PROCEEDINGS B

royalsocietypublishing.org/journal/rspb

Research

Cite this article: Tamè L, Khan N, Allarakhia K, Longo MR, Azañón E. 2026 Tactile adaptation transfers between distance and continuous size. *Proc. R. Soc. B* **293**: 20252678.
https://doi.org/10.1098/rspb.2025.2678

Received: 17 October 2025
Accepted: 19 December 2025

Subject Category:
Behaviour

Subject Areas:
cognition, physiology

Keywords:
touch, adaptation, size constancy, tactile aftereffect, anisotropy, somatosensory system

Authors for correspondence:
Luigi Tamè
e-mail: l.tame@kent.ac.uk
Elena Azañón
e-mail: eazanyon@gmail.com

Tactile adaptation transfers between distance and continuous size

Luigi Tamè[1], Naiha Khan[2], Kane Allarakhia[1], Matthew R. Longo[2] and Elena Azañón[3,4,5,6]

[1]University of Kent, Canterbury, UK
[2]Department of Psychological Sciences, Birkbeck, University of London, London, UK
[3]Leibniz Institute for Neurobiology, Magdeburg, Germany
[4]Faculty of Medicine, Otto-von-Guericke University, Magdeburg, Germany
[5]Center for Behavioral Brain Sciences, CBBS, Magdeburg, Germany
[6]Center for Intervention and Research on Adaptive and Maladaptive Brain Circuits Underlying Mental Health, Jena-Magdeburg-Halle, Germany

LT, 0000-0002-9172-2281; MRL, 0000-0002-2450-4903

Tactile spatial perceived distance between two touches is larger on sensitive skin regions. While such distortions are substantial for the perception of distance between two distinct touches, they are significantly reduced when participants estimate the size of a single continuous object touching the skin. Here, we examine whether some of the mechanisms involved in processing the distance between two touches are shared with and influence those underlying the perception of continuous objects, leveraging adaptation aftereffects. In experiment 1, participants adapted to specific distances between two points, and we assessed the effect on both point-based and continuous object perception. Experiment 2 tested whether adaptation to continuous objects influenced distance perception similarly. Results showed that two-point adaptation induced aftereffects of similar magnitude for both two-point and object stimuli, while adaptation to continuous objects produced larger aftereffects specifically for object stimuli. These results indicate that aftereffects generated by simple touches generalize across different stimulation types, whereas those induced by continuous objects remain stimulus specific. Therefore, it is reasonable to assert that the distance perception of two touches arises at early stages of tactile processing that subsequently affects perception at later stages. Whereas distance perception of continuous objects is processed at later stages and is object specific.

1. Introduction

Tactile spatial perception features a variety of illusions and spatial distortions [1]. For instance, when two-point stimuli are applied at a consistent distance to both the dorsum of the hand and the arm, the distance tends to be perceived as larger on the hand, a phenomenon referred to as Weber's illusion [2]. Similarly, when stimuli are applied along the proximo-distal and medio-lateral axes of the hand, the distance across the hand is typically perceived as much larger than the along-hand distance [3], an effect found on several other body parts, such as the forearms [4,5], feet [6], thighs [4,7], face [8–10] and tongue [11]. While both of these effects mirror low-level features of the somatosensory system, such as cortical magnification factors and the geometry of tactile receptive fields in somatosensory cortex, the illusions are substantially smaller than would be expected on the basis of these factors alone [12,13], suggesting an active process of tactile size constancy that corrects for distortions.

THE ROYAL SOCIETY PUBLISHING

Given these perceptual anisotropies of tactile distance, it is intriguing that we do not typically perceive everyday objects, such as keys, as changing in size or shape when we explore them haptically with the palm of our hand. Indeed, haptic object recognition is known to be highly accurate [14,15]. This process of tactile size constancy could explain how accurate haptic object recognition can coexist with large perceptual distortions. A recent study [16] showed differences in tactile distance anisotropies on the hand dorsum between a pair of pointy sticks and a continuous object. When participants were asked to estimate the distance between two touches on the dorsum of the hand, typical anisotropies in the perception of the distance were found, with the proximo-distal distance between the two points perceived as larger than along the hand dorsum. Interestingly, when participants were asked to estimate the size of two continuous objects in the two orientations, the perceptual anisotropy was highly reduced. This pattern suggests that tactile size constancy processes may apply more effectively to objects than to simple touches. This indicates that there may be important differences between the tactile perception of the distance between two isolated touches and a single continuous object, but the relation between these remains poorly understood.

In this paper, we investigate the relation between tactile distance perception and tactile object perception using adaptation aftereffects. Adaptation aftereffects refer to the changes in perception of a neutral stimulus that occur after prolonged exposure to a preceding stimulus. Such adaptation aftereffects provide rich insight into how different stimulus dimensions are processed by populations of selective neurons. For example, by measuring how the magnitude of aftereffects varies when the adapting stimuli and test stimuli differ, the properties of the underlying perceptual representations can be investigated, an approach known as *cross-adaptation*. Calzolari and colleagues [17] used this approach to show that tactile distance aftereffects rely on perceptual mechanisms that are orientation specific and location specific, consistent with low-level mechanisms in primary somatosensory cortex. Previous research has therefore demonstrated adaptation aftereffects for both the perceived size of continuous objects [18–21] and the distance between two separate touches [17,22].

Here, we used such adaptation to investigate the relation between tactile distance and tactile size by testing whether there is cross-adaptation between them, i.e. whether adaptation to one dimension (e.g. distance) produces aftereffects for the other dimension (e.g. size). Demonstrating such cross-adaptation would provide evidence that these two perceptual dimensions rely, at least in part, on shared underlying neural mechanisms. We hypothesized that adaptation to the distance between two-point stimuli engages sensory mechanisms that may also contribute to the processing of continuous objects. Specifically, if common mechanisms mediate the tactile processing of two-point stimuli and continuous objects, then adaptation should transfer between the two types of stimuli. If this is not the case, both types of adaptation would be stimulus specific (i.e. stick versus stick and object versus object). By examining these effects, we aim to elucidate the relationship between simple and complex tactile processing and provide insights into tactile size constancy and perceptual rescaling mechanisms.

We conducted two experiments measuring cross-adaptation between tactile distance and continuous size. In experiment 1, we tested whether adaptation to a specific distance between two-point stimuli delivered to different regions of the dorsum of the hands would affect the subsequent perception of distances when generated by either two points or a continuous object. This allowed us to assess whether the mechanisms involved in simple distance perception extend to more complex, object-based size processing. In experiment 2, we investigated whether adaptation induced by a continuous object affects distance perception in a similar manner, thus testing whether adaptation to complex stimuli shares characteristics with point-based distance adaptation. To anticipate our findings, when tactile adaptation was induced using two touches, a clear aftereffect emerged both for touches and continuous objects testing. In contrast, when adaptation was induced using the continuous objects, the aftereffect was remarkably larger for the objects test stimuli than for the touches (i.e. sticks). These results suggest that the aftereffect generated by simple touches generalized across stimulation type (i.e. sticks and objects), whereas the aftereffect generated by continuous objects is stimulus specific (i.e. objects).

2. Experiment 1

First, we investigated whether tactile adaptation to the distance between two points (sticks) affects subsequent perception not only of point-based distance estimation but also of the perceived size of a continuous object. Specifically, we aimed to determine whether adaptation to the simplest form of tactile distance transfers to the perception of object size.

(a) Participants

Twenty members of the Birkbeck community participated after giving written informed consent. Data from one participant were excluded due to a technical error with data collection, and data from two additional participants were excluded based on model-fit criteria (see below). The remaining 17 participants (9 women, 8 men) ranged from 21 to 75 years of age (*M*: 31.9 years). All participants but one were right-handed as assessed by the Edinburgh Inventory [23] (*M*: 80.1, range: −58 to 100). Finally, at the end of the experiment, participants received credits compensation for their time, regardless of their performance.

The sticks condition of this experiment is very similar to that of experiment 1 of a previous paper on tactile distance adaptation [17], where the main comparison of the two adaptation conditions had a very large effect size (Cohen's $d_z = 2.44$). A power analysis using G*Power 3.1 software [24] with alpha of 0.05 and power of 0.80 indicated that four participants were needed to replicate this effect. As we expected that the transfer of adaptation between sticks and objects might only be partial, we tested a much larger sample than this. Our sample of 17 participants gives us power >0.80 to detect an effect even one-third the magnitude of that found in the work cited above.

(b) Stimuli

There were two types of stimuli, *sticks* and *objects* (figure 1), similar to a recent paper [16]. The sticks stimuli were pairs of wooden sticks embedded in foam board at different distances (2, 3 and 4 cm). The sticks are pointy, but not sharp, and taper to a point of approximately 1 mm in diameter. Stimuli were applied manually by the experimenter with moderate pressure. The object stimuli were pairs of plastic objects of a shape that resembles a rectangle, to which a clip was attached to allow the researcher to hold it effectively with a good grip. The lower surface of the object that touched the skin was slightly rough (this configuration increased the friction and avoided any slipping movement of the object over the skin), with a length of 2, 3 or 4 cm and a width of 0.8 cm. (These objects are part of the same set previously used in another study [16].)

(c) Procedures

Each trial consisted of an adaptation phase and a test phase. During adaptation, two isolated sticks were presented simultaneously at specific distances between the two touch points. The tip of each post was rounded, and stimuli were manually delivered by the experimenter. Participants were blindfolded and seated with their palms resting on the table, their hands positioned with the digits oriented towards the experimenter seated in front of them. Procedures for inducing tactile distance adaptation were similar to those in previous studies [17,22]. In the RH > LH condition, the right hand was adapted to a large tactile distance (4 cm) and the left hand to a small distance (2 cm). In the LH > RH condition, the stimuli were reversed. On each trial, there was 10 s of adaptation consisting of alternating application of stimuli to the two hands. Each touch lasted approximately 1 s and was alternated between the right and the left hands for a total duration of 10 s, resulting in at least 10 touches, 5 on each hand. Longer adaptation periods (approx. 60 s) were applied at the first trial of each block to counteract residual adaptation from the previous condition and establish adaptation to the new condition. This resulted in 30 touches on each hand in an alternating order. Additionally, after each break (every 20 trials), similar extended adaptation was provided to reinforce the effect and mitigate potential adaptation loss due to hand movements. Throughout the adaptation period, the adapting stimuli (the two distant sticks) were applied across the entire length and width of the participant's hand, ensuring that stimulation did not repeatedly target the exact same two points on the skin (electronic supplementary material, figure S1). This approach was intended to induce adaptation to the abstract property of distance (i.e. to a spatial relation between two tactile events), rather than adapting two specific skin locations while, in addition, preventing sensitization or discomfort from repeated stimulation of the same skin locations. The distances of the two rods were aligned with the medio-lateral hand axis.

On each trial, following adaptation, two test stimuli were applied sequentially, one to each hand, with the order counterbalanced across trials. The test stimuli consisted of either sticks or objects. Across trials, there were five pairs of test distances (on stick trials) or lengths (on object trials), which varied in the ratio of size on the two hands (left/right): 2/4, 2/3, 3/3, 3/2, 4/2 cm. Test stimuli were applied in the medio-lateral orientation, approximately in the centre of the hand dorsum, though the exact location was varied to avoid sensitization. Note that test stimuli were presented using the same orientation as in the adaptation procedure. Stimuli were applied for approximately 1 s, with an interstimulus interval of approximately 1 s. After the second touch, participants provided untimed, two-alternative forced-choice (2AFC) verbal judgements, indicating whether the first or second test stimulus felt larger. This response method was designed to be independent of the tested dimension (RH–LH). We acknowledge that stimulus duration and pressure intensity were delivered manually by the experimenter and therefore could not be identical across trials, as in previous studies [3,16,17]. However, because stimuli were applied across the entire dorsum of the hand rather than at fixed points, any minor inconsistencies are unlikely to have systematically favoured one experimental condition over another. Moreover, tactile distance aftereffects have been robustly replicated across different laboratories, experimenters and stimulus types despite inevitable variation in these parameters [1,25], further indicating that such factors are not critical determinants of the effect.

There were four blocks, two involving RH > LH adaptation and two LH > RH. The two adaptation conditions were counterbalanced using an ABBA design, with the first condition counterbalanced across participants. The first two blocks were completed in a single session, and blocks 3 and 4 in a second session on a different day. Each block consisted of 60 trials, 30 involving stick test stimuli and 30 involving object test stimuli. The 30 trials of each stimulus type consisted of six repetitions of each of the five ratios between left- and right-hand stimuli, with the order of the two hands counterbalanced. The 60 trials within each block were presented in a random order.

(d) Analysis

Responses were recoded as the proportion of trials on which the left-hand stimulus was judged as larger than the right-hand stimulus as a function of the ratio of the size of the two stimuli (LH/RH). This ratio was plotted logarithmically to produce a symmetric distribution around a ratio of 1 (i.e. the ratio at which the two distances were the same size). Psychometric functions were fit to this data using cumulative Gaussian functions with maximum-likelihood estimation using the Palamedes toolbox [26] for MATLAB (MathWorks, Natick, MA). For each participant, we fitted four psychometric functions formed by the factorial combination of stimulus type (sticks, objects) and adaptation condition (LH > RH, RH > LH).

We excluded participants from analyses if the R^2 for the psychometric functions was lower than 0.5 in any of the four conditions, consistent with other studies [3,25]. As mentioned above, data from two participants were excluded based on this criterion. The psychometric functions have two parameters, the mean of the Gaussian and the slope (i.e. the inverse of the s.d.

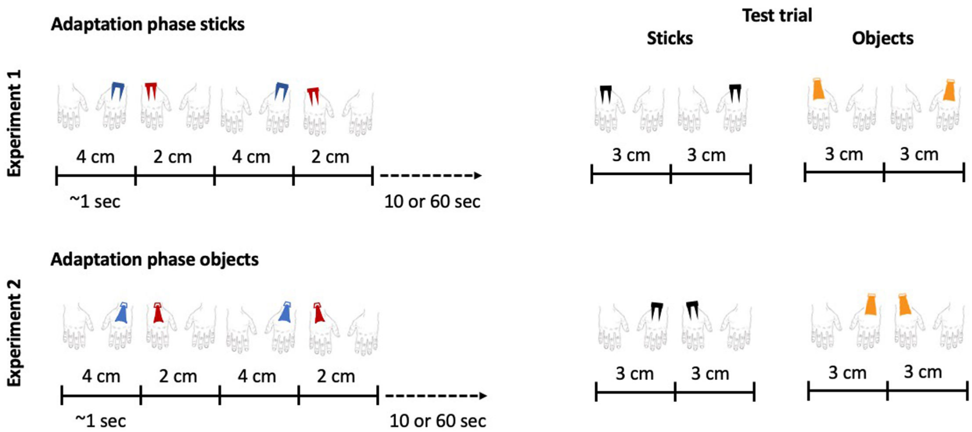

Figure 1. Bimanual adaptation procedure in experiment 1 using sticks (upper part) and in experiment 2 using objects (lower part). During adaptation, blindfolded participants were touched in alternation on the dorsum of each hand using sticks in experiment 1 and objects in experiment 2. To test the effect of adaptation, we included two conditions. In one condition, during adaptation, the 2 cm stimulus was presented on the right hand and the 4 cm stimulus on the left hand (RH < LH) in alternation for 10 or 60 s (approx. 1 s each stimulus). In the other condition, during adaptation, the mapping was reversed (RH > LH). After adaptation, two stimuli were applied in sequence, one to each hand, from five possible pairs (L/R: 2/4, 2/3, 3/3, 3/2 and 4/2 cm), and participants made unspeeded judgements of whether the first or second stimulus felt larger. In the test phase, in a randomized order, half of the trials started with the left hand and half with the right (experiment 1 shows an example of starting with the right hand, and experiment 2 shows starting with the left hand). In the test phase of both experiments, sticks (black) and objects (orange) were presented in random order. All stimuli were oriented across the width of the hand (as illustrated in the figure).

of the Gaussian). The mean corresponds to the point of subjective equality (PSE), i.e. the ratio between the left- and right-hand test stimuli for which the participant is equally likely to judge each as larger. The slope represents the precision of judgements, and we used it as a secondary measurement to evaluate participants' abilities in the two tasks as done in a previous study using similar stimuli [16]. Our hypotheses concern primarily the PSE. All statistical tests were conducted on log-transformed PSEs, which were converted back to ratios for reporting mean values. Experimental scripts, raw data and analysis scripts are available on the Open Science Framework [27].

(e) Results and discussion

An adaptation aftereffect is expected to bias distance judgements, such that perceived distances differ systematically between the two adaptation conditions. Specifically, when the LH is adapted to the larger stimulus and the RH to the smaller one, test distances on the LH should be perceived as smaller than those on the RH. The opposite perceptual bias is expected when the adaptation mapping is reversed. We therefore tested the magnitude of adaptation aftereffects by directly comparing these two complementary conditions, rather than by assessing deviations from an arbitrary baseline.

There were clear opposite aftereffects, as shown in figure 2. R^2 values indicated that the psychometric functions provided a good fit to the data, accounting for an average of 94.2% and 92.8% of variance in the stick trials in the LH > RH and RH > LH conditions, and 87.2% and 90.1% in the objects trials. A 2 (adaptation condition, RH > LH versus RH < LH) × 2 (test stimulus type, sticks versus object) repeated-measures ANOVA on PSE values revealed a large main effect of adaptation condition, $F_{1,16} = 14.66$, $p < 0.002$, $\eta_p^2 = 0.478$, indicating the expected adaptation aftereffect. However, this effect was not modulated by an interaction between adaptation condition and test stimulus type, $F_{1,16} = 0.90$, $p = 0.36$, $\eta_p^2 = 0.053$. Clear adaptation aftereffects were found for both sticks, $t(16) = 3.80$, $p < 0.002$, $d_z = 0.921$, and for objects, $t(16) = 3.03$, $p < 0.01$, $d_z = 0.735$. In addition, the magnitude of the adaptation effect (i.e. the difference in PSE between the LH > RH and RH > LH conditions) for sticks and objects was significantly correlated across participants, $r(15) = 0.595$, $p < 0.02$.

There was also a non-significant trend towards a main effect of test stimulus type, $F_{1,16} = 4.23$, $p = 0.057$, $\eta_p^2 = 0.209$. This effect was not predicted but would indicate a tendency for the right-hand test stimuli to be judged as larger, in the RH > LH condition, when testing with objects as compared to sticks.

For completeness, we also conducted a similar ANOVA on the slopes of the psychometric functions, though this did not relate directly to our experimental hypotheses. However, we believe that it is useful to provide this additional analysis given its relevance to task difficulty and because it might offer useful information for future studies. There was a significant main effect of test stimulus type, $F_{1,16} = 5.96$, $p = 0.027$, $\eta_p^2 = 0.271$. This indicates that slopes were higher for sticks than for objects, as is clearly apparent in figure 2, and is consistent with the results from a previous experiment [16]. Thus, discriminating which of two continuous objects is larger is more difficult for participants than discriminating between two pairs of sticks. There was no effect of adaptation on slopes, $F_{1,16} = 0.53$, $p = 0.477$, $\eta_p^2 = 0.032$, nor an interaction, $F_{1,16} = 0.487$, $p = 0.495$, $\eta_p^2 = 0.030$.

These results provide a clear replication of the tactile distance aftereffects reported in previous studies [17,22]. Moreover, they show that such aftereffects transfer to affect the perception of continuous size.

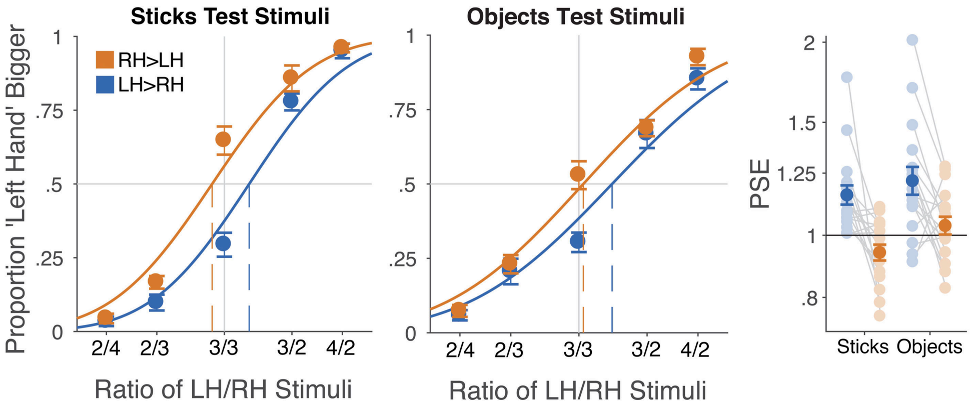

Figure 2. Results from experiment 1, in which adapting stimuli were pairs of sticks. Two-point adaptation using sticks induced aftereffects of similar magnitude for both two-point and object test stimuli. Blue lines represent the condition in which the left hand was adapted with a larger stimulus than the left hand, whereas orange lines represent the condition in which the right hand was adapted with a larger stimulus than the left hand. Curves are cumulative Gaussian functions. Error bars represent the ±s.e.m. Vertical lines represent PSEs.

3. Experiment 2

In experiment 2, we examined whether adaptation induced by a continuous object would affect subsequent distance perception in a manner similar to two point-based distance adaptation and whether it would transfer to the latter. This allowed us to test whether tactile adaptation mechanisms involved in the processing of continuous stimuli, which probably engage higher-order and more associative sensory processing, can influence the perception of pure distance between two points, a task that probably involves earlier populations of neurons tuned to distance encoding.

(a) Participants

Twenty-four new participant members of the University of Kent community participated. Data from three participants were not usable due to a technical error with data collection. Data from a further three participants were excluded based on model-fit criteria (due to R^2 being lower than 0.5 in at least one condition). The remaining 18 participants (10 women, 8 men) ranged from 18 to 28 years of age (*M*: 20.1 years). All participants but two were right-handed as assessed by the Edinburgh Inventory (*M*: 63.0, range: −69 to 100). Finally, at the end of the experiment, participants received credits compensation for their time, regardless of their performance.

(b) Procedure and analyses

Stimuli, procedures and analyses were identical to experiment 1, except that the adapting stimuli were large (4 cm) and small objects (2 cm), instead of sticks (identical to those used for the object-test stimuli in experiment 1).

(c) Results and discussion

The results from experiment 2 are shown in figure 3. As in experiment 1, R^2 values showed good fit of the psychometric functions to the data, accounting for an average of 97.0% and 97.9% of variance in the stick's trials in the LH > RH and RH > LH conditions, and 92.4% and 91.4% in the object's trials. A 2 (adaptation condition, RH > LH versus RH < LH) × 2 (test stimulus type, sticks versus object) repeated-measures ANOVA revealed a significant main effect of adaptation condition, $F_{1,17} = 40.44$, $p < 0.0001$, $\eta_p^2 = 0.704$, again showing a classic adaptation aftereffect. As in experiment 1, significant adaptation was found both for sticks stimuli, $t(17) = 2.84$, $p < 0.02$, $d_z = 0.669$, and for objects stimuli, $t(17) = 7.28$, $p < 0.0001$, $d_z = 1.716$. The magnitude of adaptation for the two types of test stimuli was significantly correlated across participants, $r(16) = 0.568$, $p < 0.02$.

Unlike in experiment 1, however, the main effect of adaptation was modulated by an interaction with test stimulus type, $F_{1,17} = 48.06$, $p < 0.0001$, $\eta_p^2 = 0.739$. This interaction reflects the fact that the adaptation effect was substantially larger for object test stimuli than for stick. There was no main effect of test stimulus type, $F_{1,17} = 0.10$, $p = 0.75$, $\eta_p^2 = 0.006$.

A 2 × 2 ANOVA on the slopes of the psychometric functions revealed a significant main effect of test stimulus type, $F_{1,17} = 18.87$, $p < 0.001$, $\eta_p^2 = 0.526$. As in experiment 1, slopes were substantially higher for sticks than for objects. There was no main effect of adaptation, $F_{1,17} = 0.54$, $p = 0.473$, $\eta_p^2 = 0.031$, nor an interaction, $F_{1,17} = 1.07$, $p = 0.316$, $\eta_p^2 = .059$.

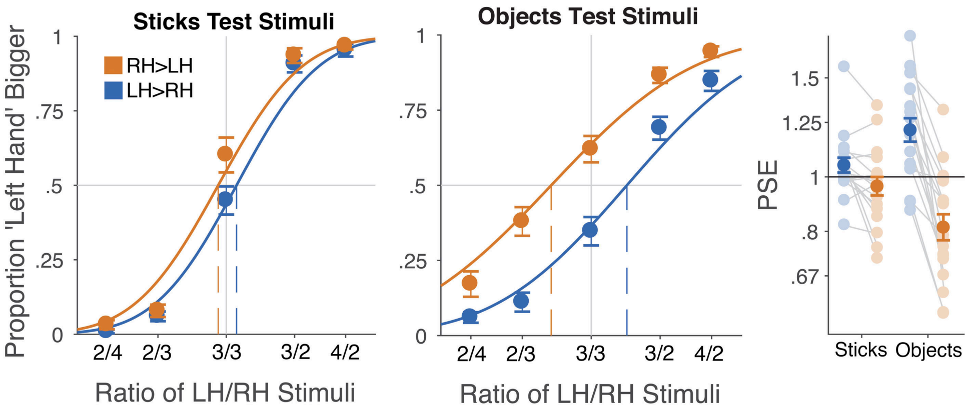

Figure 3. Results from experiment 2, in which the adapting stimuli were continuous objects. Two-point adaptation using objects induced aftereffects only for objects test stimuli. Blue lines represent the condition in which the left hand was adapted with a larger stimulus, whereas orange lines represent the condition in which the right hand was adapted with a larger stimulus. Curves are cumulative Gaussian functions. Error bars represent the ±s.e.m. Vertical lines represent PSEs.

4. General discussion

Our results demonstrate the presence of tactile distance aftereffect both when the adapting stimuli are sticks and when they are continuous objects. That is, after prolonged adaptation to a tactile distance, participants perceive subsequent smaller distances as being smaller than they actually are, and distances that are larger as being even wider than they are. In our study, this effect was evident for both sticks and continuous objects when adaptation was induced with sticks. In contrast, it was significantly stronger for objects than for sticks when the adaptation was induced with continuous objects. This suggests that the generalizability of the adaptation effect is determined by the type of stimulus used to adapt. Namely, it generalizes when sticks are used, but remains effector-specific when a continuous object is used as adapting stimuli. The distinct effects produced by the two types of induced adaptation suggest that different representational levels mediate these phenomena.

The tactile aftereffect observed when adapting with sticks aligns with previous findings by Calzolari *et al*. [17], who used a similar passive adaptive touch on the hands. Their study revealed a highly specific tactile aftereffect, which was orientation- and skin-region specific, with no transfer to the contralateral hand or between the palm and dorsum of the same hand. These characteristics led the authors to suggest that the effect arises at the early stages of the tactile perception process. Our findings extend these results by demonstrating generalization of the effect across different stimulation types (sticks and continuous objects). In line with the interpretation of Calzolari and colleagues [17], we propose that this generalization may derive from low-level changes in the primary somatosensory cortex (e.g. changes in tactile RF geometry). Therefore, these basic changes induced by adaptation to distance through two isolated touches persist during the processing of more complex stimuli, such as continuous objects, and directly influence their perception. Note that such a proposed explanation refers to both sticks and objects; however, in the case of objects, the effect is partially attenuated due to the richer information provided by the objects' contact with the skin that can be used by the somatosensory system to implement more effective mechanisms of size constancy [16,28], as discussed in more detail below.

This result aligns with recent findings by Jeschke *et al.* [29], demonstrating that adaptation to a distance through two isolated touches at the fingertip influences texture perception, particularly roughness. Interestingly, while our study manipulated object length, Jeschke *et al.* focused on the spacing between elements in gratings, specifically the inter-element distance.

Touch is processed at different stages [30,31] from primary somatosensation to higher-order representations (or somatoperception), following a hierarchical organization that contributes to somatic perceptual constancy. These different stages and their interactions are combined to give rise to the final tactile percept, with higher-order organizational principles shaping tactile perception while co-existing with low-level processing mechanisms [32]. In this framework, we suggest that such early stages in somatosensory processing directly influence subsequent perceptual processing.

The tactile aftereffect observed following adaptation with continuous objects exhibited greater specificity, with the adaptation aftereffect being significantly stronger for continuous objects (same) and reduced in magnitude for the sticks (different). This increased specificity may arise because with continuous objects, early stages of tactile processing play a less prominent role, as they are overshadowed by higher-order processing that derives from the richer set of information coming from the stimulus, such as edges and a greater skin surface engagement. Supporting this view, van der Horst and colleagues [33], in a haptic experiment in humans, have shown that a dynamic curvature aftereffect is transferred between the hands, suggesting that dynamically obtained curvature information (i.e. complex tactile stimuli) is represented at a high level of tactile representation processing. In line with this notion, it has been proposed [16] that, unlike a focal touch (i.e. stick), an object that is touching the skin surface provides a much richer sensory input. Such additional input is most likely to be used by the somatosensory system to implement more effective mechanisms of size constancy. These mechanisms would allow a more truthful representation of the stimuli, reducing the low-level distortions that derive from the nature of our receptors, such as the varying size and shape of the tactile RFs. As discussed by Tamè *et al.* [16], a plausible hypothesis is that when an object, rather than a stick, contacts the skin, background information from a lateral inhibition mechanism triggers a process in which tactile RFs, which are actually distorted on the hand dorsum, change shape, reducing their natural oval shape and becoming more circular. Indeed, it is known that lateral inhibition plays an important role in the perception of objects on the skin [28]. This suggests that one consequence of lateral inhibition is to make tactile RFs more circular than they would otherwise be. This can be considered a natural potential mechanism of size constancy.

The reduced magnitude of the aftereffect when testing with the sticks after object adaptation may derive from the inability to access higher-level information that was previously present during object adaptation. It is also reasonable to assert that higher-level processes are less likely to modulate low-level representations because of the hierarchical principle that governs somatosensory processing, at least in the present context of distance estimation during passive touch. Therefore, we suggest that sticks and continuous objects are mediated by distinct representations that occur at different levels within the tactile processing hierarchy.

Ethics. Procedures were approved by the Department of Psychological Sciences Research Ethics Committee at Birkbeck (Ethic ID: 171887) and University of Kent (Ethic ID: 202116329106027301) committees for research on human subjects, and were consistent with the principles of the Declaration of Helsinki.

Data accessibility. Experimental scripts, raw data and analysis scripts are available on the Open Science Framework [27].

Declaration of AI use. We have not used AI-assisted technologies in creating this article.

Authors' contributions. L.T.: conceptualization, data curation, project administration, supervision, writing—original draft, writing—review and editing; N.K.: investigation; K.A.: investigation; M.R.L.: conceptualization, formal analysis, resources, visualization, writing—original draft, writing—review and editing; E.A.: conceptualization, formal analysis, software, writing—original draft, writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Conflict of interest declaration. We declare we have no competing interests.

Funding. Experiment 1 was supported by a grant from the European Research Council (ERC2013-StG-336050) under the FP7 to M.R.L.

References

1. Longo MR. 2022 Distortion of mental body representations. *Trends Cogn. Sci.* **26**, 241–254. (doi:10.1016/j.tics.2021.11.005)
2. Weber EH. 1996 De subtilitate tactus. In *E. H. Weber on the tactile senses* (eds HE Ross, DJ Murray), pp. 21–128. London, UK: Academic Press.
3. Longo MR, Haggard P. 2011 Weber's illusion and body shape: anisotropy of tactile size perception on the hand. *J. Exp. Psychol. Hum. Percept. Perform.* **37**, 720–726. (doi:10.1037/a0021921)
4. Green BG. 1982 The perception of distance and location for dual tactile pressures. *Percept. Psychophys.* **31**, 315–323. (doi:10.3758/bf03202654)
5. Chang KC, Longo MR. 2022 Similar tactile distance anisotropy across segments of the arm. *Perception* **51**, 300–312. (doi:10.1177/03010066221088164)
6. Manser-Smith K, Tamè L, Longo MR. 2021 Tactile distance anisotropy on the feet. *Atten. Percept. Psychophys.* **83**, 3227–3239. (doi:10.3758/s13414-021-02339-5)
7. Tosi G, Romano D. 2020 The longer the reference, the shorter the legs: how response modality affects body perception. *Atten. Percept. Psychophys.* **82**, 3737–3749. (doi:10.3758/s13414-020-02074-3)
8. Longo MR, Ghosh A, Yahya T. 2015 Bilateral symmetry of distortions of tactile size perception. *Perception* **44**, 1251–1262. (doi:10.1177/0301006615594949)
9. Longo MR, Amoruso E, Calzolari E, Ben Yehuda M, Haggard P, Azañón E. 2020 Anisotropies of tactile distance perception on the face. *Atten. Percept. Psychophys.* **82**, 3636–3647. (doi:10.3758/s13414-020-02079-y)
10. Fiori F, Longo MR. 2018 Tactile distance illusions reflect a coherent stretch of tactile space. *Proc. Natl Acad. Sci. USA* **115**, 1238–1243. (doi:10.1073/pnas.1715123115)
11. Chalmers R, Longo MR. 2025 Tactile distance anisotropy on the tongue. *Q. J. Exp. Psychol.* 17470218251330597. (doi:10.1177/17470218251330597)
12. Taylor-Clarke M, Jacobsen P, Haggard P. 2004 Keeping the world a constant size: object constancy in human touch. *Nat. Neurosci.* **7**, 219–220. (doi:10.1038/nn1199)
13. Longo MR. 2017 Distorted body representations in healthy cognition. *Q. J. Exp. Psychol.* **70**, 378–388. (doi:10.1080/17470218.2016.1143956)
14. Klatzky RL, Lederman SJ, Metzger VA. 1985 Identifying objects by touch: an 'expert system'. *Percept. Psychophys.* **37**, 299–302. (doi:10.3758/bf03211351)
15. Lederman SJ, Klatzky RL. 1990 Haptic classification of common objects: knowledge-driven exploration. *Cogn. Psychol.* **22**, 421–459. (doi:10.1016/0010-0285(90)90009-s)
16. Tamè L, Limbu S, Harlow R, Parikh M, Longo MR. 2022 Size constancy mechanisms: empirical evidence from touch. *Vision* **6**, 40. (doi:10.3390/vision6030040)
17. Calzolari E, Azañón E, Danvers M, Vallar G, Longo MR. 2017 Adaptation aftereffects reveal that tactile distance is a basic somatosensory feature. *Proc. Natl Acad. Sci. USA* **114**, 4555–4560. (doi:10.1073/pnas.1614979114)
18. Uznadze D. 1966 *The psychology of set*. New York, NY: Consultants Bureau.
19. Maravita A. 1997 Implicit processing of somatosensory stimuli disclosed by a perceptual after-effect. *Neuroreport* **8**, 1671–1674. (doi:10.1097/00001756-199705060-00022)
20. Frisco F, Daneyko O, Maravita A, Zavagno D. 2023 The influence of arm posture on the Uznadze haptic aftereffect. *J. Exp. Psychol. Hum. Percept. Perform.* **49**, 1271–1279. (doi:10.1037/xhp0001144)
21. Hidaka S, Tucciarelli R, Yusuf S, Memmolo F, Rajapakse S, Azañón E, Longo MR. 2024 Haptic touch modulates size adaptation aftereffects on the hand. *J. Exp. Psychol. Hum. Percept. Perform.* **50**, 989–999. (doi:10.1037/xhp0001231)
22. Hidaka S, Tucciarelli R, Azañón E, Longo MR. 2020 Tactile distance adaptation aftereffects do not transfer to perceptual hand maps. *Acta Psychol.* **208**, 103090. (doi:10.1016/j.actpsy.2020.103090)
23. Oldfield RC. 1971 The assessment and analysis of handedness: the Edinburgh Inventory. *Neuropsychologia* **9**, 97–113. (doi:10.1016/0028-3932(71)90067-4)
24. Faul F, Erdfelder E, Lang AG, Buchner A. 2007 G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* **39**, 175–191. (doi:10.3758/bf03193146)
25. Hidaka S, Tamè L, Zafarana A, Longo MR. 2020 Anisotropy in tactile time perception. *Cortex.* **128**, 124–131. (doi:10.1016/j.cortex.2020.03.011)
26. Prins N, Kingdom FAA. 2018 Applying the model-comparison approach to test specific research hypotheses in psychophysical research using the Palamedes Toolbox. *Front. Psychol.* **9**, 1250. (doi:10.3389/fpsyg.2018.01250)
27. Tamè L, Khan N, Allarakhia K, Longo MR, Azanon E. 2025 Tactile adaptation transfers between distance and continuous size. See https://osf.io/yc63m/overview?view_only=abfa1eb5caa24f1b8724e802d18ee5b9.
28. von Békésy G. 1967 *Sensory inhibition*. Princeton, NJ: Princeton University Press.

29. Jeschke M, Drewing K, Azañón E. 2023 The tactile distance aftereffect transfers to roughness perception. In *2023 IEEE world haptics conference (WHC)*, Delft, The Netherlands, pp. 8–13. IEEE. (doi:10.1109/WHC56415.2023.10224476)

30. Tamè L, Azañón E, Longo M. 2019 A conceptual model of tactile processing across body features of size, shape, side, and spatial location. *Front. Psychol.* **10**, 291. (doi:10.3389/fpsyg.2019.00291)

31. Longo MR, Azañón E, Haggard P. 2010 More than skin deep: body representation beyond primary somatosensory cortex. *Neuropsychologia* **48**, 655–668. (doi:10.1016/j.neuropsychologia.2009.08.022)

32. Tamè L, Longo MR. 2023 Emerging principles in functional representations of touch. *Nat. Rev. Psychol.* **2**, 459–471. (doi:10.1038/s44159-023-00197-6)

33. van der Horst BJ, Willebrands WP, Kappers AML. 2008 Transfer of the curvature aftereffect in dynamic touch. *Neuropsychologia* **46**, 2966–2972. (doi:10.1016/j.neuropsychologia.2008.06.003)