



Commentary

Is motor cortex deactivation during action observation related to imitation in infancy? A commentary on Köster et al., 2020

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ABSTRACT

Sensorimotor alpha suppression is present both during the observation and execution of actions, and is a commonly used tool to investigate neural mirroring in infancy. Köster et al. (2020) used this measure to investigate infants' motor cortex activation during the observation of action demonstrations and its relationship to subsequent imitation of these actions. Contrary to what is implied in the paper and to common findings in the literature, the study's results appear to suggest that the motor system was *deactivated* during the observation of the actions, and that greater *deactivation* during action observation was associated with a greater tendency to copy the action. Here we present potential methodological explanations for these unexpected findings and discuss them in relation to common recommendations in the field.

Commentary

Köster et al., (2020) measured alpha oscillations (here 7-10Hz) over the sensorimotor cortex during the observation of action demonstrations in 10- and 20-month-old infants, and investigated the relationship between this activity and subsequent imitation of the observed actions in the 20-month-olds. Sensorimotor alpha oscillations as measured by EEG are a commonly used tool to investigate neural mirroring in infants. While at rest, sensorimotor neurons fire spontaneously in synchrony, leading to large amplitude oscillations in the alpha frequency band (typically 6-9Hz in infants and 8-13Hz in adults). When sensorimotor neurons are activated their firing becomes desynchronized, leading to a decrease in power in the alpha band in channels overlying the sensorimotor cortex (Pfurtscheller & Lopes da Silva, 1999). Thus, a reduction in alpha power over the sensorimotor cortex (also called mu suppression) during action observation compared to a baseline period has been widely interpreted as activation of the motor system in response to observing actions (e.g. Marshall & Meltzoff, 2011; Muthukumaraswamy, & Johnson, 2004). However, contrary to findings typically reported in the literature, Köster et al. found that, overall, infants' action observation was associated with an *increase* in 7-10Hz alpha power, thereby indexing *deactivation* of the sensorimotor cortex. Moreover, the 20-month-olds showed significantly greater alpha power during the observation of actions they subsequently imitated than during the observation of actions they did not reproduce. The fact that greater *deactivation* of the sensorimotor cortex during action observation was associated with a greater

tendency to copy the action appears inconsistent with the authors' suggestion that motor simulation plays a role in imitative learning. In this commentary we outline possible methodological explanations that could account for these unexpected findings, and discuss them in relation to common recommendations in the field.

The first potential explanation for Köster et al.'s findings relates to the baselines that were used. To assess neural activation during the action demonstrations overall, a pre-stimulus baseline from -500 to -200 ms before the stimulus onset was used. However, it is unclear what this baseline entailed, as the article does not specify what kind of stimuli were presented in between trials nor their timing. Due to sensorimotor alpha suppression being a relative measure, the baseline stimuli that are used can have a big impact on the results of a study. Firstly, the baseline stimuli should ideally be equally interesting to the experimental stimuli and contain a similar level of motion, but not contain the variable of interest (i.e. goal-directed movement) (Cuevas, Cannon, Yoo, & Fox, 2014). For example, previous studies have used abstract non-biological motion (e.g. de Klerk, Johnson, Heyes, & Southgate, 2015) or moving objects that were subsequently used in the goal-directed actions (e.g. Warreyn et al., 2013). These approaches allow one to control for activation related to motion perception, and to ensure that infants are equally engaged during the baseline and trial periods. Without information about what kind of stimuli were presented during the inter-trial interval, it is unclear whether the overall apparent increase in alpha power during the action demonstrations may be related to the nature of the baseline stimuli. Secondly, it is important to ensure that the baseline duration is jittered. Previous studies have shown that sensorimotor

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alpha suppression is predictive (Southgate, Johnson, Osborne, & Csibra, 2009) and that when infants can anticipate the onset of the next trial this can lead to significant suppression during the pre-stimulus baseline period (e.g. de Klerk, Southgate, & Csibra, 2016). If the baseline stimuli presented during the inter-trial interval in the study by Köster et al. had a fixed duration, infants may have shown an anticipatory decrease in alpha power in the 500 milliseconds leading up to the onset of the next trial, resulting in an apparent increase in sensorimotor alpha power during the action demonstration.

Critically, for the analyses investigating the relationship between motor cortex activity during action observation and subsequent imitation of the actions in the 20-month-olds Köster et al. used a different baseline period (from -1,000 ms to -200 ms before the onset of the action demonstration). This baseline was taken from the object presentation phase (0-2s from trial onset), during which the experimenter was talking and performing pointing gestures while presenting the object. This choice of baseline could explain why actions that were subsequently imitated by the 20-month-olds elicited a greater increase in sensorimotor alpha power during the action demonstration. If during the presentation of objects infants found interesting they showed increased sensorimotor cortex activation (e.g. due to enhanced processing of the experimenter's actions or enhanced anticipation of the upcoming action demonstration), this could have resulted both in greater relative deactivation during the demonstration phase of these objects, as well as in a greater tendency to remember the subsequently observed actions, and to reproduce them later. Such potential differences could be assessed by analyzing activity during the 0-2s object presentation period as a function of whether the action with that object was later imitated or not¹. The fact that several of the demonstrated actions were not novel and potentially easily afforded by the objects (e.g. lifting or shaking an object or moving it across the table), while in contrast, most objects would have been relatively unfamiliar to infants is consistent with the possibility that infants' action imitation may have been primarily linked to their interest in the object rather than to their interest in the observed action.

A second potential explanation for Köster et al.'s counterintuitive findings relates to potential overt movement in the included trials. As sensorimotor alpha power decreases both during the execution and observation of actions, any study aiming to investigate motor cortex activation specifically related to the *observation* of actions, will need to ensure that the activation is not the result of overt movements performed by the infant². Therefore, EEG sessions need to be video-coded to exclude any trials in which infants performed overt movements. No trial exclusions based on participants' movements are mentioned in the paper by Köster et al., leaving open the possibility that the general increase in 7-10Hz power over the sensorimotor cortex could in fact reflect differences in stillness of the participants between the baseline period and the subsequent action demonstration period. For instance, if infants moved more during the baselines than they did during the action demonstrations, this would explain the overall sensorimotor cortex deactivation found during action observation.

Relatedly, given that infants tend to be more still when they are attending to something, a higher level of interest, and hence greater stillness during the action observation phase could also explain why greater sensorimotor cortex deactivation was found during the observation of actions that were reproduced during the imitation phase. One way to assess this attentional explanation of the findings would be to investigate occipital alpha suppression during action observation and its relationship to subsequent imitation. It has been suggested that mu suppres-

sion studies should always include occipital channels in the analyses to ensure that experimental effects are specific to the sensorimotor alpha rhythm (see Hobson & Bishop, 2017). The authors did report significant suppression in the 3-6 Hz frequency band (typically referred to as theta; Orekhova, Stroganova, & Posikera, 1999) over occipital areas during the action demonstrations; investigating this activation pattern as well as occipital alpha power in relation to the infants' subsequent imitation could give more insight into potential differences in attentional engagement between conditions.

To conclude, in this commentary we have outlined various methodological considerations that may have contributed to Köster et al.'s unexpected findings. Based on these considerations we argue that currently, the study's results do not warrant the interpretation that motor simulation underlies imitation learning, as proposed in the paper. While motor simulation would be indexed by a decrease in sensorimotor alpha power during action observation, Köster et al. find an increase in 7-10Hz alpha power (reflecting deactivation or inhibition of the motor cortex) during the observation of actions that is related to subsequent imitation of these actions. If these results are not a consequence of one of the methodological points outlined above, they could generate interesting avenues for future research as they suggest that inhibition of the motor cortex may have given rise to activation in other areas that support the retention of the observed actions. Throughout this commentary we have proposed potential additional analyses that could help to better understand the current study's results. Additionally, we have outlined recommendations for researchers investigating sensorimotor cortex activation in infancy (see also reviews by Cuevas et al., 2014 and Hobson & Bishop, 2017) that highlight the importance of reporting decisions about baseline stimuli, trials with overt movement, and comparisons with occipital electrode sites to ensure that studies can be meaningfully interpreted and compared, and the field moved forward.

Data and code availability statement

No data or code were used when writing this commentary

Declaration of Competing Interest

None

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¹ While Figure 2A in Köster et al. shows no evidence of alpha suppression during the 0-2 second object presentation phase, this plot is not split depending on whether the observed actions were subsequently imitated.

² Note that we are not talking about infants' movements resulting in EEG artefacts here, but rather about motor cortex activity that is functionally related to infants' movements.