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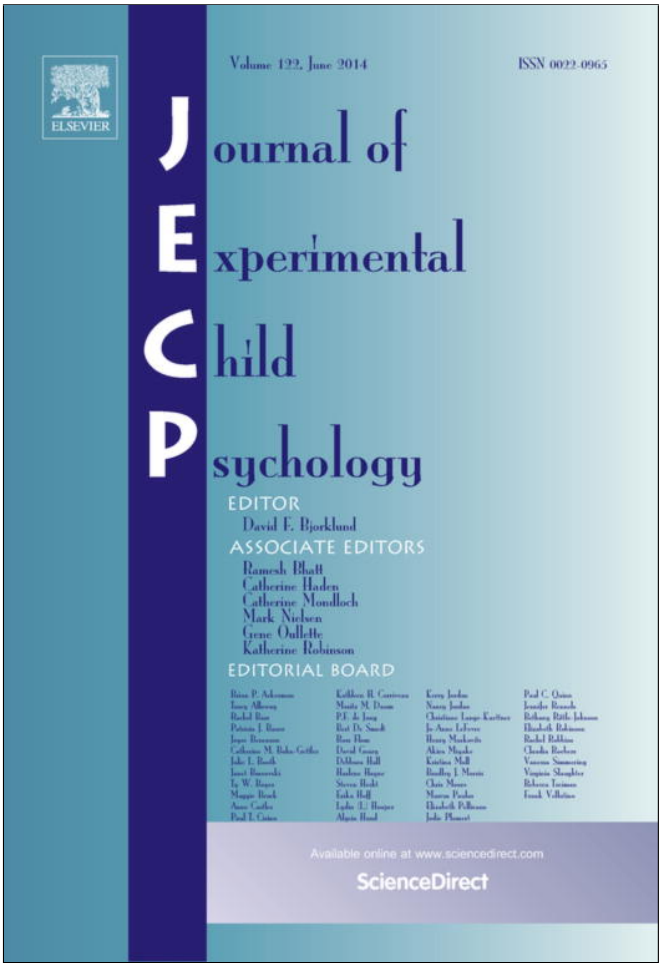

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Metacognitive monitoring of oneself and others: Developmental changes during childhood and adolescence

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ABSTRACT

The current study examined the development of people's knowledge about others' learning and memory processes. To this end, participants of four different age groups (6- and 7-year-old children, 8- to 10-year-old children, 14- and 15-year-old adolescents, and adults) observed another person performing a paired associate learning task, allocating either little or more time to the paired associates. Participants were asked to estimate the likelihood of recall by giving judgments of learning (JoLs) for every item pair (Other Task). In addition, we manipulated whether participants performed an equivalent task themselves (Self Task) before or after the evaluation of the other. Our results show significant developmental effects, with the older two age groups, but not the younger two age groups, differentiating between the short and long video sequences when giving JoLs in the Other Task. Moreover, the results revealed an impact of having performed the Self Task beforehand on participants' JoLs in the Other Task, suggesting that metacognitive knowledge about the other is informed by experiential cues during the actual (i.e., firsthand), learning process.

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Introduction

The relationship between knowledge about one's own cognitive processes (i.e., metacognition) and knowledge about other people's cognitive states and processes (i.e., social cognition) is hotly debated within cognitive psychology (e.g., Carruthers, 2009; Proust, 2013) and particularly within developmental psychology (e.g., Lecce, Zocchi, Pagnin, Palladino, & Taumoepeau, 2010; Lockl & Schneider, 2007). Knowledge about others' cognitive processes plays a central role in understanding and predicting others' behavior (Moore, 2006). Yet, research in this domain has focused almost exclusively on the question of how children represent others' knowledge states and desired action goals (e.g., Flavell, 1999; Lockl & Schneider, 2007; Meltzoff, 1995). Another important yet neglected area of research concerns knowledge about others' learning and memorizing processes (i.e., metamemory). A deeper insight into how humans come to such an understanding contributes to the research area of social metacognition and helps to understand the cognitive processes underlying knowledge about others' learning and knowledge states (for reviews, see Frith, 2012; Jost, Kruglanski, & Nelson, 1998). Furthermore, the evaluation of others' abilities and competencies plays an important role in establishing and coordinating cooperative activities (e.g., Sebanz, Bekkering, & Knoblich, 2006) such as forms of self-regulated cooperative and collaborative learning (e.g., Slavin, 1990).

A considerable amount of research has provided evidence that children's own metacognitive performances develop largely between early childhood and adolescence (for a review, see Schneider & Pressley, 1997). Traditionally, research in the area of metamemory focused on explicit metacognitive knowledge (e.g., Kreutzer, Leonard, & Flavell, 1975; O'Sullivan, 1993; O'Sullivan, 1997). During recent years, however, the research focus has shifted to an examination of the development of metacognitive monitoring and control abilities (for a review, see Schneider & Lockl, 2008). Although recently some signs of early implicit metacognitive abilities have been reported (e.g., Balcomb & Gerken, 2008; Call & Carpenter, 2001; Lyons & Ghetti, 2013; Paulus, Proust, & Sodian, 2013), the majority of studies reported developmental changes in metacognitive monitoring and control across school ages (e.g., De Neys & Feremans, 2013; Roebers, von der Linden, Howie, & Schneider, 2007; cf. Schneider & Lockl, 2008). For example, Koriat, Ackerman, Lockl, and Schneider (2009a) reported that, in a self-paced condition, 7- to 10-year-old children relied on the *easily learned, easily remembered* (ELER) heuristic (i.e., assuming an inverse relation between recall probability and learning effort) as measured in trials to acquisition to evaluate their learning performances. As a typical measure for the metacognitive evaluation of one's own learning, judgments of learning (JoLs) were assessed. When presented with items of different levels of difficulty, children gave higher JoLs for items on which they needed fewer trials to acquisition. Moreover, the 8- to 10-year-olds showed a more progressed reliance on this heuristic in their JoLs, using it even when presented only with difficult items. Koriat, Ackerman, Lockl, and Schneider (2009b) provided further evidence for the existence of the memorizing effort heuristic in 9- to 12-year-olds but not 7- and 8-year-olds. In their study, children gave higher JoLs when the amount of time spent studying the item decreased. These findings provide support for theoretical accounts positing that metacognitive abilities need not depend on explicit knowledge about cognition but can be based on data-driven cues during the actual learning process (e.g., Hertzog, Dunlosky, Robinson, & Kidder, 2003; Koriat, Ackerman, Adiv, Lockl, & Schneider, in press; Koriat, Ma'ayan, & Nussinson, 2006).

Metacognitive development is not restricted to early and middle childhood but rather continues during adolescence. For example, Weil and colleagues (2013), adopting a procedure by Fleming, Weil, Nagy, Dolan, and Rees (2010), presented 11- to 41-year-old participants with a perceptual task, in which participants needed to visually identify pop-out targets, and a metacognitive judgment task, in which they needed to indicate the confidence of their decision. The analyses showed that metacognitive abilities increased during adolescence and plateaued during adulthood. Moreover, van der Stel and colleagues (van der Stel, Veenman, Deelen, & Haenen, 2010; see also van der Stel & Veenman, 2010) reported that the frequency of metacognitive activity when solving math problems increased between 13 and 15 years of age and that in 14- and 15-year-olds the quality of metacognitive activity was a stronger predictor for task performance than in 13- and 14-year-olds. These studies relate to findings of developmental plasticity in adolescents' metacognitive abilities (Williams et al., 2002) and to recent neuroimaging findings demonstrating developmental changes in metacognitive and mind-reading

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skills across adolescents (for a review, see Burnett, Sebastian, Cohen Kadosh, & Blakemore, 2011). Taken together, the reviewed literature suggests that metacognitive abilities develop from early childhood well into and throughout adolescence (Schneider, 2008).

Notwithstanding the rich literature on children's own metacognitive abilities and the relevance of knowing about others' learning and memory performances for efficient forms of cooperative learning, surprisingly little is known about how children monitor others' learning and memory and, more concretely, about which cues they rely on when evaluating others' learning performances. Some evidence for a potential mechanism underlying the assessment of others' learning and memorizing comes from the adult literature, suggesting a tight relationship between one's own metacognitive processes and an understanding of others' learning and memorizing (Koriat & Ackerman, 2010; Undorf & Erdfelder, 2011). Koriat and Ackerman (2010) examined adults' application of the memorizing effort heuristic (i.e., the inverse relation of study time and JOLs) when monitoring another person's learning of paired associates. To manipulate study time, participants observed short and long video sequences depicting another person performing a paired associate learning task. Importantly, the authors also manipulated whether participants performed an equivalent task themselves before estimating the other's JoLs or afterward. The results showed that participants applied the memorizing effort heuristic only after having had the experience of studying paired associates themselves. In a further control experiment, participants first performed the task themselves and then evaluated the other but were not asked to give JoLs after their own learning. In this situation, participants did not apply the memorizing effort heuristic to the other's learning, suggesting that pure familiarity with the nature of the task was not enough to correctly apply the heuristic; the experiential cues that play a critical role in reliable metacognitive judgments are, rather, activity dependent.

From a developmental point of view, it remains an open question at what age and how children come to evaluate others' learning performances and predict their recall abilities. Moreover, it is unclear whether their own metacognitive experiences facilitate their understanding of others' learning achievements. Developmental evidence for an impact of own experiences on the processing and understanding of others' behavior has recently been provided in the literature on action perception (e.g., Paulus, 2012; Paulus, Hunnius, van Elk, & Bekkering, 2012; Sommerville, Woodward, & Needham, 2005), suggesting a tight relation between action production and action perception. Does this relation also hold for the understanding of others' learning processes? The current contribution examined these questions by means of a cross-sectional study with four different age groups: 6- and 7-year-olds, 8- to 10-year-olds, 14- and 15-year-olds, and adults. Drawing on the design of Koriat and Ackerman (2010), we presented participants with short and long video sequences of another person's learning of paired associates and asked them for their JoLs of the other's learning. In addition, to examine the impact of own experience, we manipulated whether participants performed an equivalent task themselves before or afterward. Based on recent findings of early metacognitive abilities during the preschool period (e.g., Lyons & Ghetti, 2013), we examined whether 6- and 7-year-olds would already be able to correctly apply the memorizing effort heuristic to others' performance. Given that other studies on the allocation of study time to difficult versus easy items reported a developmental onset at around 8 years of age (Dufresne & Kobasigawa, 1989), and given that Koriat et al. (2009a) found a progressed reliance on the ELER heuristic in the JoLs of 8- to 10-year-olds but not 6- and 7-year-olds, we included a group of 8- to 10-year-olds. Finally, given recent findings of a protracted development of metacognitive abilities into adolescence (van der Stel et al., 2010; Weil et al., 2013), we included a group of 14- and 15-year-olds in the current study. For purposes of comparison and as a validation of our procedure (cf. Koriat & Ackerman, 2010), we also included a group of adults.

Method

Participants

The final sample consisted of 38 6- and 7-year-old children (*M* = 6.9 years, *SD* = 0.45; 16 boys and 22 girls; 18 in Other–Self condition and 20 in Self–Other condition), 40 8- to 10-year-old children (*M* = 9.3 years, *SD* = 0.68; 16 boys and 24 girls; 20 in Other–Self and 20 in Self–Other), 38 14- and

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15-year-old adolescents (*M* = 14.5 years, *SD* = 0.05; 21 boys and 17 girls; 19 in Other–Self and 19 in Self–Other), and 35 adults (*M* = 23.9 years, *SD* = 6.3; 5 men and 30 women; 18 in Other–Self and 17 in Self–Other). Participants in each age group were randomly assigned to the Self–Other and Other–Self conditions. All child participants were typically developing children and were of mixed socioeconomic status. Informed consent for participation was given by the children's caregivers. The adult participants were undergraduate students and received course credit for participation.

Materials

Self task

Materials of the Self Task included 20 pairs of pictures. Following Undorf and Erdfelder (2011), the list consisted of 10 difficult (i.e., semantically not related) picture pairs (e.g., cat–lemonade, key–chocolate) and 10 easy (i.e., semantically associated) picture pairs (e.g., knife–fork, table–chair). Two additional picture pairs (one easy and one difficult) were used for familiarization. The picture pairs were collected in a binder so that on each page of the binder one pair could be presented. A second binder consisted of sheets of paper showing only the left picture of the pictures pairs. Furthermore, materials included a 5-point smiley scale. The smileys ranged from sad-looking to neutral-looking to happy-looking smileys. Moreover, the materials included one buzzer button (5 cm diameter, 3.5 cm high).

Other task

The Other Task was adopted from Koriat and Ackerman (2010). Materials included two video clips showing a 20-year-old female actor performing a paired associate learning task. Both clips showed the same scene of an actor picking up a paper on which the paired stimuli to be learned were depicted, studying them, and putting the paper away. The video sequences depicted the actor from a front view so that only the back of the paper was visible. One clip lasted 5 s, and the other clip lasted 10 s. Both clips were duplicated so that the final set of stimuli for the Other Task consisted of 10 short and 10 long video clips. In addition, the same smiley scale as in the Self Task was employed.

Procedure

Participants were tested individually in a quiet room. Experimental sessions consisted of two tasks, the Self Task and the Other Task, and were videotaped. Participants either first completed the Self Task and then completed the Other Task (Self–Other condition) or vice versa (Other–Self condition). The order of tasks was balanced between participants (see "Participants" section above). Before being confronted with the two main tasks, participants were familiarized with the nature of the tasks (i.e., paired associate learning tasks) and the stimulus material used in the study by presenting them with two item pairs as examples.

Self task

The task was administered at a table using the binder with the picture pairs. Participants were told to learn paired associates so that they would be able to later recall the second item when being presented with the first item. Furthermore, participants were instructed that their success in the task would depend on the number of correctly remembered items as well as on the study time they would need to learn the items. In other words, they were asked to learn the pairs as well and as fast as possible. In addition, they were instructed to estimate the likelihood of their recall for every picture pair.

The experimenter presented the picture pairs in a random order one pair at a time. When participants finished learning the respective pair, they pressed the buzzer button, which was placed in front of them. Immediately after each item, the experimenter covered the respective picture pair and participants were asked to estimate the likelihood of recalling the second picture when being confronted with the first picture. To this end, they used the 5-point smiley scale. The sad-looking smiley represented *very unlikely*, and the happy-looking smiley represented *very likely*. Participants' choices were coded online by the experimenter on a scale from 1 to 5, respectively. Subsequently, the next item pair was presented.

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Other task

Participants were instructed about the paired picture associate task in the same manner as in the Self Task with one important difference: They were told that they would observe another person learning the pairs as well and as fast as possible and that after every video they would need to estimate the likelihood of the other person recalling the second item of the picture pair in a later recall task. Note that participants did not have access to the content of the pairs (i.e., they saw only the white and empty back of the paper).

A total of 20 video sequences (10 short and 10 long) were presented in one of two pseudo-randomized orders on a computer screen in front of participants. After every video sequence, participants were asked to evaluate the other's likelihood of recalling the items by using the smiley scale in the same manner as in the Self Task. Subsequently, the next video sequence was presented. Two additional video sequences (one short and one long) were used to familiarize participants with the task.

Posttest

After the last task, participants were administered a cued recall assignment. The "first" items of the picture pairs studied in the Self Task were presented one after the other, and participants were encouraged to correctly recall the respective second items. Participants were given a maximum of 10 s to answer the question. When no answer was provided, they were asked a second time. When participants were unable to recall the respective item, they were presented with the next pair.

Results

Posttest

We first analyzed whether our manipulation of item difficulty in the Self Task was successful. To this end, we calculated two percentage correct values for each participant (for group means, see Table 1) and, by means of paired-samples t tests, compared whether in the posttest participants of each age group had better recall for easier items than for more difficult items. The t tests showed that, in each age group, participants recalled the easier items better than the more difficult items: 6- and 7-year-olds, $t(37) = 12.40$, $p < .001$, $d = 4.08$; 8- to 10-year-olds, $t(39) = 10.72$, $p < .001$, $d = 3.43$; 14- and 15-year-olds, $t(37) = 5.95$, $p < .001$, $d = 1.96$; adults, $t(34) = 6.65$, $p < .001$, $d = 2.28$. This confirmed that the manipulation of item difficulty was successful.

In addition, we coded from the movies the study times participants invested in the easy and difficult items (for an overview, see Table 2). Due to technical reasons, the data of only 32 6- and 7-year-olds, 32 8- to 10-year-olds, 14 14- and 15-year-olds, and 22 adults could be analyzed. Data were submitted to a mixed-model analysis of variance (ANOVA) with the within-participants factor item difficulty (easy or difficult) and the between-participants factor age group (6- and 7-year-olds, 8- to 10-year-olds, 14- and 15-year-olds, or adults). The analyses revealed a main effect of item difficulty, $F(1, 96) = 145.05$, $p < .001$, $\eta^2 = .60$, and an interaction effect between item difficulty and age group, $F(3, 96) = 10.43$, $p < .001$, $\eta^2 = .25$. To examine the nature of the interaction effect, we calculated the difference in study time (DST) by subtracting, for every participant, the average time spent studying the difficult items minus the average time spent studying the easy items (see Table 2).

Table 1
Group means.

	Posttest: easy items	Posttest: difficult items
6- and 7-year-olds	71.8 (3.5)	28.4 (4.1)
8- to 10-year-olds	92.8 (1.6)	53.3 (3.9)
14- and 15-year-olds	97.4 (1.0)	75.0 (4.0)
Adults	98.0 (0.8)	77.4 (3.5)

Note. The two columns give the average percentage recall of easy and difficult items in the posttest. Values in parentheses represent standard errors of the means.

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Table 2
Overview.

	Easy items	Difficult items	DST
6- and 7-year-olds	5.47 (0.48)	6.29 (0.50)	0.82 (0.36)
8- to 10-year-olds	4.70 (0.48)	7.43 (0.50)	2.74 (0.36)
14- and 15-year-olds	5.15 (0.72)	8.26 (0.83)	3.12 (.40)
Adults	3.71 (0.58)	7.46 (0.60)	3.74 (.44)

Note. The first column gives the study times (in seconds) for the easy items, and the second column gives the study times for the difficult items. The third column shows the average difference in study time (DST), calculated by subtracting the study times for easy items from the study times for difficult items. Values in parentheses represent standard errors of the means.

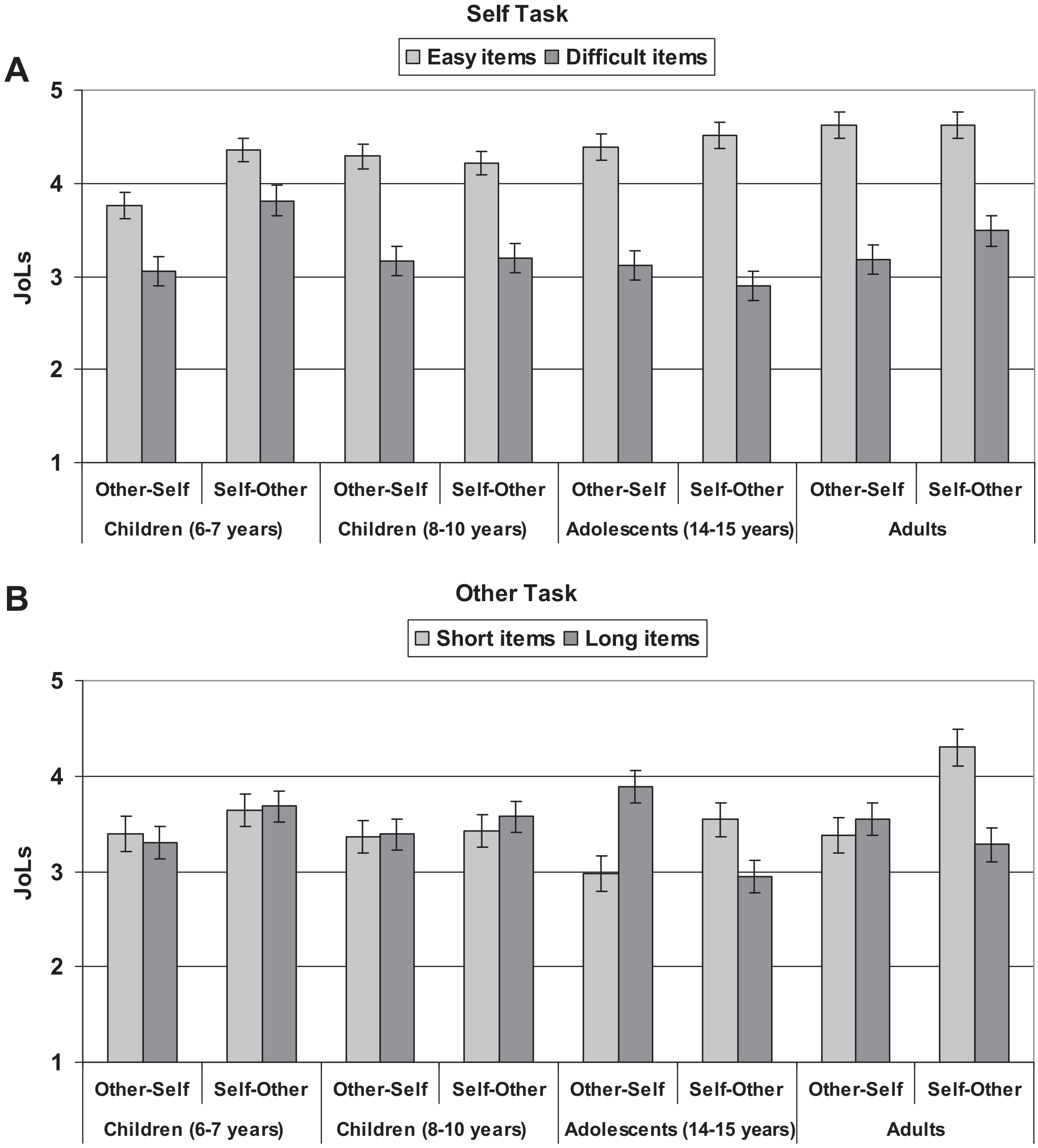

Fig. 1. Mean judgments of learning (JoLs) for the Self Task (A) and the Other Task (B). Error bars depict standard errors of the means.

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Independent-samples post hoc t tests showed that all of the DSTs of the three older age groups differed significantly from the DST of the youngest age group (all $ps < .001$). There was no significant difference between the three oldest age groups (all $ps > .05$). In addition, single-samples t tests against zero yielded significant differences for all age groups: 6- and 7-year-olds, $t(31) = 2.36$, $p = .03$, $d = 0.85$; 8- to 10-year-olds, $t(31) = 6.04$, $p < .001$, $d = 2.17$; 14- and 15-year-olds, $t(13) = 7.70$, $p < .001$, $d = 4.27$; adults, $t(21) = 11.76$, $p < .001$, $d = 5.13$. This suggests that all participants spent more time studying difficult items than studying easy items.

Judgments of learning

Descriptive results for participants' average JoLs for easy and difficult items in the Self Task are shown in Fig. 1A, and participants' average JoLs for short and long video sequences in the Other Task are presented in Fig. 1B. We first compared participants' JoLs across task order and age groups in order to assess whether there was a differential influence of difficulty in the Self Task and of observed duration of learning in the Other Task.

Data were submitted to a mixed-model ANOVA with the within-participants factors task (Self Task or Other Task) and item difficulty (easy or difficult) and the between-participants factors order (Self first or Other first) and age group (6- and 7-year-olds, 8- to 10-year-olds, 14- and 15-year-olds, or adults). This ANOVA yielded significant main effects of the factors task, $F(1, 143) = 49.50$, $p < .001$, $\eta^2 = .26$, item difficulty, $F(1, 152) = 117.87$, $p < .001$, $\eta^2 = .45$, and order, $F(1, 143) = 4.88$, $p < .05$, $\eta^2 = .03$. These effects were further qualified by significant two-way interactions between the factors item difficulty and order, $F(1, 143) = 6.61$, $p = .01$, $\eta^2 = .04$, item difficulty and age group, $F(3, 152) = 4.37$, $p < .01$, $\eta^2 = .08$, task and item difficulty, $F(1, 152) = 118.37$, $p < .001$, $\eta^2 = .45$, and order and age group, $F(3, 143) = 2.96$, $p < .05$, $\eta^2 = .06$; by significant three-way interactions among the factors item difficulty, order, and age group, $F(3, 143) = 5.71$, $p = .001$, $\eta^2 = .11$, task, item difficulty, and order, $F(1, 143) = 11.92$, $p = .001$, $\eta^2 = .08$, task, item difficulty, and age group, $F(3, 143) = 4.83$, $p < .01$, $\eta^2 = .09$; and a significant four-way interaction among the factors task, item difficulty, order, and age group, $F(3, 143) = 3.86$, $p = .01$, $\eta^2 = .08$. To explore these interactions, we conducted two separate ANOVAs for each task (i.e., Self Task and Other Task) with the within-participants factor item difficulty (easy or difficult) and the between-participants factors order (Self first or Other first) and age group (6- and 7-year-olds, 8- to 10-year-olds, 14- and 15-year-olds, or adults).

Self task

The ANOVA on the Self Task yielded a significant main effect of item difficulty, $F(1, 143) = 470.48$, $p < .001$, $\eta^2 = .77$, and a main effect of order, $F(1, 143) = 4.30$, $p < .05$, $\eta^2 = .03$, indicating that participants gave higher JoLs when the Self Task preceded the Other Task ($M = 3.89$, $SE = 0.07$) than when the order was reversed ($M = 3.70$, $SE = 0.07$). These main effects were further qualified by significant two-way interactions between the factors item difficulty and age group, $F(3, 143) = 12.07$, $p < .001$, $\eta^2 = .20$, and order and age group, $F(3, 143) = 3.37$, $p < .05$, $\eta^2 = .07$.

To follow up on the interaction between order and age group, we averaged across item difficulty and compared order separately for each age group by means of post hoc paired-samples t tests. These post hoc analyses yielded a significant effect only for the 6- and 7-year-olds, $t(36) = 3.32$, $p = .002$, $d = 1.11$, Self–Other ($M = 4.08$, $SE = 0.13$), Other–Self ($M = 3.41$, $SE = 0.16$). They did not yield a significant effect for the 8- to 10-year-olds, $t(38) = 0.10$, $p = .92$, $d = 0.03$, Self–Other ($M = 3.71$, $SE = 0.15$), Other–Self ($M = 3.73$, $SE = 0.14$), the 14- and 15-year-olds, $t(36) = 0.37$, $p = .71$, $d = 0.12$, Self–Other ($M = 3.71$, $SE = 0.09$), Other–Self ($M = 3.75$, $SE = 0.09$), or the adults, $t(33) = 0.81$, $p = .43$, $d = 0.28$, Self–Other ($M = 4.06$, $SE = 0.15$), Other–Self ($M = 3.90$, $SE = 0.12$).

To follow up on the interaction between item difficulty and age group, we compared item difficulty separately for each age group by means of post hoc paired-samples t tests across order. These post hoc analyses yielded significant differences for all age groups: 6- and 7-year-olds, $t(37) = 5.51$, $p < .001$, $d = 1.81$; 8- to 10-year-olds, $t(39) = 10.19$, $p < .001$, $d = 3.26$; 14- and 15-year-olds, $t(37) = 18.20$, $p < .001$, $d = 5.98$; adults, $t(34) = 11.78$, $p < .001$, $d = 4.04$. This suggests that all participants gave higher JoLs for easier items.

To examine whether there were age differences in the size of the effect of item difficulty, we calculated a difference score (DS) for each participant by subtracting the Self_difficult value from the

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Self_easy value. A one-way ANOVA on the DS with age as the between-participants factor confirmed the previous interaction effect, $F(3, 147) = 12.13$, $p < .001$. Bonferroni-corrected post hoc tests showed that the DS of the 6- and 7-year-olds ($M = 0.62$, $SE = 0.11$) differed significantly from the DSs of the 8- to 10-year-olds ($M = 1.07$, $SE = 0.11$), the 14- and 15-year-olds ($M = 1.44$, $SE = 0.08$), and the adults ($M = 1.30$, $SE = 0.11$), whereas the DSs of the three older age groups did not differ significantly from each other. This pattern shows that the youngest groups showed a less strong differentiation between easy and difficult items compared with the older age groups.

Other task

The ANOVA on the Other Task yielded a significant interaction between the factors item difficulty and order, $F(1, 143) = 11.91$, $p = .001$, $\eta^2 = .08$, which was further qualified by a significant three-way interaction among the factors item difficulty, order, and age group, $F(3, 143) = 5.89$, $p = .001$, $\eta^2 = .11$. To follow up on these interaction effects, we conducted separate ANOVAs with the within-participants factor item difficulty (easy or difficult) and order (Self first or Other first) for each age group. The ANOVAs for the 6- and 7-year-olds and the 8- to 10-year-olds yielded no significant effect (all *ps* > .15 and all *ps* > .42, respectively).

The ANOVA for the 14- and 15-year-olds yielded a significant interaction effect between the factors item difficulty and order, $F(1, 36) = 17.83$, $p < .001$, $\eta^2 = .33$ (all other *ps* > .15). Subsequent post hoc paired-samples *t* tests showed that participants gave significantly lower JoLs for short items than for long items, $t(18) = 4.81$, $p < .001$, $d = 2.27$, when the Other Task preceded the Self Task, indicating that they judged the learner's likelihood to recall to be higher when she spent more time learning a given pair. Yet, when the Self Task preceded the Other Task, participants showed a tendency to give higher JoLs for short items than for long items, $t(18) = 1.96$, $p = .065$, $d = 0.92$. This shows that the different experiences with the Self Task affected participants' evaluation of the other's learning achievements.

The ANOVA for the adult group yielded a significant main effect of item difficulty, $F(1, 33) = 4.81$, $p < .05$, $\eta^2 = .13$. This effect was further qualified by a significant interaction effect between the factors item difficulty and order, $F(1, 33) = 9.45$, $p < .01$, $\eta^2 = .22$. Subsequent post hoc paired-samples *t* tests showed that there was no significant difference between participants' JoLs for short and long items, $t(17) = 0.59$, $p = .57$, $d = 0.29$, when the Other Task preceded the Self Task. Yet, when the Other Task followed the Self Task, participants gave significantly higher JoLs for short items than for long items, $t(16) = 4.05$, $p = .001$, $d = 2.03$.

Discussion

The current study examined the development of people's knowledge about others' learning and memory processes. To this end, participants of four different age groups (6- and 7-year-olds, 8- to 10-year-olds, 14- and 15-year-olds, and adults) observed another person performing a paired associate learning task, allocating either little time (5 s) or more time (10 s) to the paired associates. Participants were asked to estimate the likelihood of recall by giving JoLs for every item pair (Other Task). In addition, we manipulated whether participants performed an equivalent task themselves (Self Task) before or after the evaluation of the other. Our results show significant developmental effects with the older two age groups, but not the younger two age groups, in differentiating between the short and long video sequences when giving JoLs in the Other Task. Moreover, the results revealed an impact of having performed the Self Task beforehand on participants' JoLs in the Other Task, suggesting that metacognitive knowledge about the other is informed by experiential cues during the actual (i.e., first-hand) learning process.

The JoLs of the Self Task, as well as an analysis of participants' study times, provide evidence that participants of all age groups clearly differentiated between easy and difficult items. In addition, we found a developmental effect, with the oldest three age groups (i.e., participants from 8 years onward) showing a stronger differentiation than the youngest age group (i.e., 6- and 7-year-olds) (cf. Koriat & Ackerman, 2010). How can this developmental effect be explained? On the one hand, one could assume that younger children might tend to overestimate their performances (particularly because

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JoLs were given immediately after learning), and as a consequence, due to ceiling effects in JoLs, the difference between easy and difficult items was reduced. Yet, given that we found no main effect of age on JoLs, this explanation seems unlikely. On the other hand, this finding relates to proposals assuming an increased sensitivity to feedback and experiential cues during the study experience with age (Koriat et al., 2009a). This increased sensitivity could have enabled the older children, but not the younger children, to more clearly differentiate between items perceived as difficult and items perceived as easy. It should be noted that the analyses also revealed an effect of order for the youngest group of children, showing that they gave lower JoLs in the Self Task when it was presented after the Other Task. One could speculate that this could be due to fatigue. Alternatively, it is possible that the experience of having observed the learning of another person across a number of trials might have sensitized younger children—who normally tend to overestimate themselves—for the difficulty of the task, which leads to reduced JoLs.

Here, it is interesting to note that an additional post hoc analysis, assessing changes of JoLs in the Self Task over time by comparing JoLs given on the first five items with JoLs given on the second five items (easy and difficult items, respectively), revealed a main effect of time that was independent of age and item difficulty, $F(1, 99) = 7.31$, $p < .01$, $\eta^2 = .07$. This effect shows that participants' gave the first five items on average higher JoLs ($M = 3.92$) than the second five items ($M = 3.79$), suggesting that during the learning process participants' realized the difficulty to remember the whole set of items and, thus, became more conservative in their JoLs. Yet, given that this effect was independent of age, it cannot explain the finding of less differentiation between easy and difficult items in the youngest age group.

Finally, it should be mentioned that the results of the posttest confirmed that the difficult pairs were less likely to be remembered than the easy pairs. Moreover, an analysis of participants' allocation of study times in the Self Task showed that all age groups spent significantly more time studying the difficult items than the easy items. These findings not only confirm that our manipulation of item difficulty was successful, they also suggest that participants' differential allocation of high and low JoLs is related to actual performance differences.

The main finding of our study concerns the developmental differences in participants' judgments of others' learning. The results strongly suggest that the 6- and 7-year-olds, as well as the 8- to 10-year-olds, do not rely on study time allocation as a heuristic to evaluate others' learning. The results of the 6- and 7-year-olds relate to findings of no application of the memorizing effort heuristic during own self-paced learning in this group (Koriat et al., 2009b). That is, despite some evidence of implicit metacognitive abilities in preschool children (Balcomb & Gerken, 2008; Call & Carpenter, 2001; Lyons & Ghetti, 2013), the 6- and 7-year-olds did not rely on study time allocation as a valid cue to predict others' recall performances. One explanation is that this developmental difference can be explained by the fact that both types of metacognitive judgments (i.e., judging one's own learning and judging another person's learning) are informed by different cues. Whereas the former often assesses metamemory in situations where children need to evaluate their memory during actual recall (and, thus, can rely on cues such as recall fluency), our task assessed prospective judgments about others' future performances, that is, judgments for which no data-driven cues during the actual learning process were available. Therefore, the judgments about others seem to be based on an (implicit) theory about the relation between learning time and task performance. As such, our findings suggest that the 6- and 7-year-olds do not possess an (implicit) theory on the relation between study time and task performance.

Let us consider the results of the next age group. The 8- to 10-year-olds did not use study time as a cue to evaluate others' learning. This finding contrasts with their differential allocation of study time to easy and difficult items (Dufresne & Kobasigawa, 1989) and with their ability to use study time as a cue for later recall in self-paced learning tasks (Koriat et al., 2009b). This finding of a developmental lag between adequate judgments of learning for self and inadequate judgments of learning for other suggests that the 8- to 10-year-olds are not able to extract from their own experience a rule that can be applied to others. This differs from research in the theory-of-mind tradition, where it has been found that by the end of the preschool years children have acquired integrated representations of mental agency that can likewise be applied to self and other (Moore, 2006). How can this developmental lag be explained? We suggest two interpretations that are not mutually exclusive. On the one hand,

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judgments about others' beliefs and desires play an important role in social interactions, for example, to efficiently communicate and interact with others. Thus, within their daily social interactions, children learn from early on to pay attention to others' knowledge states and desires (Carpendale & Lewis, 2004). In contrast, knowledge about others' learning processes and achievements constitutes a more specialized kind of knowledge that is made more salient when entering school.

On the other hand, this developmental lag could be related to the nature of metacognitive knowledge itself. The fact that there is no transfer of the memorizing effort heuristic to others is in line with theoretical approaches that suggest a developmentally prior reliance on implicit metacognitive cues in actual learning over an explicit understanding of the rule (Proust, 2013). It is plausible, from this theoretical viewpoint, that generalizing to others one's own activity-dependent cues is made possible only by a conceptual redescription of the associated experience. More concretely speaking, metacognitive research has shown that people are not aware of the causal relevance of the experiential characteristics of the task (e.g., its duration); rather, they tend to be conscious of its intrinsic characteristics (e.g., the relatedness of the words to be learned) or of its extrinsic characteristics (e.g., the type of task). For example, a study on foresight bias by Koriat and Bjork (2006) showed that only theory-based debiasing, not mnemonic (experience-based) debiasing, allows participants to transfer the resistance to the illusion of competence to new items. Now, how do participants in our study come to generalize their experience acquired in the Self Task to the other (Other Task)? Is conscious awareness a precondition of this generalization (i.e., concept application) or incipient theory formation or, rather, its consequence? On the one hand, one could argue that consciousness allows the cues gained in the agent's own experience of the task to become generalizable to others. Yet, Koriat and Ackerman (2010, Experiment 1) showed that these cues are not available to self-report, although a judgment of learning is being requested from the participants in the Self condition. The authors suggested that it is the Other condition that helps participants, having been earlier in a Self condition, to realize the diagnostic value of the memorizing effort heuristics (cue validity) rather than to merely use it in their JOLs (cue utilization). Alternatively, it is possible that conscious awareness results from the underlying representational process, as claimed by Karmiloff-Smith (1992), who considered that "re-representation" is a domain-general process whose function is to allow cognitive agents to generalize knowledge first acquired behaviorally in a given domain. During this process, representations become more manipulable and flexible, available for theory building, and conscious. A conceptual redescription, on a plausible interpretation, occurs under the following circumstances. Needing to predict others' performance might automatically trigger a theory-based form of attention to the task, which might then facilitate theory building from the acquired experience of the task. The explicit JOL formed about others might generate a form of explicit (theory-based) conscious awareness under the combined influence of the additional inferential capacity gained from theory use and the availability of verbal report. Further research is needed to examine this issue in greater detail.

Independent of this issue, our observation is coherent with the social–cognitive point of view, according to which the failure of the 8- to 10-year-olds to adequately use study time allocation to evaluate others' learning points to an ongoing development of social–cognitive competencies across middle childhood. Other studies indeed have demonstrated a protracted development of the understanding of others' mental activity. For example, Flavell, Green, and Flavell (1993) investigated children's understanding of the stream of consciousness. They reported that even by 6 or 7 years of age, only 50% of the children (in contrast to 95% of the adults) understood that a quietly sitting person does not have an empty mind but, rather, has an ongoing mentation.

The results of the adolescent participants (14- and 15-year-olds) revealed an interesting different pattern. In contrast to the younger children, who did not rely on study time allocation to differentiate between the pairs (or to judge which pairs would be recalled), they did rely on this cue to predict learning in others. Importantly, however, their evaluation crucially depended on whether or not they had antecedently performed an equivalent task themselves. With no prior experience of the task, they applied an inverse heuristic, assuming a higher likelihood of recall for longer studied items. This could point to the application of a simple intuitive heuristic stating that longer learning is indicative of higher likelihood for recall. In contrast, having had firsthand experience, this pattern switched. In this condition, participants showed a tendency to apply the memorizing effort heuristic to the other; that is, they assumed a higher likelihood of recall for shorter studied items. This indicates that the adolescents

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relied on their own experience to extract the heuristic and to apply it to the other. Overall, these findings suggest that the adolescents are on a transitory stage compared with our adults, who showed a clear reliance on the memorizing effort heuristic in their evaluation of the other's learning when having had own experience with the task (cf. Koriat & Ackerman, 2010; Undorf & Erdfelder, 2011).

Our finding of a developmental onset of an increasing reliance on the memorizing effort heuristic when assessing others' learning during adolescence extends findings of developmental changes in metacognitive abilities during late childhood (e.g., Dufresne & Kobasigawa, 1989; Ghetti, Lyons, Lazzarin, & Cornoldi, 2008; von der Linden & Roebers, 2006). It provides empirical support to developmental approaches assuming that adolescence is a critical phase for the development of metacognitive abilities (Schneider, 2008). For example, neuroimaging findings on brain development have shown that the brain areas related to mentalizing and metacognitive judgments undergo major developmental changes during adolescence (Burnett et al., 2011; Giedd et al., 1999). Moreover, recent behavioral studies have reported a developmental increase in metacognitive abilities during adolescence (e.g., van der Stel et al., 2010; Weil et al., 2013). Our study extends these findings by demonstrating that developmental changes during adolescence are not restricted to self-directed metacognitive judgments but are also visible in judgments of others' learning.

The current results show that the older age groups allocated JoLs to short and long items in the Other Task differently when having performed a corresponding task (Self Task) beforehand. One could argue that this effect might be due to the fact that in the Self Task participants realized that the pairs differ systematically in associative relatedness. Being aware of the different semantic relations, participants applied this knowledge in the Other Task and, thus, differentiated between short and long items in their JoLs. However, Koriat and Ackerman (2010) included a second experiment in which participants were able to actually see the paired associates that the actor studied in the Other Task. If pure knowledge about semantic relatedness were enough to yield the effect, we would expect the same finding of different JoL allocations to short and long items in the Other Task also when this task is performed before the Self Task. Importantly, Koriat and Ackerman reported that even though participants were aware of the semantic relations, their JoLs did not differ for short or long items. An additional experiment showed that the impact of the Self Task on the Other Task was dependent on having provided JoLs in the Self Task because there was no effect when participants merely performed the learning task themselves without giving JoLs. These findings support the conclusion that the firsthand experience of monitoring their own learning was the driving factor subserving the transfer from the Self Task to the Other Task.

Our finding that metacognitive knowledge about the other is informed by experiential cues during the actual firsthand learning process not only provides empirical support to data-driven theories of metacognition (e.g., Koriat et al., in press) but also contributes to the literature on social–cognitive development. A number of recent findings have suggested that firsthand action experience affects the processing of others' actions (e.g., Meltzoff, 2007; Paulus et al., 2012; Sommerville et al., 2005). This line of research focused predominantly on young children's predictions and understanding of others' object-directed actions. Our study extends this research tradition to children's developing understanding of others' learning. It suggests that, whereas an understanding of others' simple object-directed actions is present very early in development, the understanding of more complex activities such as others' learning shows a protracted developmental pathway. Notwithstanding these task-specific age differences in children's social understanding, our results are in line with proposals that own action experience informs action processing (e.g., Meltzoff, 2007) and extends these developmental theories to the realm of social metacognition for the first time.

Moreover, recent studies about explicit metacognitive knowledge have shown that theory-of-mind competencies at 3 to 5 years of age predicted declarative metamemory at 5 years (Lockl & Schneider, 2006; Lockl & Schneider, 2007). These results indicate a link between early social–cognitive knowledge and later developing metacognitive knowledge. Our study adds to these findings by providing evidence for a converse relationship: Children's own metacognitive experience affects their evaluation of others' learning outcome.

The current results also have implications for theory and practice of collaborative forms of learning (e.g., Slavin, 1990). Here, children engage with other children in a joint learning activity. Cooperative forms of activities have been shown to be most successful when the single individuals are able to

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estimate their partners' abilities and capacities (Sebanz et al., 2006). The current findings suggest that during middle childhood children have problems in using another person's study time allocation as a cue to estimate his or her performances. These difficulties might need to be taken into account when designing cooperative learning programs. In addition, our findings raise the question of how to improve children's ability to adequately evaluate others' learning and memorizing. Future research is needed to examine this question.

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