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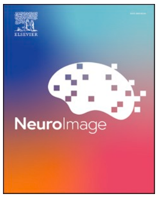

The somatosensory side of the affordance: How seeing an object influences touch

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ABSTRACT

Object perception is inherently multisensory, as the brain integrates information across sensory modalities to facilitate the interaction with them. This intrinsic 'action potential' of objects is described by the concept of affordance, which refers to the opportunities for interaction that an object offers to an organism, depending on both the object's physical characteristics and the organism's sensorimotor abilities. Converging evidence demonstrated that seeing affordable objects modulates motor activity. Coherently, viewing graspable objects can also induce a somatosensory activation associated with their tactile manipulation. Yet, little is known about the representation of affordances in the somatosensory system. Here, we investigated whether visual perception of affordable objects modulates somatosensory evoked activity. Participants viewed images of affordable and non-affordable objects, while concomitantly probing the somatosensory system with tactile stimuli delivered to both index fingers. We found that viewing graspable objects enhances somatosensory processing, as indicated by higher somatosensory evoked potentials to tactile stimuli when paired with images of affordable objects compared to non-affordable objects.

These findings suggest that the observation of affordable objects triggers somatosensory responses associated with potential actions, supporting the view that object perception is a dynamic multisensory process. In everyday interactions, objects like cups are consistently grasped, leading to the formation of strong multisensory associations between objects' visual features and tactile afferences. Once well-established, these associations may allow vision alone to activate stored tactile representations, enhancing somatosensory engagement, as observed in our study.

1. Introduction

In recent decades, the understanding of the relationship between perception and action underwent a profound paradigm shift. Traditionally, perception was conceived as an input system accumulating sensory information from the environment, while action was considered as an output system producing motor responses relying on this information. However, converging evidence in the last two decades demonstrated that action and perception are not independent processes but are mutually connected in a dynamic, bidirectional system (Garbarini and Adenzato, 2004; Lakoff, 2012; Lakoff and Johnson, 1999; Wilson, 2002). As a result, "we must perceive in order to move, but we must also move in order to perceive" (Gibson, 1979), so that, rather than being an epiphenomenon of perception, action itself plays a direct role in shaping perceptual experience. This perspective represents the foundation of the concept of affordances, defined as the opportunities for interaction that an object offers an organism, depending on both the object's physical characteristics and the organism's sensorimotor abilities (Gibson, 1979). For instance, an apple affords grasping for an animal with hands, while for a limbless creature, such as the caterpillar, it may afford crawling over or occupying it. Affordances thus constitute a direct link between perception and action, highlighting the way organisms perceive the world in terms of possible motor interactions rather than passive sensory inputs.

Converging neurophysiological evidence from both non-human as well as human primates provided empirical evidence in support of the

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concept of affordance, demonstrating that merely observing affordable objects activates corresponding motor representations (for reviews, see Rizzolatti and Fogassi, 2014; Sakreida et al., 2016). In non-human primates, this is proved by the discovery of canonical neurons that encode the motor potential of visual objects (Bonini et al., 2014; di Pellegrino et al., 1992; Gallese et al., 1996; Rizzolatti et al., 1996), thus offering a direct neurophysiological basis for the affordance hypothesis (Garbarini and Adenzato, 2004).

Indeed, these bimodal visuo-motor neurons discharge not only when the monkey actively grasps affordable objects, but also when it merely sees them, often showing a similar visual and motor selectivity for a specific object. For instance, neurons coding for precision grip fire when observing small objects, whereas neurons coding for power grip are activated when looking at larger objects (Murata et al., 2000). In human primates, a series of studies described the presence of compatibility effects between response components and visual object properties, in terms of alignment (Ellis and Tucker, 2000), orientation (Bub et al., 2015; Derbyshire et al., 2006), size (Ellis and Tucker, 2000), and position in space (Costantini et al., 2011, 2010; Ruggiero et al., 2024). This effect, reflected in faster reaction times when participants execute a motor act congruent with that afforded by a seen object, paralleled by neuroimaging evidence (Buccino et al., 2009; Cardellicchio et al., 2011; Creem-Regehr and Lee, 2005; Mustile et al., 2021; Proverbio, 2012; Rowe et al., 2017a), confirms the existence of affordances-related mechanism also in the human brain.

While extensive research has demonstrated the motor system's involvement in affordance processing, less attention has been paid to the role of the somatosensory system (Proverbio et al., 2011; Smith and Goodale, 2015; Sun et al., 2016). Coherently, viewing affordable objects can also modulate somatosensory processing associated with their manipulation. Indeed, when seeing and manipulating an object, the brain learns to associate its visual features with the corresponding tactile afferences. Over time, this coupling becomes automatic, and, as a result, merely viewing an affordable object may enhance somatosensory processing. It must be recognized that non-affordable objects, such as houses, can also be touched. However, not all tactile experiences are equal in terms of motor relevance. What distinguishes affordable objects is not merely their tactile accessibility, but their potential for goal-directed, object-specific actions, such as grasping, lifting, or manipulating. A house, for instance, while touchable, does not afford immediate interaction in the same way a cup does.

In the present electrophysiological (EEG) study, we investigated whether seeing affordable objects can specifically evoke neural activations in somatosensory cortex, by leveraging a robust and validated EEG protocol that allows to unveil the role of somatosensory information during the perception of visual stimuli (Arslanova et al., 2023, 2019; Fanghella et al., 2022; Forster and Abad-Hernando, 2024; Galigani et al., 2025; Galvez-Pol et al., 2020; A. 2018a; Sel et al., 2020). In our study, we presented images of affordable and non-affordable objects that, in half of the trials, were coupled with tactile probes. Differences in somatosensory evoked potentials (where tactile stimulation is identical between conditions) should directly reflect the differential modulation over somatosensory activity induced by the visual content (images of affordable and non-affordable objects). Accordingly, we predict that, if viewing affordable object selectively activates the somatosensory system, we should observe higher somatosensory evoked activity when probing the somatosensory system during the presentation of images of affordable than non-affordable objects.

2. Materials and method

2.1. Participants

Eighteen volunteers participated in a single 2.5-h session (mean age ± SD = 26.44 ± 3.13 years, 11 females). All participants had normal (self-reported) or corrected to normal vision and were right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971). All participants signed the informed consent, and the studied conformed to the standards required by the Declaration of Helsinki and was approved by the Ethics Committee of the University of Torino (prot. n. 122,572). The size of the samples was decided in accordance with previous studies employing the same experimental protocol (e.g., Arslanova et al., 2023, 2019; Fanghella et al., 2022; Sel et al., 2020). However, we acknowledge that recent developments in the field emphasize the need for larger samples to increase statistical power and improve the precision of effect estimates. As such, while our findings contribute to the growing literature on affordances, they should be interpreted with caution regarding their generalizability. The limited sample size may affect the robustness of the observed effects, and future studies employing larger and more diverse samples are necessary to confirm and extend these findings (Simons et al., 2017).

2.2. Experimental procedure

EEG was recorded while participants were presented with pictures depicting images of affordable (i.e., a cup with its handle facing left) and non-affordable (i.e., a house with the chimney facing left) objects, which were either blue or red (Fig. 1A). Participants viewed visual stimuli either alone (visual-only trials) or, in half of the trials, combined with a brief task-irrelevant tactile stimulation delivered to both hands (visuo-tactile trials). Each image (20 * 15 cm) was presented for 300 ms, with an intertrial interval ranging from 3.5 to 4.5 s. Overall, participants performed a total of 768 trials: this equals 384 trials (192 visual-only and 192 visuo-tactile) for each condition (cup and house images; there was an equal number of red and blue stimuli). The experiment was composed of eight 8-minutes recording blocks, and each block consisted of 96 pairs of trials (half of them was visual-only and the other half visuo-tactile). Tactile stimulations were brief (200 μs) transcutaneous electrical stimuli consisting in constant current square-wave pulses (DS7A, Digitimer) delivered using two separate stimulators (DS7A, Digitimer), one for each hand (Del Vecchio et al., 2021; Fossataro et al., 2020). Stimulation was applied to the dorsum of the index finger of both hands to investigate the contribution of both hemispheres. Each hand was equipped with a pair of cup electrodes (positive and negative), ensuring that the electrical circuit was completed locally within each hand. The stimulation intensity was adjusted according to the individual sensory threshold (estimated using the methods of limits (Gescheider, 1997). The mean (± SD) bilateral threshold stimulus intensity was 3.72 ± 1.09 mA. During the experiment, the stimulation intensity was set slightly above the threshold (stimulation intensity = threshold intensity*2), so that participants consistently perceived the tactile stimulation throughout the experiment, which was never painful (see e.g. Fossataro et al., 2023; Galigani et al., 2020; Ronga et al., 2021a). To simplify the experimental design and avoid the presence of an additional factor (i.e., orientation side) that would have required a double number of trials, we chose to present all visual stimuli (i.e., the cup and the house) with a consistent left-facing orientation. Furthermore, by orienting the handle of the cup to the left, we aimed to minimize the influence of manual dominance, given that all participants were right-handed. Since all participants were right-handed, presenting the handle to the dominant side could have confounded affordance-related effects with stronger motor associations or more robust cortical representations typical of the dominant hand (e.g., Proverbio et al., 2013; Rowe et al., 2017). In contrast, presenting the handle to the non-dominant side (left) makes it easier to interpret any observed lateralized activation: if stronger responses emerge in the right hemisphere, this would more likely reflect an affordance effect tied to the handle's orientation, rather than mere manual dominance. Once the visual orientation was fixed to one side, we delivered tactile stimulation bilaterally to both hands. This allowed us to engage somatosensory cortices in both hemispheres and assess whether the affordance-related modulation was lateralized (i.e., stronger contralateral to the handle) or

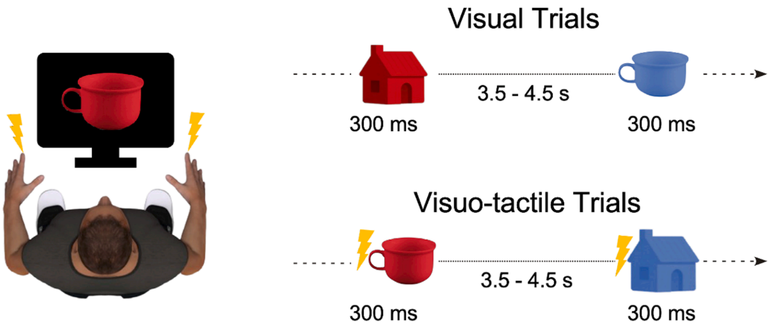

Fig. 1. Experimental paradigm. Visual stimuli represented images of affordable (i.e., a cup) and non-affordable (i.e., a house). Each image was presented for 300 ms, with an intertrial interval ranging from 3.5 to 4.5 s. In half of the trials tactile stimulation to both index fingers was administered at the onset of visual stimuli. The lightning represents the tactile stimulus.

instead more broadly distributed.

Paradigm presentation was controlled and by Eprime V2.0 software (Psychology Software Tools Inc., Pittsburgh, PA, USA). Tactile stimulus delivering was managed by Eprime and directly controlled by an Arduino © platform, which was connected to the two Digitimer DS7A via two BNC cables.

To ensure participants' attention remained on the visual stimuli, they performed an orthogonal task, verbally reporting the image color around one second after the image disappeared from the screen by saying 'b' for blue and 'r' for red. Crucially, the mean of accuracy percentage rates demonstrates that participant focused their attention on the presented visual stimuli in both conditions (mean ± SD: cup = 99.957 ± 0.099, house = 99.971 ± 0.123).

2.3. Electrophysiological recording

Participants were seated in a sound attenuated, dimly lit room, at a distance of about 80 cm from the computer. EEG were recorded using 32 Ag- AgCl electrodes mounted on the scalp according to the International 10–20 system and referenced to the nose. Electrode impedances were kept below 5 kΩ. To track ocular movements and eye blinks, the electrooculogram was recorded placing two surface electrodes, one placed over the right lower eyelid and the other placed lateral to the outer canthus of the right eye. Continuous EEG was recorded using a *HandyEEG-SystemPLUS Evolution* amplifier (Micromed) and a 1024 Hz sampling rate.

EEG data were pre-processed using Letswave v.6 (http://www.nocions.org/letswave/). The EEG signal was band-pass filtered (0.05–30 Hz) using a fast Butterworth filter (4th order) and then epoched into segments lasting from 1000 ms before to 1000 ms after the image onset. Segments were then baseline corrected to the first 100 ms before the stimulus. Artifacts due to eye blinks and eye movements were removed using a validated method based on an Independent Component Analysis (ICA- Jung et al., 2000). Blinks were found to be the most frequent cause of rejection. Finally, grand averages were computed separately for each condition (Cup and House condition) and for visual-only and visuo-tactile trials.

2.4. Data analysis

To unveil the modulation of somatosensory activity induced by the visual content, we applied the method proposed by Galvez-Pol and colleagues (2020, 2021) and extensively validated and replicated (Arslanova et al., 2023, 2019;4 Fanghella et al., 2022; Forster and Abad-Hernando, 2024; A. Galvez-Pol et al., 2018, 2018; Sel et al., 2020). According to this method, we subtracted activity elicited by visual-only trials from activity elicited by visuo-tactile trials (i.e., visuo-tactile minus visual-only). By performing this subtraction, thus removing the propagation of visual evoked potentials on the scalp, we can observe how visual contents (i.e., images of affordable and non-affordable objects) modulate somatosensory processing, over and above carry-over effects (Arslanova et al., 2023, 2019; Fanghella et al., 2022; Forster and Abad-Hernando, 2024; A. Galvez-Pol et al., 2018, 2018; Sel et al., 2020). Furthermore, beyond tactile activity (i.e., visuo-tactile minus visual-only), we also separately analyzed the EEG activity elicited by visual-tactile and visual trials.

To compare the event-related potentials in the different conditions, we performed point-by-point *t*-tests corrected with 1000 permutations between Cup and House conditions. Point-by-point analysis allow us to quantify possible effects at all time points and electrodes, thus assessing the specificity of the effect. Point-by-point analyses represent a statistical approach common in EEG studies (Bruno et al., 2020; Galigani et al., 2021; Harris et al., 2018; Novembre et al., 2018; Ronga et al., 2021a; Sarasso et al., 2022) directed to highlight significantly different event-related potentials time windows among different experimental conditions. They allow to point out significant amplitude differences and possible latency shifts at the same time, since both are captured by divergent responses distributions across time. Since this statistical approach is based on one comparison per time point, this raises the problem of multiple comparisons. To face this issue, a cluster-based non-parametric test statistic was performed (1000 random permutations; alpha level=0.05; percentile of mean cluster sum set as threshold=95) (Maris and Oostenveld, 2007). Permutation testing is based on temporal adjacency and yields the identification of significantly different time point clusters between conditions for each channel. More specifically, we employed permutation testing as implemented in Letswave6 toolbox (Nocions, Louvain, Belgium) for Matlab (Mathworks, Natick, MA), based on (Maris and Oostenveld, 2007). The toolbox compares the EEG signal of different conditions by means of a t-value. Then, all samples whose t-value is greater than threshold are clustered in connected sets on the basis of temporal adjacency (i.e., time-windows) and, after computing the sum of the t-values within each time-window, cluster level statistics are calculated by selecting the largest of the time-windows statistics, i.e., this method selects the portion of the curves in which the difference between conditions is significant for the greatest number of adjacent points. Then, the statistical test is performed by calculating a p-value under the permutation distribution and comparing it with the critical alpha level. The permutation distribution is obtained by randomly permuting the participant-specific average waveforms in the different conditions within every participant for 1000 times and, after the test statistic is calculated for each random partition, a histogram of the random partitions' test statistics is created. From the test statistic that was actually observed, and the histogram obtained from random partitions' test statistics, the proportion of random partitions that results in a larger test statistic than the observed one is calculated. This proportion is the p-value under the permutation distribution. If the p-value is smaller than the critical alpha level, then the datasets in the experimental conditions are considered as significantly different.

3. Results

The point-by-point analysis run over tactile activity (obtained by subtracting visual from visuo-tactile activity (i.e., visuo-tactile minus visual-only) revealed a higher amplitude of somatosensory responses over centro-parietal electrodes in response to affordable than non-affordable objects (Fig. 2). Indeed, tactile stimuli simultaneously presented with images depicting cups evoked higher activity as compared to tactile stimuli simultaneously presented with images depicting houses, and such effect was maximal over the right hemisphere (contralateral to the cup handle orientation) (encompassing Cz, C3, Cp1, P3, Pz, C4, Cp2, Cp6, P4; maximal over Cp2: 217–283 ms, $t_{17}=3.724$, $p = 0.002$).

Interestingly, the same differential effect was evident at a similar latency even while analysing EEG responses to bimodal stimulation. Indeed, the point-by-point analysis run on visual-tactile trials revealed higher EEG activity in affordable than non-affordable condition over a fronto-centro-parietal cluster in a later latency (encompassing electrodes from Fpz to Pz over both hemispheres; maximal over Cp2: 228–298 ms, $t_{17}=4.964$, $p < 0.001$) (Fig. 3). However, at earlier latency, in visuo-tactile trials we also observed an opposite pattern, with higher EEG activity in non-affordable than affordable condition over a spread centro-parieto-occipital cluster (encompassing electrodes from Fcz to Oz over both hemispheres; maximal over Cz: 112–193 ms, $t_{17}=-4.478$, $p < 0.001$) (Fig. 3). This differential effect at earlier latency likely represents a carry-over effect of visual responses over somatosensory cortices, with non-graspable objects eliciting greater visual responses possibly due to higher perceptual complexity (e.g., more edges or features of the house than the cup). Indeed, the analysis of visual-only trials revealed higher responses to non-affordable (more complex) than affordable objects over a spread cluster including central, parietal, and occipital sensors at the same latency (encompassing electrodes from Fcz to Oz over both hemispheres; maximal over P8: 103–160 ms, $t_{17} = -4.515$, $p < 0.001$) (Fig. 4).

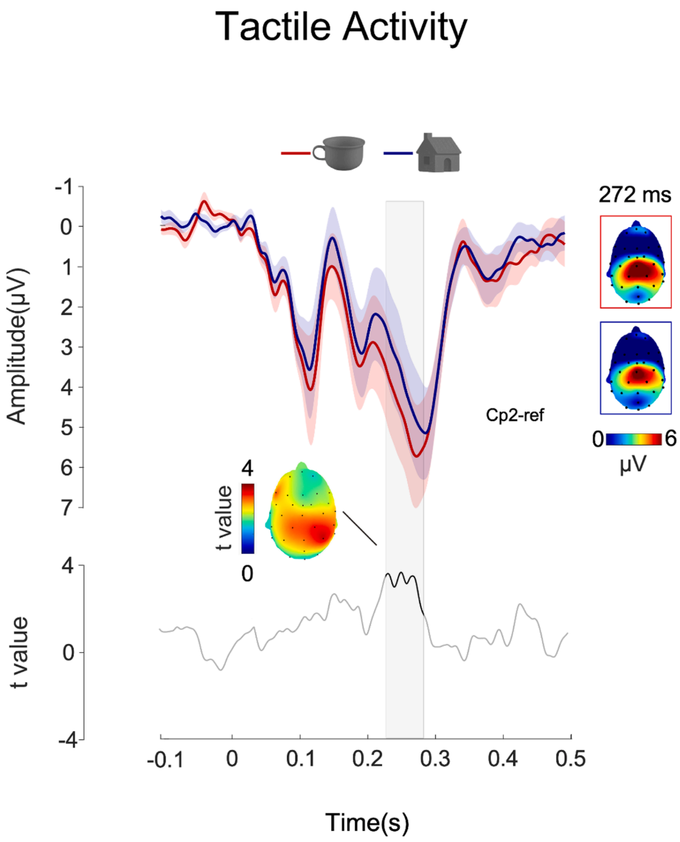

Fig. 2. Tactile activity. The panel represents visually-driven tactile activity (generated by subtracting visual-only from visuo-tactile trials; i.e., visuo-tactile minus visual-only) in response to images depicting affordable (cups) and non-affordable (houses) objects. We performed a point-by-point analysis that allowed to quantify possible effects at all time points and electrodes. Time window with significantly different event-related potentials is highlighted by the grey bar. Significant differences emerged in a time-window encompassing the P300 component, with effects observed in the positive ascending portion of the waveform around 300 ms post-stimulus. T values appear below waveforms; scalp distribution of effects is shown on topographical t maps. Current Source Density (CSD) maps for peak latencies within the significant range are also displayed. Shaded areas represent event-related potentials sem.

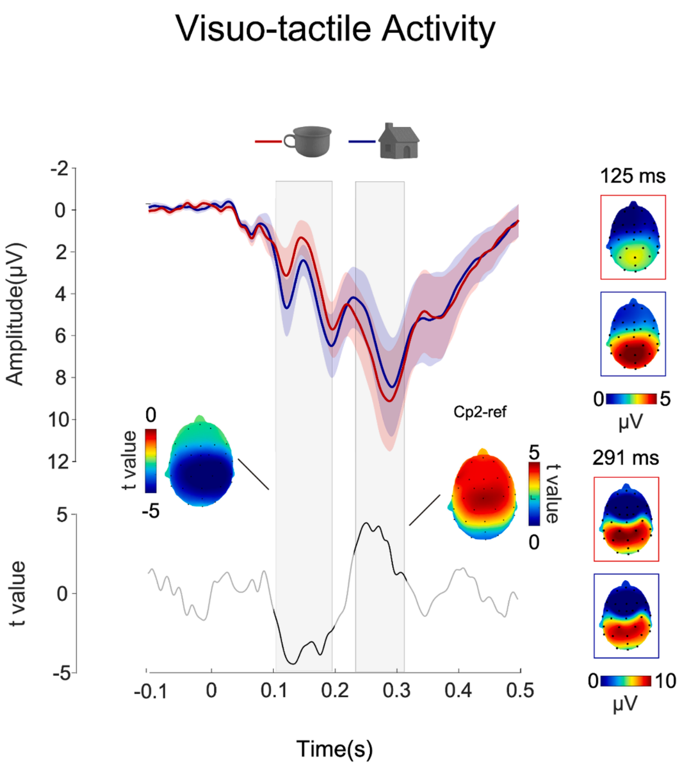

Fig. 3. Visuo-tactile activity. The panel represents visuo-tactile activity elicited by the simultaneous presentation of tactile stimuli and images depicting affordable (cups) and non-affordable (houses) objects. We performed a point-by-point analysis that allowed to quantify possible effects at all time points and electrodes. Time windows with significantly different event-related potentials are highlighted by grey bars. Significant differences emerged in time-windows encompassing the P100–P200 and P300 components, with effects observed in the positive ascending portion of the waveform between 100 and 200 ms and around 300 ms post-stimulus, respectively. T values appear below waveforms; scalp distribution of effects is shown on topographical t maps. CSD maps for peak latencies within the significant range are also displayed. Shaded areas represent event-related potentials sem.

4. Discussion

In the present study, we investigated whether the visual perception of affordable objects can modulate somatosensory processing. While previous research has largely focused on the motor aspects of affordance processing, showing that simply observing graspable objects can activate motor-related cortical regions in the human (Buccino et al., 2009; Cardellicchio et al., 2011; Costantini et al., 2011, 2010; Derbyshire et al., 2006; Ellis and Tucker, 2000; Grèzes and Decety, 2002) and the monkey brain (e.g., Bonini et al., 2014; di Pellegrino et al., 1992; Gallese et al., 1996; Murata et al., 2000; Rizzolatti and Fogassi, 2014), there is little evidence about how visual perception of affordable objects

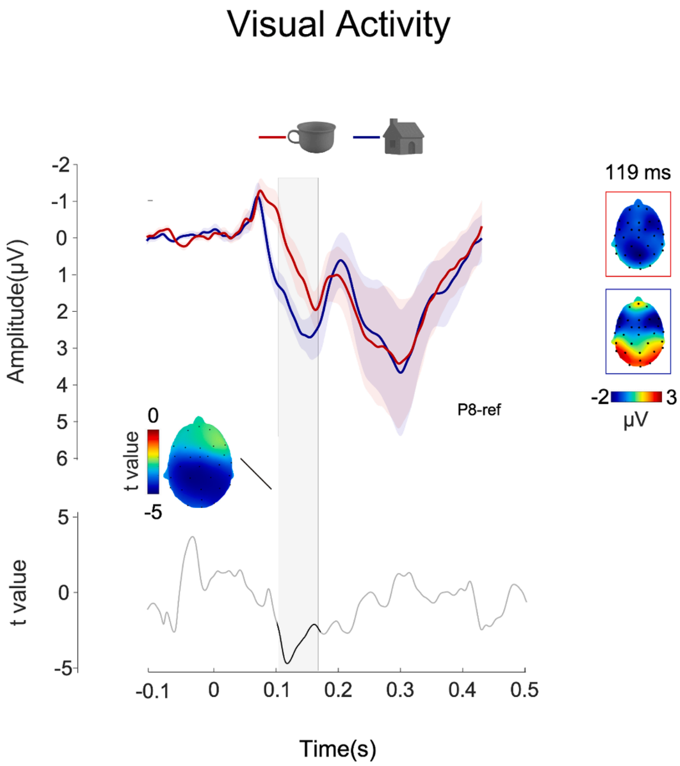

Fig. 4. Visual activity. The panel represents visual activity elicited by images depicting affordable (cups) and non-affordable (houses) objects. We performed a point-by-point analysis that allowed to quantify possible effects at all time points and electrodes. Time window with significantly different event-related potentials is highlighted by the grey bar. Significant differences emerged in a time-window encompassing the P100 component, with effects observed in the positive portion of the waveform around 100 ms post-stimulus, T values appear below waveforms; scalp distribution of effects is shown on topographical t maps. CSD maps for peak latencies within the significant range are also displayed. Shaded areas represent event-related potentials sem.

modulates somatosensory responses. We hypothesized that seeing objects affording action, such as graspable items, could trigger somatosensory responses typically associated with their manipulation. Consistent with this prediction, our findings reveal that the somatosensory system is indeed modulated by object affordances, responding more strongly to tactile input when paired with images of affordable than non-affordable objects.

Crucially, by employing a validated EEG protocol designed to investigate the modulation of somatosensory responses induced by the visual content (Arslanova et al., 2019; Fanghella et al., 2022; Forster and Abad-Hernando, 2024; A. Galvez-Pol et al., 2018; Galvez-Pol et al., 2020), we presented images of affordable (i.e., cup) and non-affordable (i.e., house), while concomitantly delivering tactile probes to both index fingers. We found that viewing an object that affords grasping actions enhanced somatosensory activity with respect to a non-affordable object, thus suggesting that affordable objects are specifically represented within the somatosensory system. Importantly, this somatosensory enhancement emerged even though the tactile input was physically identical across conditions, thus demonstrating that the modulation was driven by the visual characteristics and affordances of the presented image.

In more detail, while analysing subtracted trials (visuo-tactile minus visual-only), we observed significant modulations of somatosensory responses at around 220 ms, with tactile probes simultaneously presented with images depicting cups that evoked increased somatosensory responses as compared to tactile probes simultaneously presented with images depicting houses. By contrast, while performing separated analyses on both visuo-tactile and visual-only trials, early differences observed in the same latency within around 100–200 ms are likely attributable to low-level visual properties of the stimuli, with non-graspable objects eliciting greater visual responses possibly due to higher perceptual complexity (e.g., more edges or features). Indeed, several evidence has shown that visual stimuli with greater perceptual complexity evoke stronger neural responses, likely due to increased demands on feature detection (Bányai et al., 2019; Bonacci et al., 2020; Bradley et al., 2007; Müller et al., 2003; Shigeto et al., 2011). Such visual activity is known to propagate beyond occipital cortices and can mask concurrent activity in sensorimotor regions (Ganis et al., 2016; Schadow et al., 2007). In this light, the enhanced activation observed for non-graspable stimulus (i.e., the house) in visual-tactile and visual activity may be explained by its greater perceptual richness or feature density compared to the graspable object (i.e., the cup), which had a simpler and more uniform visual structure. Crucially, by applying the subtraction method proposed by Gálvez-Pol and colleagues (2020), we were able to dissociate these overlapping sources and investigate how affordances modulate tactile processing. Specifically, subtracting the visual-only signal from the visuo-tactile condition allowed us to describe somatosensory responses to graspable objects at around 220 ms, over and above the visual carry-over effect. Interestingly, this affordance-driven effect at a middle-late latency may be coherent with the involvement of secondary somatosensory and multisensory regions (Bernasconi et al., 2018; Fossataro et al., 2023; Ronga et al., 2021b). Indeed, at around 220 ms after the presentation of tactile stimuli, their processing already engaged the primary somatosensory cortex and spread to secondary somatosensory cortex and multisensory areas (whose activity is revealed by middle-late components of somatosensory evoked potential). This result is in line with previous evidence from intracortical recording in human (Del Vecchio et al., 2020) and non-human (Hihara et al., 2015) primates, which described the visual responsiveness of the secondary somatosensory cortex to the observation of actions involving haptic control, also extending it to the observation of static graspable objects.

Furthermore, these electrophysiological effects were more pronounced over the right hemisphere, consistent with the contralateral organization of somatosensory processing relative to the orientation of the cup handle (oriented to the left). This lateralized pattern also aligns with evidence in the motor domain indicating that viewing graspable objects modulates motor-related activity in the hemisphere contralateral to the afforded hand. Accordingly, neuroimaging and transcranial magnetic studies have demonstrated increased BOLD activity in motor areas and increased corticospinal excitability in response to graspable objects, in particular in the hemisphere contralateral to the hand involved in the possible interaction with the object (Cardellicchio et al., 2012, 2011; Cattaneoet al., 2010; Grèzes and Decety, 2002). Hence, these findings support the notion that the perception of affordances in objects, such as the orientation of a handle, can automatically engage not only motor but also somatosensory systems in a lateralized way. While both the cup and the house were lateralized to the left to ensure comparable visual configurations, we acknowledge that the lateralization of the house (via the chimney) could be less visually salient than that of the cup's handle. This difference may have contributed to the more lateralized EEG response observed for the cup. Future studies may benefit from using control objects with more pronounced lateral features to better match the visual orientation of affordable stimuli and to more clearly isolate affordance-related effects. Additionally, presenting affordable objects in both left- and right-oriented versions could further clarify the specific contribution of stimulus lateralization to the observed neural effects.

In this context, our findings reveal that the somatosensory system is activated by the observation of affordable objects, thus providing evidence of the existence of a tactile counterpart of motor affordances (Gibson, 1979). While previous research has highlighted the reciprocal and often inhibitory interactions between the motor and somatosensory systems (Chapman et al., 1987; Juravle et al., 2013; Peters et al., 2025; Rossi et al., 1998; Tamè et al., 2015; Tokimura et al., 2000), making it plausible that the mere visual presentation of an object, by activating the motor system, could lead to a suppression of somatosensory activity, our results point in the opposite direction. Specifically, they are consistent with an interpretation in which somatosensory engagement is enhanced through the anticipation of tactile consequences associated with potential interaction. Indeed, aligning with preliminary evidence (Proverbio, 2012; Proverbio et al., 2011; Smith and Goodale, 2015; Sun et al., 2016), the fact that somatosensory activity is selectively modulated when viewing an object that implies an action involving tactile feedback demonstrates that objects are perceived not only based on the actions they afford, but also in terms of the tactile sensations associated with these actions. The neural foundations of this phenomenon are identifiable in Hebbian learning mechanisms and rooted in the everyday experience (see e.g., De Klerk et al., 2021; Keysers and Gazzola, 2014). Indeed, in the motor context we continuously associate the visual features of objects with tactile afferences originating by their manipulation. Once such associative mechanism becomes well-established, visual exposure to affordable objects may activate stored representations of their typical tactile properties (Galvez-Pol et al., 2018b; Guidali et al., 2020), inducing the increased somatosensory engagement.

In conclusion, our study provides evidence that visual perception of affordable objects enhances somatosensory processing, thus increasing our understanding of how the brain integrates sensory information to construct a rich and interactive representation of the environment. Future research could capitalize on our results to further explore haptic perception, i.e., a sensory system that uses touch to obtain information about the environment. In this context, future studies can investigate the somatosensory coding of affordances in a developmental perspective to describe the milestones of haptic perception in infancy. Furthermore, the current results may represent a starting point in designing assessment tools for haptic perception deficits, often underestimated in clinical practice, and for the quantification of their possible improvement after rehabilitation intervention.

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CRediT authorship contribution statement

M. Galigani: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **M. Romeo:** Writing – review & editing, Investigation. **V. Bruno:** Writing – review & editing, Investigation, Conceptualization. **B. Forster:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **F. Garbarini:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

None.

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Data availability

De-identified data will be deposited at Mendeley Data (https://data.mendeley.com/preview/7ftpfv9s7j?a=9ed0c0e0-dc64-41e3-9bb9-2165abfa075c).

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