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## Young children use imitation communicatively

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## **Highlights**

- Imitation conveys social information, but do children imitate communicatively? (80)
- We tested whether children modify their imitation to ensure the model can see it. (83)
- Children's actions were blocked vs. not blocked from the model's view by a barrier. (85)
- They imitated above the barrier when the model could not otherwise see. (73)
- Children actively use imitation communicatively in certain contexts. (70)

## Abstract

There is growing evidence that children imitate not just to learn from others but also to affiliate socially with them. However, while imitation can convey a wealth of affiliative information to others, it is not yet known whether imitators intend for this to be the case. In particular we do not know whether children imitate communicatively in some contexts, expending extra effort to make sure the demonstrator sees their imitation. Here, in two experiments ( $N = 20$ ,  $N = 48$ , respectively), we tested whether preschool-age children modify their imitation when needed to ensure that the demonstrator sees it. In each trial, children were shown a demonstration. Then, for their response, in one condition, a barrier obscured the demonstrator's view of children's imitation unless children raised their arms above the barrier while imitating. In the other condition, the demonstrator was able to see children's imitation without any additional effort from children. Results from both experiments showed that children were significantly more likely to imitate with their arms raised when their actions would otherwise be obscured from view. In the second experiment, we also coded for other communicative behaviors (e.g., social smiles, eye contact, showing gestures) and found that children often displayed communicative behaviors while imitating, as expected, in both conditions. Young children thus actively use imitation communicatively in some contexts.

Keywords: Imitation, Social imitation, Showing, Communication, Affiliation, Social motivation

Running head: COMMUNICATIVE IMITATION

### **Young children use imitation communicatively**

Imitation is a uniquely powerful learning mechanism that enables children to acquire the wealth of cultural information they need in order to function within their social groups (Lyons et al., 2007; Tomasello, 1999; Whiten et al., 2009). However, this is not all imitation is: It can also be a key component of social interaction. We imitate not just to learn from others but also to connect socially with them (Nielsen & Blank, 2011; Over & Carpenter, 2012; Užgiris, 1981; see Over, 2020, for a review). Imitation has been shown to increase in affiliative contexts. For example, 18- to 24-month-olds more closely imitate demonstrators who had previously socially engaged with them than those who had previously been aloof (Kim et al., 2018; Nielsen, 2006; Nielsen et al., 2008). In addition, 3- to 6-year-olds imitate others more closely following experiences of exclusion (Over & Carpenter, 2009; Watson-Jones et al., 2014). Furthermore, infants and young children can infer affiliative and other social relationships from watching imitative exchanges between third parties (Lieberman et al., 2018; Over & Carpenter, 2013; Powell & Spelke, 2018).

However, while imitation can convey a wealth of affiliative and other social information both to one's partner and to observers, it is not yet clear whether children actually intend to communicatively send a message with their imitation. As with unconscious mimicry (e.g., Chartrand & Lakin, 2013; Chartrand & van Baaren, 2009; Lakin et al., 2008), their imitation could instead just inadvertently make this information available to others without them meaning for this to be the case. What is needed, first, to call imitation communicative, is evidence that children are actively attempting to ensure that others see their imitation.

Several studies have found that children imitate more faithfully when the demonstrator is present (DiYanni et al., 2011; Király, 2009; Nielsen & Blank, 2011) or actively observing them (Marsh et al., 2019; Stengelin et al., 2019). While suggestive, one possible alternative interpretation of these findings is that the imitated actions were cued by associations with the demonstrator when the demonstrator was present. There have also been claims from naturalistic, observational research that young children imitate communicatively. For example, Nadel (2002) described imitative interactions between toddler peer dyads as having a communicative structure that includes role-switching, turn-taking, and referential object use. A typical imitative exchange of this kind involves one child picking up an object, similar to the one she is using herself, and offering it to a peer. The peer then takes the object and starts imitating the first child's object use. In other exchanges, a child may spontaneously start to imitate a peer. The peer then notices that she is being imitated and proposes new actions for the first child to copy (see also Eckerman et al., 1989). While it thus seems clear that toddlers can use imitation within their communicative interactions, we still do not know to what extent the imitation itself is communicative in the sense that it is important for children that their partner sees their imitation.

Bavelas and colleagues have also claimed that mimicry can serve communicative functions in adults (Bavelas et al., 1986, see also Bavelas et al., 1987). As evidence for this, Bavelas et al. (1986) reported that adult participants were more likely to mimic an experimenter's expression of pain when he was facing towards them rather than facing to the side. However, this result is difficult to interpret because participants could see more of the experimenter's face when he was facing them vs. not, thus making imitation of his expression easier in this condition.

Thus, while it is now well-accepted in the literature that imitation can serve social functions (for a review, see Over, 2020), it is still not clear whether children actively, deliberately communicate with their imitation. Here, in a novel experimental paradigm, we investigated whether children sometimes use imitation communicatively, measuring whether, when children imitate, they actively show the demonstrator that they are doing so. In two experiments, we gave children (5-year-olds and 3- to 6-year-olds, respectively) the opportunity to imitate a demonstrator under two different conditions. What differed between conditions was whether the demonstrator could see children's imitation of her action. In the Obscured condition, a barrier prevented the demonstrator from seeing children's imitation unless children raised their arms such that their hands were above the barrier. In contrast, in the Visible condition, the center of the barrier was removed such that the demonstrator was able to see children's imitation without any additional effort from children. We predicted that if children use imitation communicatively, so that their partner can see it, then they will be more likely to raise their hands above the barrier as they imitate in the Obscured condition than in the Visible condition. In the pre-registered and more highly-powered Experiment 2, we additionally coded for communicative behaviors (e.g., social smiling, showing gestures) that accompanied children's imitation, expecting that children would perform these behaviors in both conditions. If so, this would provide further support for the idea that children are actively using their imitation communicatively.

### **Experiment 1**

Given previous research which often suggests that as children reach school age, they are more likely to imitate for social reasons (Marsh et al., 2014; McGuigan et al., 2007, 2011;

Nielsen, 2006; Užgiris, 1981), we tested 5-year-olds in Experiment 1. Children participated in both the Obscured condition and the Visible condition in a within-subjects design.

## Method

**Participants.** Participants were 20 five-year-olds (mean age = 5 years, 6 months, 27 days, age range = 5 years, 0 months, 26 days to 5 years, 11 months, 13 days) tested in a child lab in [anonymized location]. Eight were female and 12 were male. An additional nine children were tested but dropped from analyses for not paying attention during the demonstration in one trial (1) or for not imitating the adult's action in one (7) or both (1) conditions.<sup>1</sup> Participants were recruited from a database of children whose parents had expressed interest in participating in developmental studies.

**Set-up and materials.** Two child-sized tables were pushed together and a child-sized chair was placed in front of each table. One table held the barrier used in the Obscured condition and the other table held the barrier used in the Visible condition (see Figure 1). The barrier used in the Obscured condition was a cardboard box, 46 x 27 x 32 cm in size, covered in brown paper. The barrier used in the Visible condition was an identically sized box with three of its six faces removed, leaving only the base and the two sides. It was also covered in brown paper. Four boxes containing the objects to be used in the imitation tasks (see below) were placed on the floor next to the outermost table legs, two on the side of the experimenter (E) and two on the side of the child.

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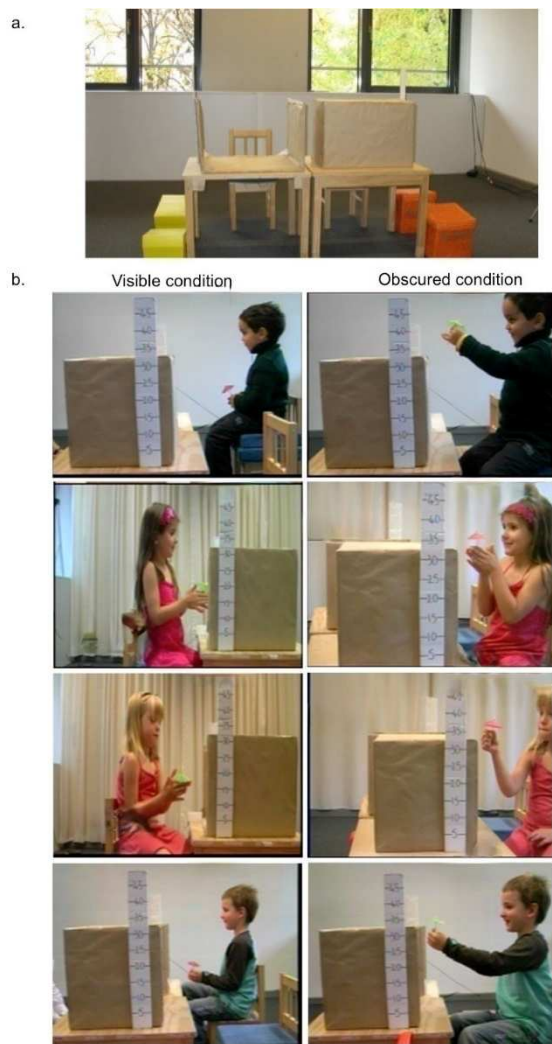
<sup>1</sup> Note that no instructions were given to children to imitate: Children were simply asked to look in their box (see the Procedure). There were other, additional attractive actions that could be performed with the target object, a cocktail umbrella, such as closing and opening it, as well as other objects in the box to play with. Thus, it was not surprising that a number of children did not imitate the demonstrated action.



The materials for one of the demonstrations consisted of a small green plastic frog, a blue building block, and a red cocktail umbrella placed inside a closed yellow wicker box. An identical set of objects was available for the child and was placed in a matching wicker box. The materials for the other demonstration consisted of a small yellow plastic duck, a purple ball, and a green cocktail umbrella placed inside a closed orange wicker box. Again, an identical set of objects was available for the child and was placed inside a matching wicker box.

**Figure 1**

*a) Set-up of Experiment 1 Showing the Barriers Used in the Visible (Left) and Obscured Conditions (Right) b) Examples of Children's Imitation in each Condition*



**Design and counterbalancing.** The order in which the conditions were presented was counterbalanced: For half of the children, the Obscured condition was presented before the Visible condition and for the other half of the children, the Visible condition was presented before the Obscured condition. The object sets associated with each condition were also counterbalanced: For approximately half (9) of the children, the frog, building block, and red umbrella were used in the Obscured condition and for the other 11 children they were used in the Visible condition.

**Procedure.** After a brief, unrelated warm-up game in which E and children catapulted soft toy animals on the floor, E asked children to sit down at a table in front of one of the two barriers. E checked whether children were sitting at a pre-specified height relative to the barrier (such that the base of the child's neck was level with the top of the barrier so, in the Obscured condition, E would not be able to see the child's hands from her kneeling position). If children were sitting too high or too low, E adjusted their height on the chair by adding or removing cushions.

Once children were sitting comfortably at the specified height, E walked to the other side of the table, pointed at her box on the floor, and said, "I'm going to look in my box." E then bent down, looked inside her box, first picking up, for example, the frog and then the building block. As she picked up each of these objects, she labeled them without enthusiasm and put them back in the box. E then picked up the red umbrella and said enthusiastically, "Ah, an umbrella," looking at children while she did so. E then demonstrated the target action – slowly rolling the upright stick of the umbrella back and forth between both her hands several times – while saying, "That's nice, I like that," and alternating her gaze between the umbrella and children's face. While demonstrating the action, E kept her arms low against her body, level with her hips.

Following the demonstration, E did not give a specific instruction to imitate to ensure that children's imitation was not motivated by an explicit verbal prompt. Instead, E simply pointed to the corresponding box on children's side of the table and said, "Look in your box." As she said this, she knelt down on the floor, thus blocking her view of children's hands in the Obscured condition for children's response. During the entire response phase, which started as soon as children took the target object, E looked only and directly into children's eyes and maintained a friendly expression; she gave no feedback. The response phase ended once children made it clear that they were finished (e.g., by setting the umbrella down). E and children then returned briefly to the warm-up game.

Following this, they moved back to the table for the second condition and E encouraged children to sit in front of the other barrier. E then repeated the procedure with the other set of objects, modeling the rolling action on the green umbrella. After children's second response period was over, E told children that they had done very well and gave them a small gift as a thank you present for their participation.

**Coding.** Children's responses were coded from videotape by the second author. First, it was necessary to determine whether children had imitated the target action. An imitative response was scored if children picked up the umbrella and rolled it back and forth using either one or both of their hands. The main question of interest was whether those children who had imitated did so with their arm(s) raised such that E could see their action above the barrier more in the Obscured than in the Visible condition. In both conditions, children were counted as imitating above the barrier if at least part of the umbrella went above the top of the barrier while they imitated (see Figure 1, panel b for examples).

All of the videos were coded independently by a rater who was unaware of the hypotheses of the study. Agreement between the two coders was perfect for whether children imitated and was very high for whether they imitated above the barrier (Cohen's kappa = .94). Disagreements were resolved by discussion. For the data for both experiments, as well as the R code for the GLMMs in the Supplementary Materials, please see [<https://osf.io/8syk9>].

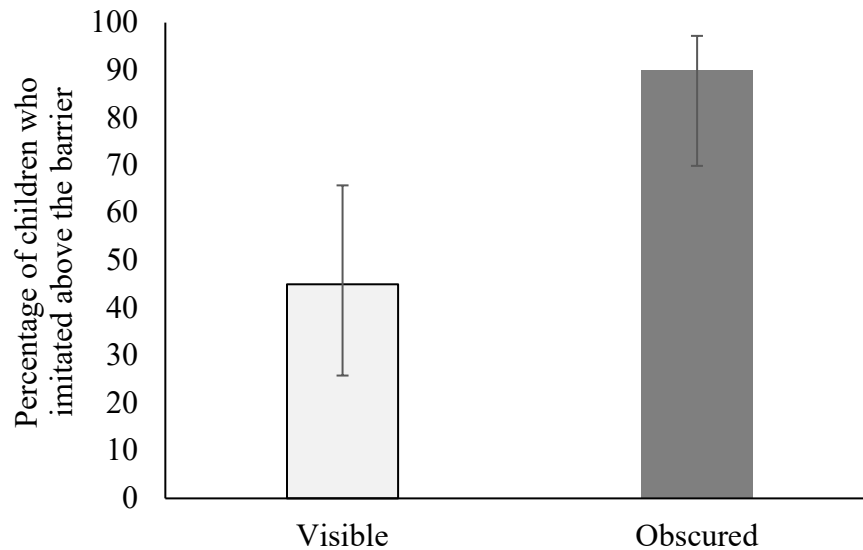
## Results

The main measure was whether children imitated above the barrier more often in the Obscured than in the Visible condition. As the data were within subjects, we analyzed them using a McNemar's test. The McNemar's test revealed that children were significantly more likely to perform in the predicted direction than in the opposite direction (exact McNemar's test,  $p = .012$ ). Ten of the 20 children performed in the predicted direction, imitating above the barrier in the Obscured condition but not in the Visible condition. One child showed the opposite pattern, imitating above the barrier in the Visible condition but not in the Obscured condition. Another child did not imitate above the barrier in either condition. The remaining eight children imitated above the barrier in both conditions. In the Obscured condition, a full 90% of children (18/20) imitated above the barrier compared to only 45% of children (9/20) in the Visible condition (see Figure 2).

**Figure 2**

*The Percentage of Children who Imitated Above the Barrier in the Visible and Obscured*

*Conditions. Error Bars Show Wilson's 95% Confidence Intervals for Proportions.*



Additionally, we carried out an exploratory analysis which investigated only the first condition children received, between subjects. All of the 10 children who received the Obscured condition first imitated above the barrier. In contrast, of the 10 children who received the Visible condition first, only four imitated above the barrier. A Fisher's exact test indicated that this difference was significant,  $p = .010$ .

Please see also section 3 of the Supplementary Materials for an exploratory analysis suggesting that there was no effect of order of condition.

## **Discussion**

We investigated whether 5-year-old children can actively use imitation communicatively. We measured whether, when children imitate, they make an effort, when needed, to make sure that the demonstrator sees their imitation. Our results confirmed that when E's view of children's behavior was obscured, children worked to ensure that she would see their imitation, raising their arms such that their imitation could be seen by E above the barrier. The vast majority (90%) of

children imitated above the barrier in the Obscured condition, and children did this significantly more often in this condition than in the condition in which E's view was unobscured. This suggests that children modified their imitation to ensure that E saw it. It is also striking to note that children in the Obscured condition raised their arms even though E had kept her arms low, against her hips, during the demonstration. This suggests that showing E their action was more important to children than producing a perfectly faithful reproduction of her action.

With Experiment 2, we aimed to replicate and extend these findings and attempt to further strengthen the case that children's imitation was communicative. Using a very similar paradigm to that in Experiment 1, we pre-registered our design and hypotheses, coded for additional communicative behaviors that the children displayed while imitating, and tested a wider age range of children, including children as young as 3 years of age.

## **Experiment 2**

Experiment 2 followed a similar procedure to Experiment 1 and was pre-registered on AsPredicted before data collection (<https://aspredicted.org/xu5uj.pdf>). In addition to the main measure, imitating above the barrier, a planned secondary measure was the additional communicative behaviors children engaged in while imitating (i.e., eye contact, social smiles, showing gestures, and verbal utterances). While again we predicted that children would be more likely to imitate above the barrier in the Obscured condition than in the Visible condition, as in Experiment 1, we expected these additional communicative behaviors to be displayed at similar rates in *both* the Obscured and the Visible conditions, since we expected that children would use their imitation communicatively in both conditions. We also included more trials in each condition to increase statistical power, and a wider age range, 3- to 6-year-olds, to explore whether younger (and older) children can use imitation communicatively as well.

## Method

**Participants.** Participants were 48 3- to 6-year-olds (24 females, mean age = 4 years, 11 months, 10 days; age range = 3 years, 6 days to 6 years, 10 months, 16 days) recruited and tested in two science centers in [anonymized location]. An additional seven children were tested but excluded from analyses. Four were excluded because they turned to show their imitation to someone other than E (i.e., their parent or sibling) in at least two trials in one condition. This meant that we could not accurately assess whether they imitated above the barrier: Once they started doing this, they typically continued to do it for their remaining trials. The other three children were excluded because the parent did not provide the child's birthdate on the consent form ( $n = 2$ ) or because in one trial the child showed her imitation to her parent, and in another trial in the same condition she did not imitate the target action, so we lost half the trials in one condition ( $n = 1$ ). See the pre-registration document for the details of the exclusion criteria. There were 24 children in the younger age group (3-4 years; 11 females) and 24 children in the older age group (5-6 years; 13 females).

**Set-up and materials.** The set-up was similar to that in Experiment 1. Instead of two child-sized tables pushed together, there was an adult-sized long table on which there were two barriers side by side. The size and shape of the barriers were altered somewhat as compared with Experiment 1 (see Figure 3) to ensure that E was not able to see children's actions behind the Obscured box unless children raised their hands above chest level. The distance between the barriers was approximately 15 cm. There were two adult-sized chairs, one in front of each barrier, for participants. For E, there was a low stool to ensure that E and children were seated at eye level to each other. The two containers holding the objects used in the imitation task (see below) were placed at each of the outer corners of the barriers (only one is shown in Figure 3).

**Figure 3**

*Set-up of Experiment 2 Showing the Barriers Used in the Visible (Left) and Obscured (Right) Conditions*



The materials for the demonstrations in one condition consisted of a green cocktail umbrella, a blue unicorn squeeze toy, a yellow stretch toy, and a purple cord bracelet (see Figure 4), which were placed inside a closed blue and white canister. The materials for the demonstrations in the other condition consisted of a sparkling blue cocktail stick, a blue squishy ball, an orange stretch toy, and a green mesh toy with a marble inside, which were placed inside another identical canister.

**Design and counterbalancing.** Children participated in both the Obscured and the Visible condition in a within-subjects design. There were four trials in each condition. The order in which the conditions were presented was counterbalanced as in Experiment 1: Half the children received the Obscured condition first and the remaining children received the Visible







condition first. Children always started on the right side of the table from E's perspective for the first condition and then moved to the left for the second condition.

The object sets associated with each condition were also counterbalanced, but the objects within each set were presented in a fixed order (e.g., the rolling action with the cocktail umbrella/stick always came first). See Figure 4 for the objects and the action demonstrated on each object.

**Procedure.** The procedure was similar to that of Experiment 1. E and children first played a warm-up game as in Experiment 1. However, then, when moving to the table, instead of adjusting the height of children's chair, E adjusted the height of the barrier by placing books under the barrier to make sure that children were sitting at the pre-specified height relative to the barrier. The general procedure for the imitation demonstrations was very similar to that of Experiment 1, except that no distractor objects were used. E took out the object and said, "That's nice, I like that," and demonstrated the action on the object three times while alternating gaze between the object and children's face. After this demonstration E sat down on her stool and silently handed the object to children across the table with a smile. Again E did not provide any instruction for the children to imitate; she just looked at children with a positive, friendly facial expression. If children did not take the object or if they did not act on it within approximately five seconds after E offered it, E prompted children by saying, "Now you."

**Figure 4**

*The Object Sets Used in each Condition Along with the Action Demonstrated on each Matching Object Pair*

Target objects (Set 1/Set 2)	Demonstrated action	What counted as imitation
Umbrella/blue cocktail stick 	Rolling stick vertically between two hands	Rolling stick vertically with fingers of one hand or between two hands
Unicorn/ball toy 	Pressing on the object between two hands	Pressing on the object with one or both hands
Yellow/red rope 	Pulling from the sides with both hands to stretch it horizontally	Pulling from the sides with both hands to stretch it in any direction
Cord bracelet/marble mesh toy 	Pushing from the sides to the center with both hands	Pushing from the sides towards the center as if to make it smaller with both hands

The response period started as soon as children took the object and ended either when children made it clear that they were finished, by putting the object down, or after 15 seconds

had passed, whichever came first. When the response period ended, E extended her hand across the table towards children to request the object back. E always offered the object and requested it back by extending her hand through the gap between the barriers. E put the object back into the canister, took the next object out of the canister while saying, “Hmm, let me see what else I have in my box,” and then proceeded with the next demonstration while standing. Unlike in Experiment 1, there was no warm-up game between the two conditions. Once children had completed four trials in one condition, for the next condition they were asked to sit on the other chair in front of the other barrier. After they had completed the four trials in the second condition, E thanked them for participating, told them they had done very well, and gave them a sticker of their choice and a certificate for their participation.

**Coding.** Children’s responses were coded from videotape by the first author using ELAN (Version 5.8, 2019). For each trial, we coded 1) whether children imitated the demonstrated action (see Figure 4 for coding criteria for imitation), and 2) whether those who imitated raised their arm(s) such that the object was visible above the top of the barrier as in Experiment 1. We then calculated the percentage of trials in which children imitated above the barrier for each condition.

We also coded the additional communicative behaviors children displayed while imitating in both conditions, as further evidence that children’s imitation was communicative. If, while they were imitating, children 1) displayed a social smile (i.e., looked at E or verbally addressed E while smiling), 2) kept looking at E’s face or alternated their gaze between the object and E’s face more than once, 3) produced any relevant verbal utterances that addressed E (e.g., “See? I can squeeze it really hard”), and/or 4) performed a showing gesture (i.e., moved the object towards E while looking at her), they received a score of 1 for additional communicative

behaviors that accompanied their imitation for that trial (again with a range of scores of 0-4 for each condition). The percentage of trials with communicative imitation was then calculated for each child for each condition.

To assess inter-rater reliability, 100% of the videotapes were independently coded by a second rater who was unaware of the hypotheses of the study. Agreement between the two coders was perfect for whether children imitated, and very high for whether they imitated above the barrier (Cohen's kappa = .93) and whether their imitation was accompanied by communicative behaviors (kappa = .90).

In response to an anonymous reviewer's request, we also coded for further information about children's responses: information about the additional, non-imitative actions children produced with the objects, and further information about the other communicative behaviors they produced while imitating. These results are reported in sections 1 and 2 of the Supplementary Materials.

## **Results**

All children imitated each of the target actions, except for four children who each did not imitate in one trial. Two of these trials were in the Obscured condition and two were in the Visible condition. As predicted, children imitated above the barrier significantly more often in the Obscured ( $M = 60.2\%$  of trials,  $SD = 39.5$ ) than in the Visible condition ( $M = 37.7\%$ ,  $SD = 33.1$ );  $t(47) = 4.08$ ,  $p < .001$ , Cohen's  $d = .59$ . The majority of children (79.2%, 38/48) imitated above the barrier in the Obscured condition at least once.

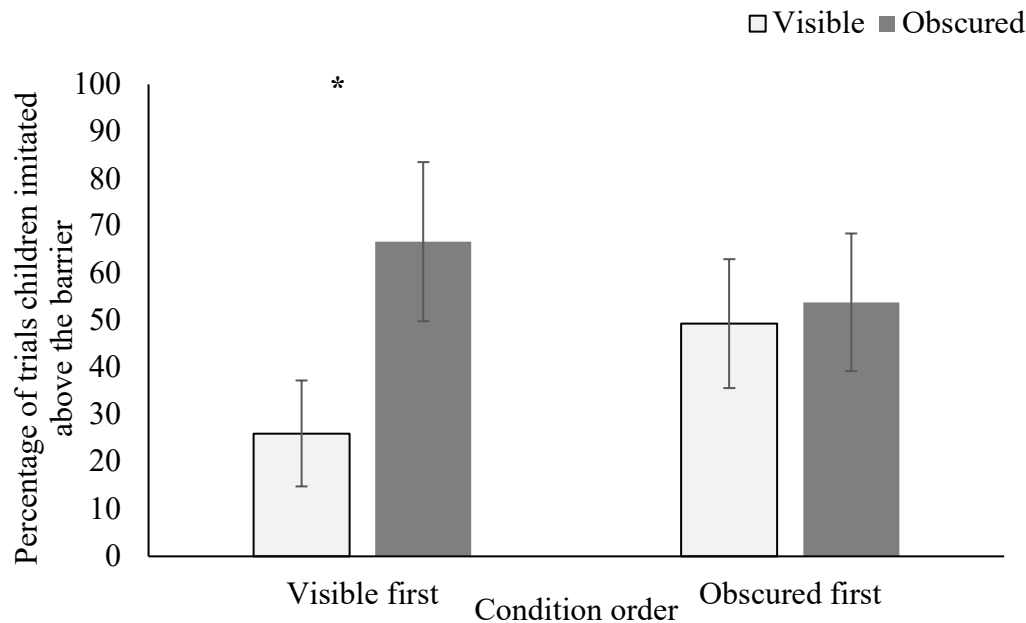
In response to an anonymous reviewer's question about possible effects of order of condition, and additionally to explore the effects of age, we also ran an exploratory mixed ANOVA with the two between-subjects factors of condition order and age group (younger/older)

and the within-subjects factor of condition. This revealed a significant interaction between condition order and condition,  $F(1, 44) = 13.63, p = .001$ , partial  $\eta^2 = .24$ , along with a main effect of condition,  $F(1, 44) = 19.24, p < .001$ , partial  $\eta^2 = .30$ , but no main effect of order,  $F(1, 44) = .16, p = .692$ , partial  $\eta^2 = .004$ . There was no three-way interaction,  $F(1, 44) = .19, p = .666$ , partial  $\eta^2 = .004$ . There was also no significant interaction between age group and condition,  $F(1, 44) = .56, p = .456$ , partial  $\eta^2 = .01$ , nor was there a main effect of age,  $F(1, 44) = 1.08, p = .305$ , partial  $\eta^2 = .02$ . Only those children who were in the Visible condition first imitated above the barrier significantly more often in the Obscured ( $M = 66.7, SD = 42.1$ ) than in the Visible condition ( $M = 26.0, SD = 28.1$ ),  $t(23) = 5.53, p < .001$ , Cohen's  $d = 1.13$ . The children who were in the Obscured condition first imitated above the barrier to a similar degree in both conditions,  $t(23) = -.69, p = .498$ , Cohen's  $d = .14$  ( $M_{Obscured} = 53.8, SD = 36.5$ ;  $M_{Visible} = 49.3, SD = 34.1$ ; see Figure 5). In section 3 of the Supplementary Materials, we also report generalized linear mixed models (GLMMs) in which the binary data (i.e., imitating above the barrier vs. not) were analyzed trial-by-trial. These analyses also indicated a significant effect of an order by condition interaction,  $p < .001$ , mirroring the findings above. Given this interaction between order of condition and condition, we did a further exploratory analysis that analyzed only the first condition children received, between-subjects. Here, children imitated above the barrier significantly more often in the Obscured condition ( $M = 53.8, SD = 36.5$ ) than in the Visible condition ( $M = 26.0, SD = 28.1$ );  $t(46) = 2.96, p = .005$ , Cohen's  $d = .85$ .

**Figure 5**

*Percentage of Trials in which Children Imitated above the Barrier in each Condition. Error Bars*

*Show 95% Confidence Intervals. \*  $p < .001$*



In both conditions, children's imitation was accompanied by other communicative behavior(s) in the majority of trials ( $M_{\text{Obscured}} = 63.7\%$ ,  $SD = 34.5$ ;  $M_{\text{Visible}} = 62.2\%$ ,  $SD = 34.2$ ), with no difference between conditions, as predicted,  $t(47) = .25$ ,  $p = .805$ , Cohen's  $d = .03$ . An exploratory age group by condition mixed ANOVA revealed no significant interaction between age group and condition,  $F(1, 46) = 2.37$ ,  $p = .131$ , partial  $\eta^2 = .05$ , no significant main effect of age group,  $F(1, 46) = 1.04$ ,  $p = .313$ , partial  $\eta^2 = .02$ , and, as predicted, no significant main effect of condition on children's communicative behavior,  $F(1, 46) = .063$ ,  $p = .802$ , partial  $\eta^2 = .001$ .

## Discussion

Experiment 2 replicated the findings of Experiment 1 with a larger sample of children, from a wider age range. Children aged 3 to 6 years again raised their arms to imitate above the barrier more often in the Obscured condition than in the Visible condition. Thus, again, children

were willing to expend extra effort while imitating to make sure that the demonstrator saw their imitation. While this result needs to be considered with some caution due to an unexpected order effect, a follow-up analysis treating condition as a between-subjects variable again showed that children imitated above the barrier significantly more often in the Obscured than the Visible condition.

In addition, in Experiment 2, we found that children produced communicative behavior such as social smiles, eye contact, utterances, and/or showing gestures towards E while imitating in the majority of trials in *both* conditions, as predicted. This strengthens the interpretation that children were imitating communicatively.

### **General Discussion**

In two experiments we showed that young children monitor the demonstrator's visual access to their imitation and expend effort to modify their imitation, when necessary, so that the demonstrator can see it. These findings, along with the additional communicative behaviors children displayed while imitating in Experiment 2, go beyond previous findings demonstrating that imitation serves social functions in development (e.g., Nadel, 2002; Nielsen, 2009; Over & Carpenter, 2012; Užgiris, 1981). In addition, they provide experimental evidence that children sometimes actively use imitation communicatively.

Note that we are not arguing that this type of imitation is communicative in the richest sense of communication used by philosophers (e.g., Grice, 1957, 1975; for example, with consideration of the Gricean maxims of quantity, relation, etc.) – though there may be some cases in which some Gricean maxims may apply when people communicate via imitation. Probably, even within the current experiments, there is a range of complexity underlying individuals' imitation, from informative intentions to communicative intentions (Sperber &

Wilson, 1986). That is, with a given communicative act, one could simply have an informative intention, to inform the addressee of something, or one could in addition have a communicative intention, to make mutually manifest one's informative intention – to make it obvious to the recipient that one is communicating. While the latter case is characterized as 'ostensive communication,' the former case is still communication too, just of a different, more minimal type. When children simply raised their arms so that E could see their imitation in the Obscured condition, without any further accompanying communicative behaviors, they might have intended just to inform E that they were imitating. However, as shown in Experiment 2, often children also produced additional communicative behaviors such as showing gestures and verbalizations. These suggest that in addition to an informative intention, they also had a communicative intention: They intended for E to know that they were trying to show her their imitation ostensively. These latter cases would go beyond the more limited sense of communication previously outlined by social psychologists, as simply behavior that is more likely to be displayed in the presence of others (e.g., Kraut & Johnston, 1979), or as outlined by evolutionary biologists, as behavior that results in a reaction by an observer (e.g., Wilson, 1975).

There are many different messages that an imitator could potentially communicate via imitation (and that a social partner could infer from being imitated). For example, in the case of empathic responding, imitating a social partner's facial expression may nonverbally convey the message "I feel your pain" (Bavelas et al., 1986). In other settings, imitation may convey information about achievement ("I can do that too") or relative status ("I admire you") or may serve to seek approval ("Did I do it right?"), or mark the shared experience ("Yes, this is fun, isn't it?"). One of the most important messages that imitation may convey, however, is "I am like you" or, at a group level, "I am one of you" (Carpenter, 2006; Over & Carpenter, 2012).



In the current Experiment 2, two-thirds of children (32/48) provided a relevant verbal utterance for the experimenter during their imitation at least once. The majority of these utterances were object labels (e.g., “Stress ball,” “These are bubbles”), descriptives (e.g., “It’s squishy,” “It’s blue”) or exclamations (e.g., “Wow,” “Cool,”); however, some were more complex (e.g., “This is so fun, I can squeeze it really hard. See, it comes to my finger right there”). As almost all of them were accompanied by looks and/or smiles to E, it seemed that many of these utterances may have been designed to establish or extend a joint attentional interaction around the objects and/or actions. However, at the same time, many nonverbal messages may have been conveyed as well. Future research should investigate what types of messages children (and adults) can convey with communicative imitation. Future research could also ask children (and adults) what types of messages they infer from being imitated by others, and what types of messages third parties are trying to convey when they imitate each other.

While we found in the current experiments that sometimes children imitate communicatively, we are not arguing that imitation is always communicative. There are many situations in which children imitate without any communicative goals, for example when they are not in a social setting and their goal is simply to learn how an apparatus works in the most efficient manner (Over & Carpenter, 2012). It is also easy to imagine social settings in which one might wish to imitate without overtly communicating this. For example, imitation could be used as a strategic tool to persuade others, as evidenced by the finding that school-aged children imitate their peers more when they were explicitly encouraged to exert social influence on their partners (Thelen et al., 1980). Furthermore, while adolescents might wish to copy the fads and fashions of their more popular peers, doing this too ostensively might backfire in making them be seen as “posers.” Imitation can also be detrimental in situations in which it has reputational

costs; for example, 5-year-old children infer that people who imitate have lower relative status than the people they are imitating (Over & Carpenter, 2015). The set-up in the current experiments might have encouraged communicative imitation because the demonstration was carried out in a communicative way and the interaction had a turn-taking structure, but different set-ups might result in less communicative imitation.

One finding worth noting is that children still sometimes imitated with raised arms in the Visible condition (in roughly 40% of trials in both experiments). Sometimes this may have been as a showing gesture for the experimenter – as expected, children often produced other communicative behaviors in this condition too. Alternatively, in some cases this might have been a carryover effect from having had the Obscured condition first: Children got used to raising their arms in that condition and just continued doing this. Another possibility is that the sides of the ‘barrier’ present in the Visible condition could have caused this behavior for some reason. We included them to have a reference point for coding and to make the conditions as similar as possible, but perhaps children would have raised their arms less if they had not been present.

In conclusion, in the current study, we have documented that children as young as 3 years of age care whether the demonstrator sees their imitation, and that they are willing to expend effort to make their imitation visible to the demonstrator when needed. Children’s imitation is also often accompanied by communicative behaviors such as smiles, utterances, and showing gestures for the demonstrator. This shows that in some situations they actively intend to imitate communicatively. Previous research has mostly focused on how adults communicate to children within instrumental imitative interactions to convey culturally important knowledge to them (e.g., Gergely & Csibra, 2005; 2006). Here we demonstrate that children are active contributors to these communicative imitative interactions as well. Children do not just passively absorb

information from knowledgeable models, but they also actively communicate imitatively back with them as part of a social interaction.

## References

- Bavelas, J.B., Black, A., Chovil, N., Lemery, C.R., & Mullett, J. (1987). Form and function in motor mimicry: Topographic evidence that the primary function is communicative. *Human Communication Research, 14* (3), 275-299. <https://doi.org/10.1111/j.1468-2958.1988.tb00158.x>
- Bavelas, J.B., Black, A., Lemery, C.R., & Mullett, J. (1986). "I show you how you feel": Motor mimicry as a communicative act. *Journal of Personality and Social Psychology, 50* (2), 322-329. <https://doi.org/10.1037/0022-3514.50.2.322>
- Carpenter, M. (2006). Instrumental, social, and shared goals and intentions in imitation. In S.J. Rogers & J. Williams (Eds.), *Imitation and the development of the social mind: Lessons from typical development and autism* (pp. 48–70). New York: Guilford
- Chartrand, T. L., & Lakin, J. L. (2013). The antecedents and consequences of human behavioral mimicry. *Annual Review of Psychology, 64*, 285-308. <https://doi.org/10.1146/annurev-psych-113011-143754>
- Chartrand, T.L., & van Baaren, R. (2009). Human mimicry. *Advances in Experimental Social Psychology, 41*, 219-274. [https://doi.org/10.1016/S0065-2601\(08\)00405-X](https://doi.org/10.1016/S0065-2601(08)00405-X)
- DiYanni, C., Nini, D., & Rheel, W. (2011). Looking good versus doing good: Which factors take precedence when children learn about new tools? *Journal of Experimental Child Psychology, 110*(4), 575-591. <https://doi.org/10.1016/j.jecp.2011.06.002>
- Eckerman, C., Davis, C., & Didow, S. (1989) Toddlers' emerging ways to achieve social coordination with a peer. *Child Development, 60*, 440-53.
- ELAN (Version 5.8) [Computer software]. (2019). Nijmegen: Max Planck Institute for Psycholinguistics, The Language Archive. Retrieved from <https://archive.mpi.nl/tla/elan>
- Gergely, G., & Csibra, G. (2005). The social construction of the cultural mind: Imitative learning as a mechanism of human pedagogy. *Interaction Studies, 6*, 463-481. <https://doi.org/10.1075/is.6.3.10ger>
- Gergely, G. & Csibra, G. (2006). Sylvia's recipe: The role of imitation and pedagogy in the transmission of human culture. In N. J. Enfield & S. C. Levinson (Eds.), *Roots of human sociality: Culture, cognition, and human interaction* (pp. 229-255). Oxford, UK: Berg Publishers.

- Grice, H. P. (1957). Meaning. *The Philosophical Review*, 66 (3), 377-388.
- Grice, H. P. (1975). Logic and conversation. In P. Cole & J. Morgan (Eds.), *Syntax and Semantics* (Vol. 3, pp. 41-58). New York: Academic Press.
- Kim, Z., Óturai, G., Király, I., Hirte, M., & Knopf, M. (2018). A variation of the social context in the warm-up period influences 18-month-olds' imitation. *Cognitive Development*, 45, 105-112. <https://doi.org/10.1016/j.cogdev.2018.01.003>
- Király, I. (2009). The effect of the model's presence and of negative evidence on infants' selective imitation. *Journal of Experimental Child Psychology*, 102(1), 14-25. <https://doi.org/10.1016/j.jecp.2008.06.003>
- Kraut, R.E., & Johnston, R.E. (1979). Social and emotional messages of smiling: An ethological approach. *Journal of Personality and Social Psychology*, 37 (9), 1539-1553. <https://doi.org/10.1037/0022-3514.37.9.1539>
- Lakin, J. L., Chartrand, T. L., & Arkin, R. M. (2008). I am too just like you: Nonconscious mimicry as an automatic behavioral response to social exclusion. *Psychological Science*, 19 (8), 816-822. <https://doi.org/10.1111/j.1467-9280.2008.02162.x>
- Lieberman, Z., Kinzler, K. D., & Woodward, A. L. (2018). The early social significance of shared ritual actions. *Cognition*, 171, 42-51. <https://doi.org/10.1016/j.cognition.2017.10.018>
- Lyons, D.E., Young, A.G., & Keil, F.C. (2007). The hidden structure of overimitation. *Proceedings of the National Academy of Sciences*, 104, 19751-19756. <https://doi.org/10.1073/pnas.0704452104>
- Marsh, L. E., Ropar, D., & Hamilton, A. F. D. C. (2014). The social modulation of imitation fidelity in school-age children. *PLoS One*, 9(1), e86127. <https://doi.org/10.1371/journal.pone.0086127>
- Marsh, L. E., Ropar, D., & Hamilton, A. F. D. C. (2019). Are you watching me? The role of audience and object novelty in overimitation. *Journal of Experimental Child Psychology*, 180, 123-130. <https://doi.org/10.1016/j.jecp.2018.12.010>
- McGuigan, N., Makinson, J., & Whiten, A. (2011). From over-imitation to super-copying: Adults imitate causally irrelevant aspects of tool use with higher fidelity than young children. *British Journal of Psychology*, 102 (1), 1-18. <https://doi.org/10.1348/000712610X493115>

- McGuigan, N., Whiten, A., Flynn, E., & Horner, V. (2007). Imitation of causally opaque versus causally transparent tool use by 3- and 5-year-old children. *Cognitive Development*, 22(3), 353-364. <https://doi.org/10.1016/j.cogdev.2007.01.001>
- Nadel, J. (2002). Imitation and imitation recognition: functional use in preverbal infants and nonverbal children with autism. In A. N. Meltzoff & W. Prinz (Eds.), *The imitative mind: development, evolution, and brain bases* (pp. 42-62). London: Cambridge University Press.
- Nielsen, M. (2006). Copying actions and copying outcomes: Social learning through the second year. *Developmental Psychology*, 42(3), 555. <https://doi.org/10.1037/0012-1649.42.3.555>
- Nielsen, M. (2009). The imitative behavior of children and chimpanzees: A window on the transmission of cultural traditions, *Revue de Primatologie*, 1 (5). <https://doi.org/10.4000/primatologie.254>
- Nielsen, M., & Blank, C. (2011). Imitation in young children: When who gets copied is more important than what gets copied. *Developmental Psychology*, 47, 1050-1053. <https://doi.org/10.1037/a0023866>
- Nielsen, M., Simcock, G., & Jenkins, L. (2008). The effect of social engagement on 24-month-olds' imitation from live and televised models. *Developmental Science*, 11 (5), 722-731. <https://doi.org/10.1111/j.1467-7687.2008.00722.x>
- Over, H. (2020). The social function of imitation in development. *Annual Review of Developmental Psychology*, 2, 93-109. <https://doi.org/10.1146/annurev-devpsych-033020-024051>
- Over, H., & Carpenter, M. (2009). Priming third-party ostracism increases affiliative imitation in children. *Developmental Science*, 12 (3), F1-F8. <https://doi.org/10.1111/j.1467-7687.2008.00820.x>
- Over, H., & Carpenter, M. (2012). Putting the social into social learning: Explaining both selectivity and fidelity in children's copying behavior. *Journal of Comparative Psychology*, 126, 182-192. <https://doi.org/10.1037/a0024555>
- Over, H., & Carpenter, M. (2013). The social side of imitation. *Child Development Perspectives*, 7(1), 6-11. <https://doi.org/10.1111/cdep.12006>

- Over, H., & Carpenter, M. (2015). Children infer affiliative and status relations from watching others imitate. *Developmental Science*, *18*(6), 917-925.  
<https://doi.org/10.1111/desc.12275>
- Powell, L. J., & Spelke, E. S. (2018). Human infants' understanding of social imitation: Inferences of affiliation from third party observations. *Cognition*, *170*, 31-48.  
<https://doi.org/10.1016/j.cognition.2017.09.007>
- Sperber, D., & Wilson, D. (1986). *Relevance: Communication and cognition*. Oxford: Blackwell.
- Stengelin, R., Hepach, R., & Haun, D. B. M. (2019). Being observed increases overimitation in three diverse cultures. *Developmental Psychology*, *55*(12), 2630–2636.  
<https://doi.org/10.1037/dev0000832>
- Thelen, M. H., Miller, D. J., Fehrenbach, P. A., Frautschi, N. M., & Fishbein, M. D. (1980). Imitation during play as a means of social influence. *Child Development*, 918-920.
- Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.
- Užgiris, I. C. (1981). Two functions of imitation during infancy. *International Journal of Behavioral Development*, *4*, 1-12. <https://doi.org/10.1177/016502548100400101>
- Watson-Jones, R. E., Legare, C. H., Whitehouse, H., & Clegg, J. M. (2014). Task-specific effects of ostracism on imitative fidelity in early childhood. *Evolution and Human Behavior*, *35*(3), 204-210. <https://doi.org/10.1016/j.evolhumbehav.2014.01.004>
- Whiten, A., McGuigan, N., Marshall-Pescini, S., & Hopper, L. M. (2009). Emulation, imitation, over-imitation and the scope of culture for child and chimpanzee. *Philosophical Transactions of the Royal Society of London: Biological Sciences*, *364*, 2417-2428.  
<https://doi.org/10.1098/rstb.2009.0069>
- Wilson, K.O. (1975). *Sociobiology: The new synthesis*. Cambridge, MA: Harvard University Press.

## Supplementary Materials

### 1. Children's other, non-imitative actions

An anonymous reviewer requested that we also code any other, non-imitative actions children performed on the target objects, along with how often these actions were produced above the barrier and whether they were accompanied by additional communicative behaviors (eye contact, social smiles, showing gestures, verbalizations, as before). This was done to see whether children also raised their arms more in the Obscured than in the Visible condition and produced other communicative behaviors when performing different actions on the target objects. We did this for Experiment 2 only, because the other communicative behaviors were only coded in that experiment. To assess inter-rater reliability, a naïve rater independently coded 20% of the sample (i.e., 10 children in total). Agreement between the two coders was very high for whether children performed a different action on the object (Cohen's kappa = .79; the disagreements in two trials were resolved upon discussion), whether these actions were performed above the barrier (Cohen's kappa = 1) and also whether they were accompanied by other communicative behaviors (Cohen's kappa = 1).

We found that these other, non-imitative actions were produced relatively infrequently: They were performed in only 18.7% of trials, by only 27.1% (13/48) of children. Eleven of these trials were in the Obscured condition and 9 were in the Visible condition. In total, children performed 13 of these other actions in the Obscured Condition, and 14 in the Visible condition. When children performed a different action on the target object, they usually did so only after imitating the demonstrated action (in the Obscured condition, in 84.6% of the cases and in the Visible condition in 71.4% of the cases). Often, they first imitated the demonstrated action, and



then performed the different action(s) as if to additionally show the demonstrator what else they could do with the object.

In the Obscured condition, they performed these actions above the barrier in 69.2% of the trials (9 out of 13) and in the Visible condition they did so in 28.6% of the trials (4 out of 14). A Fisher's exact test indicated that this difference was not significant,  $p = .057$ . In the Obscured condition, 61.5% of the non-imitative actions (8 out of 13) were accompanied by other communicative behaviors and in the Visible condition, 50.0% (7 out of 14) were accompanied by other communicative behaviors. A Fisher's exact test indicated that this difference was not significant,  $p = .703$ .

Thus, children's primary response, both in terms of frequency and order, was an imitative one. When they performed additional, non-imitative actions, they did so in similar ways to their imitative actions: often above the barrier when needed, and often accompanied by other communicative behaviors. This is not surprising, as they wanted the experimenter to see these actions – what else they could do with the objects – as well.

## **2. Children's other communicative behavior when imitating above vs. below the barrier**

An anonymous reviewer asked how often children produced other communicative behaviors (eye contact, social smiles, showing gestures, verbalizations) when they imitated below the barrier. In Experiment 2, in the Obscured condition, children's imitation was accompanied by additional communicative behaviors significantly more often when they imitated above the barrier ( $M = 64.1\%$ ,  $SD = 42.6$ ) than when they imitated below the barrier ( $M = 22.1\%$ ;  $SD = 37.5$ );  $t(47) = 4.79$ ,  $p < .001$ , Cohen's  $d = .69$ . There was no significant difference in this in the Visible condition ( $M = 63.0\%$ ,  $SD = 42.5$  for above the barrier and  $M = 44.6\%$ ,  $SD = 43.1$  for below);  $t(47) = 1.96$ ,  $p = .056$ , Cohen's  $d = .28$ . Thus, children produced other

communicative behaviors more often when they imitated above than below the barrier in the Obscured condition but produced other communicative behaviors roughly equally above and below the barrier in the Visible condition, a pattern of results that is consistent with the argument that they were taking the demonstrator's visual access to their imitation into account.

### 3. GLMM analyses

An anonymous reviewer requested that we report binomial GLMM analyses that take into account the nested structure of the data. For each experiment, a binomial GLMM was used to predict the binary outcome, whether each target action was imitated above the barrier or not. Random intercepts were used to account for inter-individual differences. All the models were fitted via maximum likelihood with “lme4” package (Bates et al., 2015) in R (version 3.6.1; R Core Team, 2019).

#### *Experiment 1*

We carried out a GLMM analysis including the fixed effect of condition (formulated as:  $\text{aboveimitation} \sim \text{condition} + (1 | \text{ID})$ ). The model indicated a significant effect of condition ( $\chi^2 = 7.59, df = 1, p = .006; b = 2.39, e^{\text{estimate}} = 11.00, SE = .87, z = 2.75, p = .006$ ). Including a fixed effect of order to the model (formulated as  $\text{aboveimitation} \sim \text{condition} + \text{order} + (1 | \text{ID})$ ) did not significantly increase the model fit ( $\chi^2 = 1.35, df = 1, p = .245$ ). Including the condition by order interaction (formulated as  $\text{aboveimitation} \sim \text{condition} * \text{order} + (1 | \text{ID})$ ) also did not significantly increase the model fit ( $\chi^2 = 1.84, df = 1, p = .174$ ).

#### *Experiment 2*

We first carried out a GLMM analysis including the fixed effect of condition (formulated as:  $\text{aboveimitation} \sim \text{condition} + (1 | \text{ID})$ ). The model indicated a significant effect of condition ( $\chi^2 = 24.68, df = 1, p < .001$ ). Including age and the condition by age interaction to the model

did not significantly increase the model fit as indicated by the likelihood ratio test of the function anova ( $\chi^2 = 1.22$ ,  $df = 2$ ,  $p = .543$ ). Including the fixed effect of order (formulated as:  $\text{aboveimitation} \sim \text{condition} * \text{age} + \text{order} + (1 | \text{ID})$ ) also did not increase the model fit ( $\chi^2 = .39$ ,  $df = 1$ ,  $p = .528$ ). However, the full model including the condition by order interaction (formulated as:  $\text{aboveimitation} \sim \text{condition} * \text{age} * \text{order} + (1 | \text{ID})$ ) significantly improved the model fit ( $\chi^2 = 20.77$ ,  $df = 3$ ,  $p < .001$ ).

Table 1 presents the parameter estimates for the fixed effects of the full model. The full model indicated a significant effect of condition ( $\chi^2 = 16.25$ ,  $df = 1$ ,  $p < .001$ ) and a significant condition by order interaction ( $\chi^2 = 17.46$ ,  $df = 1$ ,  $p < .001$ ), but no significant effect of order ( $\chi^2 = .29$ ,  $df = 1$ ,  $p = .592$ ) or of age ( $\chi^2 = .79$ ,  $df = 1$ ,  $p = .373$ ). The model indicated no significant effect of condition by age interaction ( $\chi^2 = .47$ ,  $df = 1$ ,  $p = .494$ ) and no effect of order by age interaction ( $\chi^2 = .99$ ,  $df = 1$ ,  $p = .318$ ). The model also indicated no significant three-way interaction by condition, order, and age ( $\chi^2 = .007$ ,  $df = 1$ ,  $p = .931$ ).

**Table 1**

*Estimated effects of the predictor variables on imitation above the barrier for Experiment 2*

	Estimate( $e^{\text{estimate}}$ )	SE	z value	p value
(Intercept)	-1.472 (.23)	0.594	-2.478	0.013
Condition	2.471 (11.83)	0.568	4.345	< <b>0.001</b>
Order	1.033 (2.81)	0.883	1.170	0.242
Age	-0.228 (.79)	0.910	-0.251	0.802
Condition * Order	-2.471 (.08)	0.788	-3.133	<b>0.001</b>
Condition * Age	0.318 (1.37)	0.864	0.369	0.712
Order * Age	1.061 (2.89)	1.250	0.849	0.395

Condition * Order * Age	0.096 (1.10)	1.120	0.086	0.931
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Note. Significant differences are marked in bold. Exponentiated estimates are in parentheses.

### Reference

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). lme4: Linear mixed-effects models using Eigen and S4. R package version 1.1–7. 2014.