

Probing the neural representations of body-related stimuli: a reply to Tamè & Longo's commentary

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Cite as: Galvez-Pol, A., Calvo-Merino, B., & Forster, B. (2020). Probing the neural representations of body-related stimuli: a reply to Tamè & Longo's commentary. *Cortex*. <https://doi.org/10.1016/j.cortex.2020.11.004>

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The processing of body-related stimuli (e.g., images of bodies -static or in movement) elicits simultaneous activations in visual and sensorimotor brain regions (Hardwick, Caspers, Eickhoff, & Swinnen, 2018; Molenberghs, Cunnington, & Mattingley, 2012; Urgesi, Calvo-Merino, Haggard, & Aglioti, 2007). This activity can be observed over the scalp as a mixture of sensorimotor and visual-evoked potentials (ERPs). Yet, such a mix obstructs the discrete inspection of the underlying neuronal generators. Accordingly, in Galvez-Pol et al., (2020a), we described a method that dissociates these scalp-recorded potentials and allows to examine their distinct contributions. In their constructive and well-thought commentary, Tamè and Longo (2020) highlight three aspects of this work that need to be clarified: i) whether there is a natural border between body and non-body related stimuli; ii) whether neural signals from diverse neuronal sources can be discerned by our method; and iii) whether such a method can be used with other types of stimuli.

1. Body or non-body-related stimuli, that is the question

Tamè and Longo (2020) raise the question of what visually perceived stimuli can be considered as ‘body-related’. We agree with them in acknowledging that given the role of our bodies in everyday activities, nearly anything can be seen as body-related. We could include in this category stimuli that possess one or more of the following attributes: they are graspable, manipulable, and/or it is possible to reproduce an aspect of their form (e.g., outline, motion) by using one’s body (see e.g., Schubotz, 2007; de Wit et al., 2017; Romano et al., 2019). In these cases, our bodies likely mediate how we relate to the stimuli in the environment. Through statistical regularities, we learn about these stimuli, and just their perception might activate our body representation in the brain (Almeida et al., 2018; De Vignemont, 2011; Alejandro Galvez-Pol, Forster, & Calvo-Merino, 2020; Niedenthal, 2007; Rizzolatti & Sinigaglia, 2010). In a sense, our idea of body-related stimulus resembles the classical concept of affordance coined by (Gibson, 1979) as perceivable action possibilities with the environment.

As Tamè and Longo (2020) suggest, all stimuli, including the examples described above, fall onto a point on a continuum that ranges from null to full body-relatedness. The landing point for each stimulus is not universally determined as it largely depends on the person's visual and sensorimotor experience (e.g., Calvo-Merino et al., 2006; Vannuscorps and Caramazza, 2016). The research question should determine what body/non-body stimulus categories are contrasted. For instance, we compared neural responses to stimuli that are as distant as possible on the continuum of body-relatedness while controlling perceptual parameters (Galvez-Pol, et al., 2018; Galvez-Pol, Calvo-Merino, et al., 2020). Specifically, we used images of hands in different positions and with no symbolism and polygonal shapes based on matching the hands in outline, colour, and size. Also, we ensured that these stimuli were equally matched in discriminability. Further studies could employ types of stimuli that land at different points within the body-related category (e.g., comparing images of hands vs. tools), and contribute to a better understanding of the properties and boundaries of the body-related continuum.

2. On the dissociation of sensorimotor and visual coexisting activity

The method described in Galvez-Pol et al., (2020a) dissociates ERPs, due to the processing of body-related images, by subtracting trials with visual evoked potentials from trials containing a mixture of visual and sensorimotor evoked potentials; as expressed in the equation: $[(VEP \& SEP) - VEP = SEP \text{ only}]$. Tamè and Longo (2020) raise a stimulating point: this subtraction might hold if unimodal visual and sensorimotor activities are independent and with no shared activity. We recognise that some common activity might be shared when stimulating individual sensory modalities (e.g., Gondan and Röder, 2006; Mouraux and Iannetti, 2009). In our case, if we assume common activity “c” in every unimodal stimulation [i.e., $(VEP_c \& SEP_c) - VEP_c = SEP_c$], subtracting visual (VEP_c) from visual and somatosensory evoked potentials ($VEP_c \& SEP_c$) would get rid of the double up common activity in visual and somatosensory evoked

potential trials, leaving us with SEPs including common activity. However, it is important to highlight that the ‘SEP only’ on the right-hand side of the equation should not be conceptualised as a regular unimodal SEP. Modulations of activity in such evoked potentials are not due to changes in task-irrelevant tactile or motor stimulations but to controlled variations in visually perceived stimuli (e.g., task-relevant images of bodies vs not bodies). One way to examine the correct subtraction between stimulation conditions is by inspecting the modulation of the resulting waveforms across non-central electrodes sites. For instance, the modulation of ERPs over posterior electrodes - where ERP correlates of visual processing are usually observed - should be minimal or absent; i.e., no visual activity observed after subtracting visual ERPs in the above equation.

Finally, the authors suggest that one of the embodiment effects found in our work could be a by-product of prominent common activity in the time range of ~200-300ms after stimulus onset. Here, it is essential to note that we found a modulatory effect of our experimental conditions not only in this time window, but also in earlier and later ERP components (see e.g., Supp. materials Galvez-Pol et al., 2020a). These modulations should not be expected if they were merely an overall by-product.

3. On the fundamentals of dissociating sensory-evoked activity

In their third strand, Tamè and Longo (2020) indicate that the method in Galvez-Pol et al., (2020a) could be applied to other stimuli and sensory domains. Despite that this work is based on research examining the processing of visually perceived body-related stimuli, many of the underlying notions could be applied in akin studies. For this to happen, it is important to consider that most stimuli can elicit bodily associations and sensorimotor activity regardless of the sense used to acquire the information (e.g., perceiving actions through vision or hearing; (Aglioti & Pazzaglia, 2010). Given such supramodal processing, bodily stimuli are closely related to symbolic associations/semantic categories. Considering these matters, the current

method can be adapted by replacing visual-evoked potentials elicited when using images of body stimuli by auditory-evoked potentials elicited by the sound of bodily actions (e.g., sounds of clapping or tap dance are likely associated to the hands and feet, respectively). Importantly, regardless of the nature of the perceived stimuli (visual, auditory), sensorimotor activity needs to be revealed through task-irrelevant stimulation. This stimulation is understood as the ‘ping’ of a sonar, where through echoed activity, the impulse reveals changes in sensorimotor cortices due to the sensory processing of the task-relevant stimuli.

References

- Aglioti, S. M., & Pazzaglia, M. (2010). Representing actions through their sound. *Experimental Brain Research*, *206*(2), 141–151. <https://doi.org/10.1007/s00221-010-2344-x>
- Almeida, J., Amaral, L., Garcea, F. E., Aguiar de Sousa, D., Xu, S., Mahon, B. Z., & Martins, I. P. (2018). Visual and visuomotor processing of hands and tools as a case study of cross talk between the dorsal and ventral streams. *Cognitive Neuropsychology*, *35*(5–6), 288–303. <https://doi.org/10.1080/02643294.2018.1463980>
- Calvo-Merino, B., Grèzes, J., Glaser, D. E., Passingham, R. E., & Haggard, P. (2006). Seeing or Doing? Influence of Visual and Motor Familiarity in Action Observation. *Current Biology*, *16*(19), 1905–1910. <https://doi.org/10.1016/j.cub.2006.07.065>
- De Vignemont, F. (2011). Embodiment, ownership and disownership. *Consciousness and Cognition*, *20*(1), 82–93. <https://doi.org/10.1016/j.concog.2010.09.004>
- de Wit, M. M., de Vries, S., van der Kamp, J., & Withagen, R. (2017). Affordances and neuroscience: Steps towards a successful marriage. *Neuroscience and Biobehavioral Reviews*, *80*(July), 622–629. <https://doi.org/10.1016/j.neubiorev.2017.07.008>
- Galvez-Pol, A., Calvo-Merino, B., Capilla, A., & Forster, B. (2018). Persistent recruitment of somatosensory cortex during active maintenance of hand images in working memory. *NeuroImage*, *174*(March), 153–163. <https://doi.org/10.1016/j.neuroimage.2018.03.024>
- Galvez-Pol, A., Calvo-Merino, B., & Forster, B. (2020). Revealing the body in the brain: an ERP

- method to examine sensorimotor activity during visual perception of body-related information. *Cortex*, *125*, 332–344. <https://doi.org/10.1016/j.cortex.2020.01.017>
- Galvez-Pol, A., Forster, B., & Calvo-Merino, B. (2020). Beyond action observation: Neurobehavioral mechanisms of memory for visually perceived bodies and actions. *Neuroscience & Biobehavioral Reviews*, *116*, 508–518. <https://doi.org/10.1016/j.neubiorev.2020.06.014>
- Gibson, J. J. (1979). *The Ecological Approach to Visual Perception*. Boston: Houghton, Mifflin.
- Gondan, M., & Röder, B. (2006). A new method for detecting interactions between the senses in event-related potentials. *Brain Research*, *1073–1074*(1), 389–397. <https://doi.org/10.1016/j.brainres.2005.12.050>
- Hardwick, R. M., Caspers, S., Eickhoff, S. B., & Swinnen, S. P. (2018). Neural correlates of action: Comparing meta-analyses of imagery, observation, and execution. *Neuroscience and Biobehavioral Reviews*, *94*, 31–44. <https://doi.org/10.1016/j.neubiorev.2018.08.003>
- Molenberghs, P., Cunnington, R., & Mattingley, J. B. (2012). Brain regions with mirror properties: A meta-analysis of 125 human fMRI studies. *Neuroscience and Biobehavioral Reviews*, *36*(1), 341–349. <https://doi.org/10.1016/j.neubiorev.2011.07.004>
- Mouraux, A., & Iannetti, G. D. (2009). Nociceptive laser-evoked brain potentials do not reflect nociceptive-specific neural activity. *Journal of Neurophysiology*, *101*(6), 3258–3269. <https://doi.org/10.1152/jn.91181.2008>
- Niedenthal, P. M. (2007). Embodying emotion. *Science*, *316*(5827), 1002–1005. <https://doi.org/10.1126/science.1136930>
- Rizzolatti, G., & Sinigaglia, C. (2010). The functional role of the parieto-frontal mirror circuit: interpretations and misinterpretations. *Nature Reviews Neuroscience*, *11*(4), 264–274. <https://doi.org/10.1038/nrn2805>
- Romano, D., Uberti, E., Caggiano, P., Cocchini, G., & Maravita, A. (2019). Different tool training induces specific effects on body metric representation. *Experimental Brain Research*, *237*(2), 493–501. <https://doi.org/10.1007/s00221-018-5405-1>
- Schubotz, R. I. (2007). Prediction of external events with our motor system: towards a new framework. *Trends in Cognitive Sciences*, *11*(5), 211–218.

<https://doi.org/10.1016/j.tics.2007.02.006>

Tamè, L., & Longo, M. R. (2020). Probing the neural representations of body-related stimuli:

Comment on "Revealing the body in the brain: an ERP method to examine sensorimotor activity during visual perception of the body-related information" by Alejandro Galvez-Pol, Beatriz

Calvo-Merino and Bettina Forster. *Cortex*. <https://doi.org/10.1016/j.cortex.2020.08.019>

Urgesi, C., Calvo-Merino, B., Haggard, P., & Aglioti, S. M. (2007). Transcranial Magnetic

Stimulation Reveals Two Cortical Pathways for Visual Body Processing. *Journal of*

Neuroscience, 27(30), 8023–8030. <https://doi.org/10.1523/JNEUROSCI.0789-07.2007>

Vannuscorps, G., & Caramazza, A. (2016). Impaired short-term memory for hand postures in

individuals born without hands. *Cortex*, 83, 136–138.

<https://doi.org/10.1016/j.cortex.2016.07.019>

Author contributions: A.G-P: Conceptualization, Investigation, Methodology, Writing original draft, Writing - review & editing. B.C-M and B.F: Conceptualization, Investigation, Methodology, Writing - review & editing.

Acknowledgments: This work was supported by City University London PhD scholarship (A.G-P), the Spanish Ministry of Economy and Competitiveness (MINECO; RYC-2008-03090 and PSI2012-34558 to B.C-M). The authors are thankful to the reviewers for their constructive suggestions and comments in earlier versions of this manuscript.

Competing interests: The authors declare no competing interests.