularly as the dermatomal organization is known to be preserved in the somatotopic organization of primary somatosensory cortex (Dietrich et al., 2017; Werner & Whitsel, 1973). Cholewiak (1999) suggested that tactile distance anisotropy could be related to the fact that the dermatomes on the limbs are generally oriented along the long-axis of the limb. This means that pairs of stimuli oriented across the width of the limb are more likely to fall into different dermatomes, which could result in them feeling farther apart.

Notably, dermatomes on the torso consist of a series of thin bands running around the circumference of the torso. Thus, stimuli oriented vertically are more likely to fall into different dermatomes than stimuli oriented horizontally. Intriguingly, this difference between the arm and the torso does mirror the difference in tactile distance anisotropy we observed between the hand and the lower back. However, this cannot account for the difference between the lower and upper back. Thus, the relation between tactile distance perception and dermatomal organization remains unclear.

Another possible factor which may have influenced results on the back is the presence of the spine and, more broadly, the body midline. Indeed, Plaisier and colleagues (2020) suggested that the bias they found for vertical distances to be judged as larger than horizontal ones might be due to the proximity of the vertical distances to the spine. It is known that joints can function as attractors which can bias tactile localization (Cholewiak & Collins, 2003) and several studies have reported categorical perception effects for tactile distance judgments crossing joint boundaries (de Vignemont, Majid, Jola, & Haggard, 2008; Le Cornu Knight, Bremner, & Cowie, 2020; Le Cornu Knight et al., 2014). It is not clear whether the body midline functions as a categorical boundary in this way, though studies have found localization biases in the direction of the spine (Cholewiak et al., 2004; van Erp, 2005). One recent study compared tactile distance judgments for stimuli crossing the face midline on the forehead compared to the left or right side of the forehead, finding no evidence for any categorical effect of the face midline (Longo et al., 2020). It is possible, however, that the presence of the spine may make the midline more salient on the back. In this light, it is worth noting that stimuli on the lower back were likely to have been closer to the spine than stimuli on the upper back, although we did not measure this in our study. It is conceivable that the spine may induce differential tactile localization biases for pairs of stimuli in different orientations, which could influence tactile distance judgments, as in the present study.

There is substantial and growing evidence that many aspects of somatosensory perception and higher-level body representations may be disrupted in a range of clinical conditions, including obesity (Mölbert et al., 2016; Scarpina, Castelnuovo, & Molinari, 2014), eating disorders (Keizer et al., 2011; Spitoni et al., 2015), and pain (Förderreuther, Sailer, & Straube, 2004; Lewis, Kersten, McCabe, McPherson, & Blake, 2007; Moseley, Gallace, & Spence, 2012; Viceconti et al., 2020), though intriguingly not in focal dystonia (Mainka et al., 2021). It is particularly notable in this context that the lower back is the one region of the body which appears to show an anisotropy of tactile distance perception opposite to that on the rest of the body. Low back pain is the leading cause of disability worldwide (Hartvigsen et al., 2018), and is associated with alterations of somatotopic maps in primary (Flor, Braun, Elbert, & Birbaumer, 1997) and secondary (Hotz-Boendermaker, Marcar, Meier, Boendermaker, & Humphreys, 2016) somatosensory cortex, as well as altered tactile acuity (Catley, O'Connell, Berryman, Ayhan, & Moseley, 2014; Wand, Di Pietro, George, & O'Connell, 2010), tactile localization (Wand et al., 2013), tactile temporal perception (Moseley, Gallagher, & Gallace, 2012), proprioception (Brumagne, Cordo, & Verschueren, 2004), and body image (Moseley, 2008). It is worth noting that one recent paper found that patients with complex regional pain syndrome affecting the hand showed similar tactile distance anisotropy on the hand as controls (Reinersmann et al., 2021). A handful of recent studies have investigated tactile distance perception on the lower back in patients with chronic low back pain (Adamczyk, Luedtke, Saulicz, & Saulicz, 2018; Adamczyk, Sługocka, Mehlich, Saulicz, & Luedtke, 2018; Wang et al., 2020). All of these studies have presented stimuli only in the medio-lateral orientation, leaving it unclear whether anisotropy is affected. It is nevertheless intriguing that tactile distance judgments on the back have been found to be related to pain intensity (Adamczyk, Sługocka, et al., 2018) and altered in magnitude on the affected region of the low back (Adamczyk, Luedtke, et al., 2018; Wang et al., 2020). While one study found that two patients with unilateral low back pain showed exactly opposite patterns on the painful vs. pain-free side (Adamczyk, Luedtke, et al., 2018), a recent study using a larger sample, however, found consistent overestimation of perceived tactile distance on the painful side of the body (Wang et al., 2020). Future research should investigate whether the aspects of the somatosensory organization of the lower back that lead it to have a seemingly unique pattern of tactile distance anisotropy may be related to its predisposition for chronic pain.

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