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Why is she scratching her head? Children's understanding of others' metacognitive gestures as an indicator of learning

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ABSTRACT

Successful collaborative learning is supported by the coordination of one's own learning with the learning performance of others. One type of cues that guides the understanding of others' learning performances is their metacognitive gestures. In the current study, we investigated (a) whether 3- to 7-year-old children rely on others' gestures to judge someone else's learning progress and likely learning performance (Experiment 1; N = 76), (b) whether metacognitive gesture understanding depends on cognitive and theory of mind skills (Experiment 2; N = 59), and (c) whether this knowledge would influence children's future selective learning and selective teaching choices (Experiment 3; N = 96). Results of Experiment 1 showed that by 3 years of age children can interpret gestures as an indicator of a person's future performance and that this capacity improves with age, with older children differentiating better between the types of gestures. Experiment 2 revealed that the understanding of metacognitive gestures was not modulated by either nonverbal cognitive capacities or theory of mind skills. Experiment 3 showed a developmental difference in that 5- and 7-year-olds, like adults, consistently selected that successful learners should help someone to learn and that ineffective learners should receive help, whereas 3-year-olds selected learners at chance level. Overall, the results support views that children acquire an understanding of metacognitive gestures early in life

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and that the translation of this knowledge into selective teaching and selective learning choices improves with age.

Introduction

One of the fascinating questions that has entertained developmental psychologists' research efforts during the past years concerns children's ability to coordinate their behavior with others (e.g., Brownell, 2011; Butterfill, 2012; Hamann et al., 2012; Paulus, 2016). Such cooperative interactions not only are relevant for behavioral tasks (Sebanz et al., 2006) but also play a central role in learning contexts (e.g., Fischer et al., 2002; Weinberger et al., 2007). Yet, little is known about the development of the cognitive prerequisites that enable children to become able to participate in successful joint learning activities. Importantly, theoretical perspectives propose that successful joint activities are based on an understanding of others' knowledge and abilities (Bekkering et al., 2009; Sebanz et al., 2006). One way in which one can learn about another person's epistemic state is metacognitive gestures, defined as behavioral cues that can inform us about a person's learning performance (Proust, 2008, 2013). Whereas previous research showed that children can understand gestures (Dimitrova et al., 2017; Hodges et al., 2018; Namy, 2008; Novack et al., 2018; Stanfield et al., 2014) and infer others' knowledge and abilities by observing their behavior (Nicholls, 1978; Stipek & Mac Iver, 1989), it remains open whether children can use metacognitive gestures to infer a person's learning performance. Thus, the current study aimed to investigate the development of children's understanding of nonverbal cues in learning processes and focused on what Proust (2008, 2013) called *metacognitive gestures.*

Human communication, as a multimodal process, involves not only language (i.e., verbal communication) but also bodily signals (i.e., nonverbal communication) such as facial expressions and gestures (Semin, 2007). Verbal and nonverbal communication are crucial in every aspect of social interactions, be it in the production, the perception, or the interpretation of communication (Semin, 2007). Speech and gestures are deeply connected in adults' communication (McNeill, 1992). This strong relation, between speech and gestures, can already be observed among very young children. In fact, children start to use gestures soon after they begin to produce their first words around 1 year of age (Stanfield et al., 2014). Whereas previous research reported that children produced deictic and iconic gestures from 2 years of age (Özçalışkan & Goldin-Meadow, 2005, 2011), a growing field of research started to investigate whether children could also understand gestures. Previous studies showed that, from a very young age, children are indeed able to understand deictic gestures. In fact, from 1 year of age, children can follow pointing gestures to locate objects that are visible (Carpenter et al., 1998) or hidden from their sight (Behne et al., 2012). Around 2 or 3 years of age, children also show a comprehension of iconic and conventional gestures (see, e.g., Dimitrova et al., 2017; Hodges et al., 2018; Namy, 2008; Novack et al., 2018; Stanfield et al., 2014). In the current study, we explored whether children could understand a more complex form of gestures that convey information about a person's knowledge state.

Body movements can provide key insights into another person's mental representations (Goldin-Meadow, 2000; McNeill, 1992). Moreover, psychological models of joint action assume that successful cooperation is based on an understanding of others' knowledge, abilities, and performances (Bekkering et al., 2009; Sebanz et al., 2006). Specifically in learning contexts, inferring a person's knowledge and abilities can reveal the person's learning performance. Although direct verbal instructions are an obvious way of communicating a person's learning progress (e.g., Bahrami et al., 2010), nonverbal observable cues also constitute valuable indicators of learning progress (Flavell et al., 1993). For example, in a study by Nicholls (1978), 5- to 13-year-old children watched movies of two children solving math problems. While one of the two children engaged in active learning throughout the whole video sequence (e.g., reading the textbook or writing in a workbook), the other child spent more than half the time in activities unrelated to work (e.g., playing with a ruler, looking around). Children were then asked to evaluate how hard the two actors worked and whether one was more clever than the other. Results showed that by 5 years of age children were able to use study time as a cue to evaluate a person's efforts (for a review, see also Stipek & Mac Iver, 1989). Similarly, an appreciation of a person's performance and abilities can be inferred from different sources. For example, kindergarten and elementary school children are able to use dispositional knowledge about others to decide with whom to play a game and who should be on their team for an academic contest (Droege & Stipek, 1993). Yet, usually people are not confronted with an experimenter who provides them with dispositional knowledge about others. Rather, children need to encode relevant behavioral cues from their observation of others, interpret these behavioral cues consistently, and make decisions based on these cues.

What are the relevant behavioral cues that tell us something about others' learning performances and that could guide children's collaborative learning with others? Proust (2008, 2013) identified these cues as metacognitive gestures and suggested that they play an important role in the understanding of others' learning. Proust (2008) first described metacognitive gestures as a form of embodied communication in conversation: They can be facial movements or hand gestures, for example, that indicate a person's degree of certainty in his or her current performance or behavior. Proust (2008) suggested that metacognitive gestures calibrate the sense of effort among participants of a task. Specifically, through metacognitive gestures, observers can infer the sense of effort, or degree of understanding, of a person displaying the metacognitive gestures. For example, if a person is experiencing difficulty while learning something, a metacognitive gesture (e.g., frowning, shrugging shoulders) would inform an observer of the person's struggle. Thus, metacognitive gestures can indicate a person's degree of understanding in a given task, which in turn can be used by observers to evaluate the person's progress in a task. In fact, proficient teachers adapt their behavior and teaching in response to children's gestures. Goldin-Meadow and Singer (2003), for instance, found that teachers offered extensive and detailed instructions for children whose gestures indicated less understanding. This study provided evidence that observers can use the information conveyed by learners' gestures to adapt their own behavior (see also Goldin-Meadow, 2000).

Little is known, however, about children's understanding of metacognitive gestures. This is unfortunate given that knowledge about the development of children's appreciation of metacognitive gestures would inform theoretical work on the ontogeny of metacognition and social learning (e.g., Frith, 2012; Proust, 2013; Roebers, 2017; Sodian & Frith, 2008) as well as children's understanding of gestures (e.g., Goldin-Meadow, 2000). Although research with preschool-aged children has shown that children selectively learn from knowledgeable others (e.g., Koenig & Harris, 2005; Lucas et al., 2013; Mills, 2013) and selectively teach less knowledgeable others (Ziv & Frye, 2004), no study to our knowledge has investigated how metacognitive gestures could inform children's selective learning and selective teaching choices. If one were to find that children use metacognitive gestures to guide their own learning and teaching behaviors, it would support views that procedural metacognitive abilities emerge during early childhood (e.g., Destan et al., 2014) and contribute to successful behavioral control, namely, that young children can modulate their actions in function of the metacognitive gestures displayed by others (for reviews, see Ghetti et al., 2013; Proust, 2013).

In the current study, three experiments were designed to examine the development of children's understanding of metacognitive gestures. Past research suggested that by preschool age children are able to recognize signs of uncertainty in others and use them to guide their selective learning and selective teaching choices (cf. Harris, 2012). In the current study, children were exposed to individuals who displayed different nonverbal behaviors to communicate their ease in a learning task. Some might argue that the nonverbal behaviors employed in the current study are closer to actions than to conventionalized forms of gestures (e.g., the pointing gesture that can substitute for speech). However, metacognitive gestures are specifically defined by Proust (2013) as bodily movements that function to communicate metacognitive states (e.g., scratching one's own head to indicate effort). In this sense, Proust (2013) argued that metacognitive gestures convey meaning for the one who observes them even without being conventionalized or reflected by the one who shows them.

To understand the developmental course of metacognitive gesture comprehension, we tested 3-, 5-, and 7-year-old children. The selection of these age groups was motivated by research on gesture comprehension revealing that children from around 3 years of age are able to understand different types of gestures (Dimitrova et al., 2017; Hodges et al., 2018). For this reason, we decided to examine 3-, 5-, and 7-year-olds. In Experiment 1, we investigated whether 3-, 5-, and 7-year-olds would differentiate among three types of metacognitive gestures indicating different levels of difficulty while learning, namely, high, medium, and low ease of learning. In Experiment 2, we assessed whether children's understanding of metacognitive gestures depended on their nonverbal cognitive capacities and theory of mind skills. In Experiment 3, we went one step further and investigated whether children's evaluation of others' metacognitive gestures guide their selective learning and selective teaching choices (for reviews, see Harris, 2012; Kline, 2015; Sobel & Kushnir, 2013). Altogether, the current study assessed the claim that children's potential understanding of metacognitive gestures indeed relates to their behavioral performance and plays a role in the regulation of social interactions from early on (Proust, 2013).

Experiment 1

Experiment 1 aimed to determine whether 3-, 5-, and 7-year-old children can differentiate among three types of metacognitive gestures indicating different levels of difficulty while learning. Based on previous research revealing that children are able to understand a wide range of gestures from 3 years of age onward (Dimitrova et al., 2017; Hodges et al., 2018; Novack et al., 2018; Stanfield et al., 2014), we expected to find a developmental difference in metacognitive gesture understanding. Specifically, we predicted that younger children would have more difficulties in differentiating metacognitive gestures than older children because metacognitive gestures are relatively more complex than other types of gestures.

Method

Participants

A total of 78 German-speaking children divided into three age groups participated in the experiment. Children were recruited from the city of Munich. For each age group, we intended to reach 26 children. The data of 2 children were incomplete and thus were not included in the final dataset. The final sample consisted of 76 children: 26 3-year-olds (M = 3.69 years, SD = 0.08; 18 girls), 24 5-year-olds (M = 5.63 years, SD = 0.12; 10 girls), and 26 7-year-olds (M = 7.58 years, SD = 0.13; 13 girls). Information regarding race and ethnicity was not collected because these types of questions are sensitive and very unusual in Germany. Families were contacted by postal mail. Children's parents gave written consent at the beginning of the study. Children provided oral assent to participate in the study. The study was approved by the institutional ethics committee. Families received 5 euros for travel compensation, and children received a small gift for participating.

Material

The material consisted of three video clips without sound, each lasting 7.5 s. The basic structure of the videos was based on previous studies on metacognition (Koriat & Ackerman, 2010) and used the setup of a paired-associate learning task (e.g., Destan et al., 2017; Paulus et al., 2014). The videos showed the frontal view of a woman sitting at a table in front of a white background. In each video clip, the woman took a sheet of paper from a stack of papers lying in front of her, looked at the sheet as if studying its content, and put it away. Importantly, the three video clips differed only with respect to the metacognitive gesture and mimic displayed by the woman while studying the sheet of paper, corresponding to three levels of ease of learning preliminarily tested with adults (for sample screenshots, see Fig. 1). In one clip, the woman scratched her head while studying the sheet of paper, looking puzzled (low ease of learning, as defined by Proust, 2013). In a second clip, she lifted her index finger and pulled up her eyebrows, showing comprehension (high ease of learning). In a third clip, the woman ran her hand through her hair with a neutral expression (medium ease of learning). Note that this last condition served as a matched-control condition—doing an action with the hand near the

Fig. 1. Screenshots of the stimuli used in Experiment 1. The three types of gesture and mimic displayed in Experiment 1—namely for low (left), high (middle), and medium (right) ease of learning—are shown.

head—for comparisons and does not represent a gesture per se. Each video was presented randomly-five times on a standard laptop.

To assess children's judgments of learning (hereafter JoLs), we used a 5-point smiley scale presented on a laminated sheet of paper (cf. Lockl & Schneider, 2003; Paulus et al., 2014). The scale consisted in five smileys, with a frowning smiley on the left and a smiling smiley on the right. The smiley in the middle displayed a neutral straight mouth.

In addition, we used two pairs of pictures to provide children with an example of the kind of information the woman needed to learn. The pairs of pictures were presented on two sheets of paper, with one pair displaying a strong association between the pictures (dog–bone) and one pair displaying pictures with no association (elephant–television).

Procedure

Children were seated next to the experimenter. The stimuli were displayed on a laptop placed at a distance of approximately 30 cm from the children. The experiment started with a familiarization task, where children were familiarized with the 5-point smiley scale. The experimenter informed them that the frowning smiley meant "very unsure," the smiling smiley meant "very sure," and the neutral smiley meant "neither sure nor unsure." Children were asked four questions to assess their understanding of the scale (e.g., "How sure are you that your name is Max?", "How sure are you that it will rain later on?"). All children answered the four practice questions consistently.

Children were then presented with a picture of the woman and were told that they would see a video in which this woman needed to study several pairs of pictures (a standard paired-associate learning task; e.g., Lockl & Schneider, 2003). To provide children with a concrete example of the kinds of pictures the woman needed to learn, the experimenter randomly presented the two examples of pairs of pictures (dog–bone and elephant–television). The experimenter then hid the examples and asked children whether they remembered the pairs of pictures. All children provided correct answers.

The test trials started after children answered the two questions. The experimenter instructed children that they would see a video of the woman studying similar pairs of pictures and that they would need to indicate their degree of certainty regarding the woman's ability to remember the pairs of pictures. Specifically, children were asked, "How confident are you that the girl will remember what she just learned?" After each video clip, the experimenter paused the video and children gave their JoLs by pointing at one of the smileys on the 5-point smiley scale. The three video clips were presented five times, resulting in a total of 15 JoLs per child.

Results

Data analyses of the three experiments reported in this article were conducted with IBM SPSS Statistics (Version 25). Figures were created with RStudio (Version 2022.2.2.485) using the additional package *ggplot2* (Wickham, 2016). The datasets for Experiments 1, 2, and 3 are available at the Open Science Framework (OSF; https://osf.io/8rgzp/).

To determine whether participants differentiated among the three levels of ease of learning, we conducted a repeated-measures analysis of variance (ANOVA) with ease of learning (low, medium, or high) as a within-participants factor and age group (3-, 5-, or 7-year-olds) as a between-participants factor. The ANOVA revealed a significant main effect of ease of learning, $F(2, 146) = 157.93$, $p < .001$, $\eta^2_p = .68$, which was modulated by a significant interaction between the level of ease of learning and age group, $F(4, 146) = 18.83$, $p < .001$, $\eta^2_p = .34$. There was, however, no main effect of age group, $F(2, 73) = 1.33$, $p = .270$, $\eta^2_p = .04$ (see Fig. 2).

Post hoc analyses were conducted to further investigate the interaction between ease of learning and age group, that is, to assess developmental difference in metacognitive gesture understanding. Thus, paired-sample *t* tests were performed for each age group (applying Holm–Bonferroni correction for multiple hypotheses testing) to compare JoLs on the three levels of ease of learning. For 3-year-olds, the mean JoL given for high ease of learning was significantly higher than the mean JoLs given for low and medium ease of learning. There was, however, no difference between the JoLs given for low and medium ease of learning. Regarding 5- and 7-year-olds, their JoLs were significantly different among all three levels of ease of learning (see Table 1).

Discussion

Experiment 1 investigated whether 3-, 5-, and 7-year-old children would correctly predict a person's learning outcome based on the type of metacognitive gestures the person displayed during a learning task. The results showed that children from all age groups provided consistent JoLs according to the metacognitive gestures displayed during learning. Specifically, children of all age groups predicted that the person would remember more of what she learned when she showed high ease of learning, that she would be less likely to remember when she showed low ease of learning, and that she would neither better remember nor less remember when she showed medium ease of learning. However, with age children appeared to become increasingly more sensitive to these cues, with 5- and 7-year-olds providing higher and lower JoLs than 3-year-olds when they observed cues to high and low ease of learning. In addition, only 5- and 7-year-olds were able to differentiate between gestures displaying medium and low ease of learning, whereas no difference was observed between the JoLs for low and medium ease of learning given by 3-year-olds. This finding is in line with previous

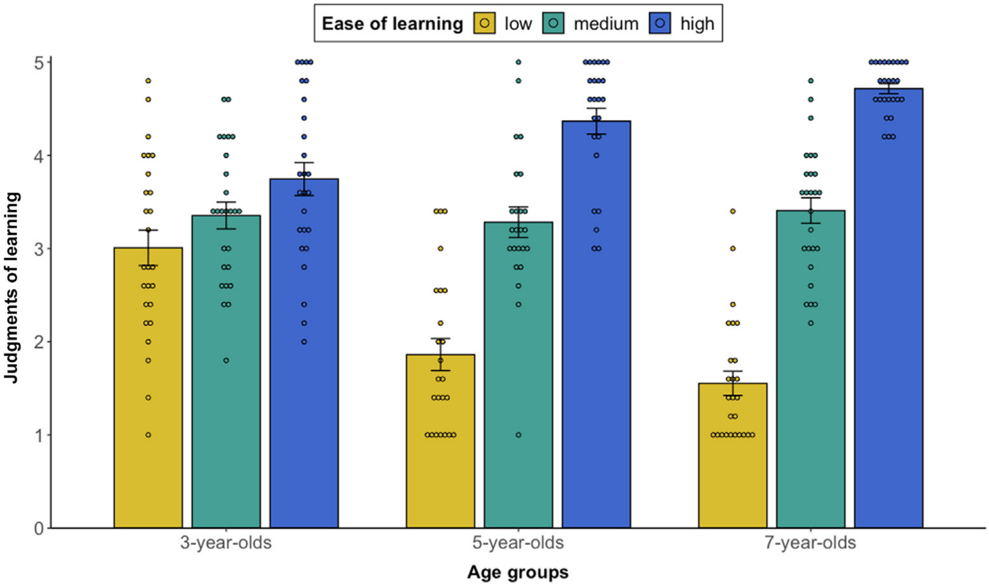

Fig. 2. Mean judgments of learning (JoLs) given for low, medium, and high ease of learning per age group. Mean JoLs from *very uncertain* (1) to *very certain* (5) of 3-, 5-, and 7-year-olds in the low (yellow/light gray), medium (green/gray), and high (blue/dark gray) ease of learning conditions, with data points displayed, are shown. Error bars represent standard errors of the mean.

Table 1
Judgments of learning per ease of learning and age group.

Ease of learning	Age group								
	3-year-olds			5-year-olds			7-year-olds		
	$t(25)$	p	d	$t(23)$	p	d	$t(25)$	p	d
High–medium	2.40	.024*	0.47	4.65	<.001*	0.95	9.82	<.001*	1.93
High–low	1.32	.014*	0.52	9.06	<.001*	1.85	20.51	<.001*	4.02
Medium–low	1.60	.123	0.31	7.07	<.001*	1.44	10.35	<.001*	2.03

Note. Statistics of paired t tests comparing the three levels of ease of learning for each of the age groups are shown.
*p value < adjusted p value with Holm–Bonferroni correction (Rank 1: adjusted p value = .017; Rank 2: adjusted p value = .025; Rank 3: adjusted p value = .050).

research on gesture comprehension showing that from 3 years of age children understand not only deictic, iconic, and conventional gestures (see, e.g., Dimitrova et al., 2017) but also metacognitive gestures representing ease of learning. The current experiment, however, suggests that children's ability to consistently interpret metacognitive gestures improves with age. In fact, this experiment revealed that children were able to accurately predict a person's performance based on the person's metacognitive gestures from 5 years of age onward. In contrast, 3-year-olds were able to understand metacognitive gestures only of high ease of learning. This suggests that there is an important developmental difference between from 3 to 5 years of age in children's reasoning about metacognitive gestures conveying different knowledge states. Experiment 2 assessed whether the developmental difference observed between 3- and 5-year-old children could be linked to better cognitive functioning and theory of mind skills.

Experiment 2

In Experiment 2, we aimed to investigate the source of the developmental change in metacognitive gesture understanding by exploring individual differences in children's performances. In particular, one could argue that children's developing understanding of metacognitive gestures is based on domain-specific knowledge of this type of gestures. Alternatively, it could be related to social-cognitive abilities, most prominently theory of mind (cf. Brosseau-Liard et al., 2015; Crivello et al., 2021; Fusaro & Harris, 2008). Finally, one could argue that metacognitive gesture understanding is based on domain-general cognitive abilities. To assess the contribution of the latter two factors, Experiment 2 tested children's appreciation of metacognitive gestures while assessing cognitive functioning and theory of mind. We expected that children's JoLs would be correlated to sociocognitive abilities, that is, that children with more advanced sociocognitive skills would be better at discriminating between metacognitive gestures.

Method

Participants

A total of 61 children aged 4 years participated in the experiment. We tested only 4-year-old children because we aimed to assess specifically which factors could explain the developmental difference in metacognitive gesture understanding between 3- and 5-year-olds observed in Experiment 1. We excluded the data of 2 participants who had very low German understanding and who consequently were not able to fully understand the instructions. The final sample size resulted in 59 4-year-olds (M = 4.48 years, SD = 0.31; 33 girls). Children were recruited from local childcare centers from the city of Munich. As for Experiment 1, information regarding race and ethnicity was not collected because these questions are sensitive and very unusual in Germany. Children's parents gave written consent, and children provided oral assent before participating in the study. The study was approved by the institutional ethics committee.

Materials

We used identical materials as in Experiment 1, namely, the same video clips, pictures of the woman presented in the videos and the 5-point smiley scale. In addition, we used the Theory of Mind scale developed by Wellman and Liu (2004), translated in German by Hofer and Aschersleben (2007), and the Primary Test of Nonverbal Intelligence (hereafter PTONI) developed by Ehrler and McGhee (2008). The Theory of Mind scale (Wellman & Liu, 2004) assesses children's understanding of desires, emotions, knowledge, and beliefs through seven tasks. The PTONI (Ehrler & McGhee, 2008) assesses the nonverbal cognitive capacities of children aged 3 to 9 years using tasks that do not involve linguistic mastery. The PTONI tasks consist of detecting from a set of pictures the one picture that mismatches the others. Children need to point to the picture that does not belong with the others. Pictures' sets are presented in order of difficulty, from lower to higher reasoning abilities (e.g., from visual and spatial perception to analogical thinking and sequential reasoning; cf. Ehrler & McGhee, 2008).

Procedure

The task related to JoLs was conducted in the same way as in Experiment 1. The only difference was that each video was presented four times instead of five times. Therefore, each child provided four JoLs for each condition (high, medium, and low ease of learning).

The tasks of the Theory of Mind scale were presented in ascending order of difficulty (Wellman & Liu, 2004). The stories were presented on a sheet of paper with Playmobil figures, and the different items were drawn on it. The scenarios for each task were identical to those of Wellman and Liu (2004).

The PTONI task (Ehrler & McGhee, 2008) was conducted according to the instructions provided in the PTONI manual. The experimenter informed children that one picture from the set was different. Children were then asked to find which picture mismatched the others. To familiarize children with the task, children performed five trials during which they could correct their answers. Once children understood the task, the test phase started. The task stopped as soon as a child provided five incorrect answers out of seven items.

Coding

The mean of the four JoLs was computed for each condition. Thus, each participant obtained a mean JoL for the high, medium, and low ease of learning conditions. To assess children's understanding of metacognitive gestures and to control for individual biases toward one side of the scale, we calculated the difference of JoL means between conditions. We assumed that greater difference between JoLs in the three conditions corresponded to better discrimination between metacognitive gestures. Specifically, we first computed the differences between JoLs in the low and medium ease of learning conditions as well as between JoLs in the medium and high ease of learning conditions. Then, we summed the differences to obtain a score of metacognitive gesture understanding. For example, if JoLs were 1, 3, and 4 for the low, medium, and high ease of learning conditions, respectively, the sum of differences was 3 [(3–1) + (4–3)]. Scores representing children's understanding of metacognitive gestures therefore ranged from -4 to 4. A negative score corresponds to JoLs that are opposite to ease of learning; participants judged that the person who displayed high ease of learning would certainly not remember what she learned and that the person who displayed low ease of learning would remember what she learned. A score of 0 means that participants did not discriminate between ease of learning (i.e., they provided the same JoL for each condition). A positive score indicates that participants provided JoLs consistent with the displayed ease of learning.

For theory of mind scores, each correctly solved task received 1 point (for details, see Wellman & Liu, 2004). According to the follow-up study by Wellman et al. (2004) and the validation study for the German version of the Theory of Mind scale (Kristen et al., 2006), only one of the false-belief tasks was included in the calculation of the total score. Thus, only 1 point was awarded for correct answers to the false-belief tasks. Participants could achieve a score from 0 to 5 points, where higher scores represent higher understanding of other people's desires, knowledge, beliefs, and emotions.

For the PTONI tasks, participants received 1 point for selecting the correct picture that mismatched the other pictures and 0 points for incorrect answers. A score was calculated based on the sum of all correct answers, which was then converted into IQ scores as a function of age (for details on the scoring procedure, see Ehrler & McGhee, 2008).

Results

The dataset for Experiment 2 is available at https://osf.io/8rgzp/.

First, we analyzed whether 4-year-olds differentiated among the three different levels of ease of learning by conducting a repeated-measures ANOVA with JoLs as the dependent variable and ease of learning (low, medium, or high) as a within-participants factor. The ANOVA revealed a significant main effect of ease of learning on JoLs, $F(2, 116) = 102.68$, $p < .001$, $\eta^2_p = .64$. Post hoc comparisons (paired-sample *t* tests applying a Holm–Bonferroni correction to the *p* values) revealed that JoLs were significantly different from one another in all three conditions of ease of learning [low–medium: $t(58) = 8.96$, $p < .001$, $d = 1.17$; low–high: $t(58) = 14.85$, $p < .001$, $d = 1.93$; medium–high: $t(58) = 5.06$, $p < .001$, $d = 0.66$].

To determine whether IQ and theory of mind scores were related to metacognitive gesture understanding, we computed Pearson's correlation coefficient between each pair of variables. IQ scores were not significantly correlated with metacognitive gesture understanding ($r = .143$, $p = .279$). Similarly, we found no significant correlation between theory of mind scores and metacognitive gesture understanding ($r = .105$, $p = .431$). However, a significant correlation was observed between IQ and theory of mind scores ($r = .294$, $p = .024$).

Discussion

The results of Experiment 2 revealed that 4-year-olds are able to discriminate among the three levels of ease of learning. Indeed, 4-year-olds were able to accurately predict that a person who gestured struggle while learning would be less likely to remember what she learned than a person who showed ease of learning. However, individual differences could not be explained by domain-general cognitive functioning or theory of mind abilities. Specifically, Experiment 2 showed that IQ scores (as measured by PTONI tasks) and theory of mind scores (as assessed by the Theory of Mind scale) were not related to metacognitive gesture understanding. This suggests that by 3 or 4 years of age children are able to interpret metacognitive gestures of ease of learning, but this ability is not modulated either by better nonverbal cognitive capacities or by more specific social-cognitive abilities. At the same time, theory of mind and general cognitive functioning scores were clearly related, underscoring the reliability of our measures. This pattern is suggestive of an interpretation that the understanding of metacognitive gestures relies on domain-specific knowledge. This is further addressed in the General Discussion.

Experiments 1 and 2 provide evidence that children from 3 or 4 years of age can predict a person's learning outcome based on her metacognitive gesture. In Experiment 3, we investigated whether children use the information they gain from metacognitive gestures to inform their possible interaction with other learners. Specifically, in Experiment 3 we assessed whether children can consistently determine who should support someone in a learning task (selective learning) and from whom one should receive help during a learning task (selective teaching). Given that Experiment 1 pointed to developmental changes from 3 to 7 years of age, we decided to test the same age groups in Experiment 3. In addition, because applying one's knowledge of metacognitive gestures can be more difficult than merely perceiving learning abilities, we also added an adult group.

Experiment 3

To assess selective *teaching* and selective *learning*, we relied on a third-party approach in which we presented participants with two protagonists: one presented as very good at learning and the other presented as very bad at learning. Similar to Experiments 1 and 2, participants also observed three female agents who displayed different levels of ease of learning (high, medium, or low ease of learning). Subsequently, participants were asked to select which female agent should receive help from the protagonist with a good memory (selective teaching) and who should assist the protagonist with the bad memory (selective learning). This procedure allowed us to assess whether children recognize the practical consequences of ease of learning. That is, if someone shows high ease of learning, then this person should be the one who helps, and if someone shows low ease of learning, then this person should be the one who receives help. Based on the results of Experiment 1, we expected to observe a developmental difference between younger and older children. Specifically, we predicted that 3-year-olds would select teaching and learning partners less accurately than older children. We also explored whether participants' performance would be correlated in selective teaching and selective learning conditions.

Method

Participants

A total of 96 German-speaking participants were tested: 22 3-year-olds (*M* = 3.55 years, *SD* = 0.10; 12 girls), 25 5-year-olds (*M* = 5.41 years, *SD* = 0.16; 16 girls), 25 7-year-olds (*M* = 7.57 years, *SD* = 0.22; 10 girls), and 24 adults (*M* = 28.02 years, *SD* = 10.27; 16 women). Families were contacted by postal mail. Adult participants were recruited from the local student population of LMU Munich. Again, information regarding race and ethnicity was not collected because these questions are sensitive and very unusual in Germany. Children's parents gave written consent at the beginning of the study, and children provided oral assent to participate in the study. Adult participants provided written consent before starting the study. The study was approved by the institutional ethics committee. Families received 5 euros for travel compensation, and children received a small gift for participating. Adults received course credits for their participation.

Materials

The stimuli consisted in nine video clips involving three different women. The video clips were similar to those used in Experiments 1 and 2. Each video clip showed a woman studying a sheet of paper while displaying one of the three metacognitive gestures presented in Experiments 1 and 2 (i.e., low, medium, or high ease of learning; see Fig. 3). The video clips were combined into sequences, where each woman performed only one of the three possible metacognitive gestures. The actor and metacognitive gestures were counterbalanced for each of the six pseudorandomized sequences. The video clips were presented on a standard laptop. The pictures of the three actresses, as well as of two additional new women, were used to assess children's selective learning and selective teaching behaviors.

Procedure

The settings and the familiarization phase were identical to Experiments 1 and 2. After seeing the video sequence, the experimenter introduced two new female protagonists, Sarah and Maria: "Look, this is Sarah. Sarah always remembers everything! Look, this is Maria. Maria can never remember anything, she always forgets everything!" As Sarah and Maria were introduced, the experimenter placed

Fig. 3. Screenshots of the stimuli used in Experiment 3. The three types of metacognitive gestures displayed—namely for low (left), high (middle), and medium (right) levels of ease of learning—are shown.

their respective pictures on the table in front of the participants. Whether Sarah or Maria had a good memory was counterbalanced between participants.

The experimenter then presented for a second time the video sequence of the three actresses performing the learning task. After playing the videos, the experimenter placed the pictures of the actresses below the picture of Sarah or Maria. The pictures of the actresses were presented in pairs, contrasting each level of ease of learning displayed, that is, high versus medium ease of learning, high versus low ease of learning, and medium versus low ease of learning. For each comparison, participants needed to answer two types of questions: assessing selective *teaching* behavior and selective *learning* behavior. To assess selective teaching behavior, participants needed to select which actress (presented in pairs) should receive help from the character with a good memory (i.e., Sarah). To assess selective learning behavior, participants needed to select which of the female actors should assist the character with the bad memory (i.e., Maria). Overall, participants provided three answers for each type of questions (pertaining to selective teaching or selective learning behaviors), one answer per combination of ease of learning (high–medium, high–low, and medium–low). The order of these two types of questions was counterbalanced between participants.

Coding

A score for correct answers was computed for each participant. In the selective *learning* condition, a correct response consisted in choosing from the pair of actresses the one who displayed the highest ease of learning. Specifically, participants received 1 point for selecting the actress who showed high ease of learning in the combinations high–low and high–medium. They received 1 point for selecting the actress who displayed medium ease of learning in the combination medium–low. For the selective *teaching* condition, the distribution of points was opposite to the selective learning condition; participants received 1 point for choosing the actress who displayed the lowest ease of learning. Overall, participants could obtain a maximal score of 3 points per condition.

Results

The dataset for Experiment 3 is available at https://osf.io/8rgzp/.

To determine whether children of different age groups, as well as adults, are able to use others' metacognitive gestures to appreciate selective learning and selective teaching behaviors, we conducted two one-way ANOVAs to compare the scores obtained by each age group (3-year-olds, 5-year-olds, 7-year-olds, and adults) in each of the two conditions (learning and teaching). The ANOVAs revealed a significant effect of age for the selective learning condition, $F(3, 92) = 6.23$, $p = .001$, $\eta^2_p = .17$, and for the selective teaching condition, $F(3, 92) = 5.35$, $p = .002$, $\eta^2_p = .15$ (see Fig. 4).

Independent *t* tests, with Holm–Bonferroni correction, were conducted to further assess age difference in performance, that is, to test the hypothesis that 3-year-olds would select teaching and learning partners less accurately than older children and adults). This analysis revealed that, overall, there was a significant difference in the scores achieved by 3-year-olds compared with adults [in the learning condition, $t(44) = 5.01$, $p < .001$, $d = 1.48$, and in the teaching condition, $t(44) = 4.12$, $p < .001$, $d = 1.22$] and compared with 7-year-olds [only in the teaching condition, $t(45) = 2.42$, $p = .019$, $d = 0.71$, but not in the learning condition, $t(45) = 1.99$, $p = .052$, $d = 0.58$]. A significant difference was also observed in scores achieved by 5-year-olds compared with adults [in the learning condition, $t(47) = 3.52$, $p < .001$, $d = 1.01$, and in the teaching condition, $t(47) = 2.98$, $p < .005$, $d = 0.85$]. There was no significant difference between any of the other age groups in both the learning and teaching conditions (all *p*s > .08). In fact, when comparing performance of each age group against chance, one-sample *t* tests revealed that performance of 3-year-olds did not differ from chance in both the learning condition, $t(21) = 1.39$, $p = .179$, $d = 0.30$, and the teaching condition, $t(21) = 1.29$, $p = .211$, $d = 0.28$. Performance was significantly above chance in the two conditions for all the other age groups (all *p*s < .04).

Moreover, an exploratory analysis was conducted to investigate whether performances in the learning and teaching conditions were different between trial types and age groups. The 3 (Trial Type: low–medium, low–high, or medium–high) × 4 (Age Group: 3-year-olds, 5-year-olds, 7-year-olds, or adults) mixed ANOVA revealed a significant effect of age group, $F(3, 92) = 6.46$, $p = .001$, $\eta^2_p = .17$,

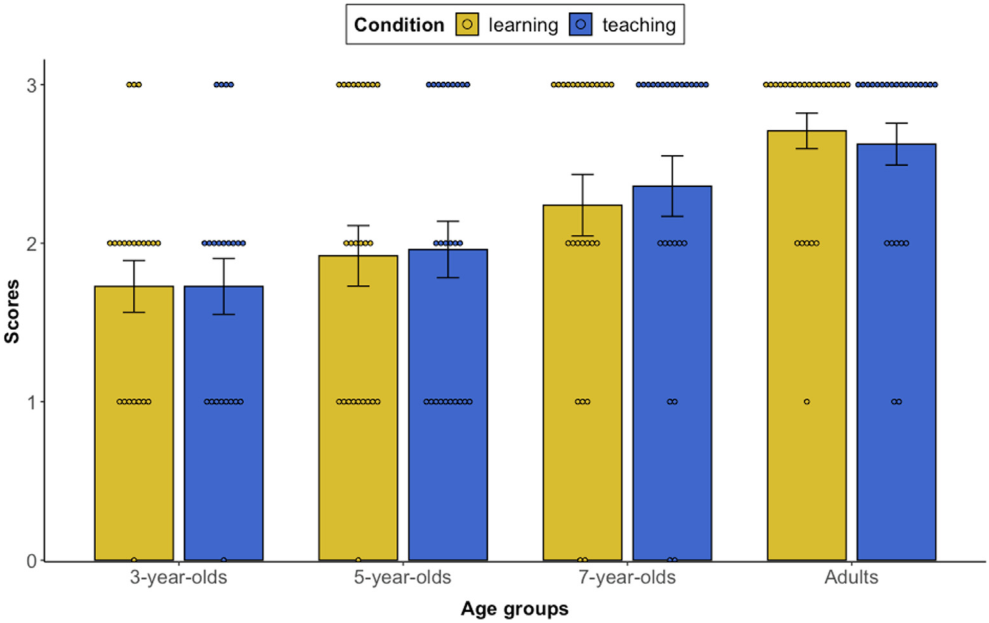

Fig. 4. Mean scores obtained in the selective learning and selective teaching conditions per age group. Mean scores of correct answers obtained by 3-year-olds, 5-year-olds, 7-year-olds, and adults in the selective learning (yellow/light gray) and selective teaching (blue/dark gray) conditions, with data points displayed, are shown. Error bars represent standard errors of the mean.

but no effect of trial type, $F(2, 184) = 1.25$, $p = .289$, $\eta_p^2 = .01$, and no interaction effect, $F(2, 184) = 1.25$, $p = .289$, $\eta_p^2 = .05$ (see Table 2).

Finally, we explored whether performances in the learning and teaching conditions correlated with each other within each age group. The two-tailed Pearson's correlations revealed a significant positive correlation between performances in the learning and teaching conditions for all age groups (3-year-olds: $r = .703$, $p < .001$; 5-year-olds: $r = .684$, $p < .001$; 7-year-olds: $r = .895$, $p < .001$; adults: $r = .779$, $p < .001$).

Discussion

In Experiment 3, we investigated whether children would rely on gestures to select future learning partners. Consistent with our predictions, the results of Experiment 3 revealed a developmental difference between 3-year-olds and older children. That is, 3-year-olds selected learning and teaching partners at chance, whereas 5- and 7-year-olds, as well as adults, accurately selected the adequate learning and teaching partners. Although the findings in this experiment clearly correspond to earlier findings (e.g., Cluver et al., 2013; Liszkowski et al., 2008), they are in contrast to one recent study by

Table 2
Performance in the learning and teaching condition across trial types and age groups.

	Age group			
Trial type	3-year-olds *M* (*SD*)	5-year-olds *M* (*SD*)	7-year-olds *M* (*SD*)	Adults *M* (*SD*)
Low–medium	0.86 (0.94)	1.48 (0.77)	1.52 (0.82)	1.75 (0.53)
Low–high	1.27 (0.94)	1.44 (0.87)	1.56 (0.82)	1.87 (0.45)
Medium–high	1.32 (0.89)	0.96 (0.94)	1.52 (0.87)	1.71 (0.69)

Kim and colleagues (2016). Surprisingly, the study by Kim et al. showed that children consistently chose to inform a more knowledgeable person (rather than a person lacking relevant knowledge) across various experimental manipulations. An important difference between Kim et al.'s (2016) experimental design and the current experiment's design can explain this discrepancy. In Kim et al.'s study, children needed to choose with whom, either a knowledgeable person or an ignorant person, they would like to share new information. In the current experiment, however, children were asked to indicate who should be helped or who should support another person. Thus, our task assessed children's reasoning about what *one* should do in a given context, whereas Kim et al. (2016) directly assessed children's *own* choices, which might have been affected by additional affiliative motives. In addition, at each age group, individual differences in the selective learning and selective teaching conditions were highly correlated, suggesting that an understanding of these two aspects develops in parallel. The findings in this experiment build on and extend earlier findings (e.g., Cluver et al., 2013) and underscore that selective learning and selective teaching develop during the preschool period (e.g., Kim et al., 2018; Sabbagh & Baldwin, 2001; Ziv & Frye, 2004). The implications of this finding are discussed in the General Discussion.

General discussion

The current study investigated children's developing understanding of metacognitive gestures. That is, we examined children's understanding of the behavioral cues that inform us about others' learning performances (Proust, 2008, 2013). An understanding of these cues plays an important role in learning to appreciate and deal with others' epistemic states. Moreover, it is foundational for cooperative interactions in learning contexts. To this end, we investigated whether children rely on gestures to judge someone else's learning progress and likely performance (Experiment 1), whether metacognitive gesture understanding depended on the development of cognitive capacities and the acquisition of a fully-fledged theory of mind (Experiment 2), and whether this knowledge would influence children's future selective learning and selective teaching choices (Experiment 3). Results of Experiment 1 showed that preschoolers use gestures as an indicator of another person's performance and that this ability improves from 3 to 5 years of age. Indeed, we found a developmental improvement in children's understanding of metacognitive gestures, with older children (5- and 7-year-olds) showing a clearer differentiation among the different gesture types. The results of Experiment 2 revealed that the developmental difference between 3- and 5-year-olds was not due to children's increased cognitive capacities or theory of mind skills, hinting at a role of domain-specific knowledge. Moreover, Experiment 3 showed that 5- and 7-year-olds, like adults, but not 3-year-olds, consistently selected that the better learner should support someone in a learning task (selective learning) and that the worst learner should receive help in the learning task (selective teaching). Overall, the results of the current study support views that children acquire an understanding of metacognitive gestures early in life and apply this knowledge to guide their behavior (Proust, 2013).

Notably, the findings from Experiment 1 demonstrated that by 3 years of age preschool children can predict another person's performance based on the person's metacognitive gestures displayed during a learning task. Previous research showed that children can use explicit knowledge about the ability of another person (Droege & Stipek, 1993) as well as knowledge about a person's past performance (Birch et al., 2008) to predict future performance. The current study revealed that such understanding can (at least partly) also be based on nonverbal epistemic gestures. It showed that already 3-year-old children have an understanding of the link between the gestures displayed by the learners and their probable success in the learning task. Noteworthy, there were also developmental improvements in such understanding. Indeed, 3-year-olds did not clearly differentiate between gestures displaying medium and low ease of learning, whereas older children more clearly associated these displayed gestures as a cue of learning progress. Therefore, it seems that children's appreciation of metacognitive gestures becomes more refined during the course of the preschool and early school years.

The nature of individual differences was assessed in Experiment 2 by focusing on 4-year-old children. Notably, we found no significant relationship among theory of mind skills, nonverbal cognitive abilities, and metacognitive gesture comprehension. This suggests a limited impact of domain-general cognitive or social-cognitive abilities in children's understanding of metacognitive gestures. One possible interpretation of this finding is that an appreciation of metacognitive gestures is rather domain specific. Interestingly, Hübscher et al. (2019) demonstrated that children from 3 years of age use prosodic and gestural cues, but not yet lexical cues, to express their uncertainty. Thus, it would be interesting to explore, for example, whether children's own capacity to lexically express their epistemic state relates to their understanding of others' metacognitive gestures. Future studies could also look at the role of language; would children who speak a language that encodes epistemic states with morphological markers (e.g., Turkish) be better at understanding others' metacognitive gestures? Similarly, it would be worthwhile to examine whether children growing up in an environment that is expressive with respect to gesturing show an improved understanding of others' metacognitive gestures.

It is important to note that the current research tested the effect of cognitive abilities and theory of mind capacities on children's *understanding* of metacognitive gestures. We did not test whether children's own selective learning and selective teaching choices were affected by those psychological mechanisms. It is possible that selective teaching and selective learning are significantly affected by children's developing sociocognitive capacities, as previous research seems to suggest (e.g., Davis-Unger & Carlson, 2008). We need to leave it to future research to explore how children's understanding of metacognitive gestures relates to their own selective learning and selective teaching behaviors.

Interestingly, in Experiment 3 the 3-year-old children's choices of selective learning and selective teaching partners based on others' metacognitive gestures were at chance level, whereas the older three age groups performed above chance in both tasks. This finding is intriguing because even though 3-year-olds were able to evaluate someone else's learning performance based on the observation of their metacognitive gestures, as shown in Experiment 1, they apparently were not able to use this knowledge to guide their future behavior. This finding is particularly interesting. On the one hand, it seems to contradict previous findings showing that preschoolers are able to not only differentiate between different knowledge states but also make choices based on this knowledge (e.g., Ziv & Frye, 2004). On the other hand, it relates to more recent work showing that selective learning and selective teaching are difficult for preschool children (Kim et al., 2018). Importantly, these studies differ in terms of the nature of the protagonists' expertise. Apparent age-related differences in selective learning and selective teaching therefore might point to developmental differences in children's understanding of expertise.

Even if younger children were aware of the learners' likely performances (as Experiment 1 would suggest), they nevertheless failed to translate this knowledge into adequate choices. One possible explanation of younger children's inability to choose an adequate learning partner could be that they simply did not know what a helpful partner would be or that they failed to take goal-directed action. However, this interpretation is unlikely given that in previous studies 3-year-olds showed superior performance in selective learning (for a review, see Harris, 2012). Another possible explanation could be that, in the paradigm of Experiment 3, children did not have the time to become aware of the actresses' knowledge state. Note that in Experiment 3 children did not evaluate the actresses' future performance (as in Experiment 1), but rather were directly asked to choose a learning partner. It is possible that first explicitly asking young children about a person's performance would scaffold their understanding of metacognitive gestures and in turn would lead them to more sensibly select a future learning partner. This interpretation relates to theoretical conceptions that explicitly asking people to reflect on a particular aspect of a task increases their performance (e.g., Koriat & Ackerman, 2010; see also Zelazo & Frye, 1998). Finally, it is possible that although young children understand differences in ease of learning, this does not play a role in their practical life. This might change once they prepare for going to school. We need to leave it to future research to explore these possibilities.

Another interesting aspect of Experiment 3 is the finding that performances in the selective *teaching* and selective *learning* conditions were strongly interrelated even for the younger age groups. This finding is interesting given that one study suggested a developmental décalage in the understanding of learning and teaching that differed across cultures (Kim et al., 2018). Yet, in Kim et al.'s (2018) study knowledge states were manipulated in terms of having perceptual access or not, whereas our study focused on ease of learning as expressed by metacognitive gestures. Moreover, it focused on differences in mean levels. Our finding indicates that there might be a shared psychological source underlying children's performances in selective learning and selective teaching.

One possible criticism of the current study could point to the fact that children's JoLs were simply matching the expression of the learner in the video with the expression of a corresponding smiley. This explanation seems unlikely, however, because it does not hold for Experiment 3, where children needed to make a partner selection based on the previously seen gestures. Indeed, it is important to note that we found the same developmental trends across the three different experimental setups and measures.

The current study contributes to our understanding of the development of gesture understanding as well as selective learning and selective teaching behaviors during the preschool years and later. It extends recent findings on metacognitive development in preschool children to the area of understanding others' cognitive performances. In particular, a plethora of research on gesture understanding in children has shown that, from a very young age, children have an understanding of different kinds of gestures such as iconic and conventional gestures (Fusaro & Harris, 2013; Goldin-Meadow, 2000). Moreover, research has shown that children adjust their speech pattern and explanations (e.g., Nadig & Sedivy, 2002) according to others' knowledge states. Our study extends the field of research on gesture development by demonstrating an understanding and the relevance of metacognitive gestures during early childhood (Proust, 2013). In addition, the current study contributes to theoretical endeavors on the development of selective learning and selective teaching (e.g., Harris, 2012) by highlighting the range of cues that children take into account in these situations.

Although the current study contributes to our understanding of the development of metacognitive gestures, it also has some limitations and leaves open questions for future research. Proust (2013) originally conceptualized the function of metacognitive gestures as a form of conversational metacognition, which might imply that they are somewhat intentionally employed by the producer as a form of communication with others. However, we do not deem it necessary that learners should be conscious of the production of these gestures during learning. Instead, we propose the possibility that there might be situations in which metacognitive gestures are an involuntary byproduct of their (un)certainty. Whether there is indeed such a difference between metacognitive gestures as epiphenomenal or as consciously produced, and whether there might be developmental differences in the understanding and production of these two types of metacognitive gestures, would constitute an interesting venture for future research. Moreover, it should be noted that the metacognitive gestures employed in the current study were rather salient. In natural settings, when judging an interaction partner's learning progress, the cues that children rely on are rarely as isolated as in the current study. Instead, other cues less salient than gestures could play a role in children's JoLs such as study time (Paulus et al., 2014), knowledge about previous behavior and ability (Ziv & Frye, 2004), and displayed attention and effort (Nicholls, 1978). In such situations, it would be interesting to know which kind of cues weigh more in children's JoLs. In addition, it would be interesting to explore the impact of metacognitive gestures in specific learning contexts. For example, one could explore whether different types of feedback on children's learning (Berner et al., 2022) affect their production of metacognitive gestures. Likewise, it might be valuable to explore whether metacognitive gestures are recognized in the home learning environment (Niklas & Schneider, 2017) and to what extent parents take them into account when interacting with their children. Finally, although the current study revealed developmental changes in children's appreciation of others' gestures in selective learning and selective teaching, the precise psychological mechanisms underlying this change remain open.

In sum, the current experiments showed that by the preschool years children can rely on metacognitive gestures to estimate a person's learning progress and—at least by the late preschool years—to make selective learning and selective teaching choices. The way in which metacognitive gestures interact with other cues that indicate learning progress and how they relate to selective learning and selective teaching are open for future research.

Data availability

The datasets and descriptions of the datasets for Experiments 1, 2, and 3 are publicly available at https://osf.io/8rgzp/ (DOI 10.17605/OSF.IO/8RGZP)

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