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Relation of Metacognitive Monitoring and Control Processes across the Life-Span

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Abstract

The two studies presented here were conducted to explore the relationship between metacognitive monitoring and control processes across the life-span. Monitoring processes often guide control processes (goal-oriented learning), yet more recent work also documents that control processes can also be based on feedback from monitoring processes (data-oriented learning). Study 1 provided first evidence for data-oriented learning in older adults and in a life-span perspective. Participants of four age groups (third-grade children, adolescents, younger and older adults) were able to adapt their Judgments-Of-Learning (JOLs) based on their Study Time (ST). Effects were most pronounced for younger and older adults. Study 2 investigated the flexible interplay between goal- and data-oriented learning within one learning task for the first time in older adults and from a life-span perspective. Adolescents and younger adults were able to switch between models while elementary children and older adults hat greater difficulties to do so. Possible causes for developmental trends are discussed. In sum, the integration of both goal- and data-oriented learning within one task seems to be a complex process.

Keywords: judgements-of-learning, life-span, metacognition, metacognitive control, metacognitive monitoring, study time

1. Introduction

Metacognitive processes that occur during learning have been studied extensively in children and adults (Schneider & Löffler, 2016; Son & Metcalfe, 2000). Efficient monitoring and control processes are assumed to increase memory performance and the use of information concerning the on-going learning process can (implicitly) help to structure one's learning behavior. Metacognitive processes are therefore relevant during everyday life, e.g., when one has to decide about whether one has memorized the departure time of one's train, but even more so in formal learning situations. Considering the increasing importance of life-long learning in recent years, a life-span perspective is important yet still rare in the metacognitive monitoring and control literature.

According to Nelson and Narens' (1990) seminal model of procedural metamemory, monitoring encompasses subjective prospective and retrospective judgments at different stages of the learning process. Of special interest for the following two studies are Judgments-Of-Learning (JOLs) which represent subjective ratings about the degree to which encoded information can be potentially recalled during a future memory test (Nelson & Narens, 1990). Control processes on the other hand concern the initiation, continuation or termination of actions during the learning process. In the following studies control was operationalized in terms of duration of Study Time (ST).

1.1 Monitoring Affects Control-Hypotheses

Maybe the most common assumption in metacognitive research is that monitoring processes influence learning behaviors, especially the selection of to-be-studied items and the allocation of study time (see, Son & Metcalfe, 2000, for a review). Effective item selection and allocation of study time should in turn lead to better memory performance. The idea that monitoring influences control processes can be derived from Nelson and Narens' model of metacognitive monitoring and control (Nelson & Narens, 1994). A number of studies were able to establish this *monitoring affects control-hypotheses* (MC-model; Nelson & Leonesio, 1988) for children, younger and older adults. For example, in the classic paradigm "allocation of study time" it was reported how much attention and time learners give to learning material. For younger adults there is ample evidence that participants study easy material longer than material they judged as difficult (Son & Metcalfe, 2000; Thiede & Dunlosky, 1999). From a developmental perspective studies indicate that this competence develops over the elementary school years. Dufresne and Kobasigawa (1989) were able to show age-related differences in the spontaneous allocation of ST. In a paired-associate learning task 10- and 12-year-old children spent more time on unrelated than related item-pairs. 6- and 8-year olds spent an equal amount of time on related and unrelated word-pairs although they were able to distinguish easy and hard pairs. Kobasigawa and Metcalf-Haggert (1993) demonstrated that even younger children in first and third grade are able to use monitoring information to regulate their ST if differences in item-difficulty are especially salient.

In sum, empirical evidence suggests that the relation between monitoring and control gets stronger over the elementary school years. Although even first grade children are able to use monitoring information to deploy their ST, regulation processes are more in accordance with JOLs for older children (Lockl & Schneider, 2002, 2003).

Older adults, like young children, seem to have accurate monitoring but show a weaker relationship between monitoring and control processes (e.g., ST) than younger adults (Dunlosky & Connor, 1997; Froger, Sacher, Gaudouen, Isingrini, & Taconnat, 2011). A possible explanation for this fact is that older adults fail to spontaneously use effective strategies as often as younger adults (Dunlosky & Connor, 1997). This idea is supported by the fact that environmental support at encoding, like an intensive strategy instruction, helps older adults to allocate their ST more efficiently (Froger, Bouazzaoui, Isingrini, & Taconnat, 2012). Also under other favorable conditions, e.g., the possibility of prelearning all word-pairs prior to the actual learning experiment, older adults seem to be able to regulate their ST on the basis of monitoring processes as effectively as younger adults (Hines, Touron, & Hertzog, 2012).

In sum, a number of studies support the idea that self-regulated learning processes are based on monitoring processes. That is learners monitor item difficulty and accordingly allocate their ST. Empirical evidence suggests that this relation grows stronger over the elementary school years, has its peak in young adulthood and declines again in older adulthood. Yet, learners across the life-span seem to act according to the monitoring affects control-hypothesis (MC-model).

1.2 Control Affects Monitoring-Model

More recent studies also detected the reverse relation: monitoring processes may also follow control processes and can be modulated consequently (Control affects monitoring-(CM) model). Koriat, Ma'ayan and Nussinson (2006) showed that in self-paced learning processes young adults used ST as a cue to infer the height of the subsequent JOLs. In these settings, ST provides information of the item difficulty or of the necessary effort to memorize an item. Accordingly, Koriat et al. (2006) referred to ST in these cases as having a "data-oriented function". That is, whereas in learning processes evocating the MC-model, ST is allocated in order to reach a specific goal ("goal-oriented learning"), in CM-processes it provides data for the monitoring procedure. This is in line with the cue-utilization view (Koriat, 1997), which postulates that JOLs are based on intrinsic, extrinsic, and mnemonic cues predictive for recall. The data-oriented function of ST is considered as an unconsciously applied mnemonic cue indicating the extent to which an item has been mastered. In other words, participants adopt an "easily learned easily remembered"-heuristic (ELER-heuristic) according to which recall performance depends on the effort spent to memorize an item: easily learned items are more likely to be remembered than items that are memorized with more effort (Koriat, Ackerman, Lockl, & Schneider, 2009a, 2009b). Thus, contrary to the predominant MC-model, in CM-processes JOLs and recall performance decrease with increasing ST. This pattern has been repeatedly found in young adults (Koriat et al., 2006; Koriat & Nussinson, 2009; Koriat, Nussinson, & Ackerman, 2014).

So far, data about the developmental course of the CM-model are rather scarce. For children from older elementary school age on, Koriat and collegues (2009a) found evidence that JOLs decreased with the amount of ST spent on an item when given no time limit. However, this relationship could not be confirmed in first and second graders. In terms of recall performance, though, in all age groups, recall increased with decreasing ST, indicating that the invested amount of effort represents a valid cue. A follow-up study by the same authors (Koriat et al., 2009b) contrasting second and forth graders' performance in a setting which provided an unlimited number of trials to acquisition found evidence that even the younger participants were able to adopt the ELER-heuristic when items varied sufficiently in intrinsic difficulty. Hoffmann-Biencourt et al. (2010) also confirmed this memorizing effort-heuristic with a similar self-paced learning task but different learning materials (picture pairs instead of word pairs) in a sample of children from grades 1 to 8. Yet, for first time, this study also documented a developmental trend in that it found a weaker relationship between ST and JOLs for younger children. A consistent use of the memorizing effort heuristic was detected for fifth- to eighth-graders, whereas for first- to fourth-graders a weaker association between ST and JOLs was found. To our knowledge no study has explored the CM-model in older adults so far.

1.3 Interplay of MC- and CM-Model

The MC- and CM-models are not considered mutually exclusive but seem to occur according to situational specifications and sometimes even within the same learning task (Koriat, Ackerman, Adiv, Lockl, & Schneider, 2014). According to Koriat and colleagues, the MC-model should apply for goal-oriented learning, that is, when learners have a particular motivation to reach a specific goal. This goal may be emphasized by incentives or rewards. The CM-model should apply if learning is self-regulated and data-oriented: learning experiences with difficult items lead to the conclusion that even with additional learning effort low recall rates are to be expected. Therefore, JOLs decrease with increasing ST assuming that ease of encoding is a diagnostic cue of recall performance. A recent study by Koriat et al. (2014) documented that adolescents and young adults are able to apply data-oriented and goal-oriented regulation differentially within the same paired-associate learning task. Fifth- and sixth-graders have difficulty to do so although they are sensitive to goal-oriented and data-oriented regulation when they occur in different tasks. In older adults, the question of application of data-oriented and goal-oriented self-regulation within the same task has not been addressed yet.

In sum, these findings indicate that important developmental changes in the interplay between metacognitive monitoring and control processes occur during middle-school years. So far, it seems that under favorable circumstances children as young as seven years old are able to infer the size of JOLs from the corresponding ST. A flexible alternation between both MC- and CM-processes does not seem to develop before early adolescence. For older adults the CM-model has not yet been explored at all. Yet, considering the importance of effective life-long learning, a better understanding of learning processes in this age group is necessary.

1.4 The Present Studies

At present, more research is needed to clarify the relationship of metacognitive monitoring and control processes. Especially the CM-model has not been investigated for older adults and empirical studies involving children are scarce. Moreover, the ability to employ both the MC- and the CM-model within the same learning task has yet to be explored more thoroughly and for a broader age range including elementary children and older adults. Given the importance of metacognitive monitoring and control processes throughout life, the following studies were designed to fill these gaps in the literature. A first aim was to explore developmental trends in the CM-model for the first time in a life-span design (Study 1) and a second goal was to investigate the interplay of the MC- and CM-models within a life-span sample (Study 2).

In study 1, participants of four age groups (early school age to later adulthood) were asked to study word pairs in a version of Koriat and colleagues (2009a) which documented a CM-model. Specifically, participants studied word-pairs in a self-regulated pace, then gave JOLs and had to recall the items at a later memory test. The task was chosen because of its suitability for a wide range of ages and because it allows a very close comparison with existing data. JOLs, ST and recall were recorded.

Previous research suggests that from the middle of the elementary school years on, children begin to successfully use the heuristic, the longer they study an item, the less likely they are to recall it, that is a CM-model (Koriat et al., 2009a; Hoffmann-Biencourt et al., 2010). Therefore, third-grade children were chosen as the youngest age group. Additionally, third-grade children possess sufficient reading skills to master the word-pair stimuli used in most previous studies on data-oriented learning. The second age group consisted of adolescents as evidence for the CM-model gets stronger from the beginning of the elementary school years to adulthood (Hoffmann-Biencourt et al., 2010) and in this period of life important changes in the flexible interplay between monitoring and control seem to occur (Koriat et al., 2014). Young adults served as a comparison group as metacognitive abilities should reach their peak at this age. Older adults were included because the literature so far lacks any empirical data on the CM-model in this age group. Additionally, our sample for the first time allows a developmental overview of metacognitive monitoring and control abilities over a very broad age range. Thus, it enables a direct contrast of metacognitive performance in the developmental course.

Concerning age effects, we expected that third-grade children are able to use information on ST for their JOLs, yet there should still be room for improvement. Adolescents should show clear use of data-oriented learning. Young adults are expected to easily use the CM-model and show the strongest association of ST and JOLs. Concerning older adults, we expected a weaker relationship between control and monitoring processes than for young adults as studies on metacognitive control predominantly show weaker performance of older adults compared to younger adults due to difficulties in executive functions (Pansky, Goldsmith, Koriat, & Perlmann-Avnion, 2009; Souchay & Isingrini, 2004). This fact is also reflected in the MC-model which shows slight deficits in older adults. The flexible use of valid cues seems to be more difficult for older than for younger adults.

2. Study 1

2.1 Method

2.1.1 Participants

A total of 112 (55 male, 57 female) participants of four age groups (28 children in 3rd grade, 28 adolescents in 7th and 8th grade, 28 younger and 28 older adults) took part in our study. Participants came predominantly from a middle class socioeconomic background. They were recruited via contacting their schools directly and via newspaper and internet advertisements. Children and adolescents received small gifts, the other participants got 10-Euro vouchers or were paid in cash. Participants' mean ages were 9.00 (SD = 0.38) for the children, 13.25 (SD = 1.04) for the adolescents, 22.00 (SD = 2.29) for the younger adults and 68.39 (SD = 5.63) for the older adults.

2.1.2 Materials

The learning items consisted of disyllabic pairs of concrete German nouns. To vary the difficulty, one half of the pairs were semantically associated (e.g., "beetle-spider"), half of the pairs were not related (e.g., "sock-digger"). The item list for children and older adults consisted of 24 word pairs; adolescents were asked to study 36 pairs, younger adults had 48 pairs. Four practice pairs not included in the analysis preceded the experiment. The different length of item lists were chosen in order to adjust the basic recall rates between the age groups. The order of presentation was randomized among the participants.

2.1.3 Procedure

The consent of the parents and of the school was obtained before beginning the study with underage participants. Participants were tested individually in quiet rooms in the school or in the laboratory. Participants first were asked to memorize the item pairs presented on a computer screen at their own pace. They were instructed to study each item pair as long as they needed to recall it in about 20 minutes.

In the JOL phase, each left noun of the item pair was presented on the screen in the same order as in the learning phase. Participants were asked to indicate the likelihood of remembering the target in about 30 minutes. JOLs were rated on a thermometer scale from 0 (very cold = very unsure) to 100 (very hot = very sure) successfully used in previous studies (Koriat et al., 2009b; Koriat & Shitzer-Reichert, 2002). The scale was introduced by underlining the similarity to the well-known "hit-the-pot-game". Thus, the closer one is to the "pot", that is, the required word pair, the "hotter" the "temperature", that is, the more confident the participant is the higher he/she positions the slider on the JOL-scale. After a short interval, the stimulus of each pair was presented and participants were asked to indicate the missing word. They were requested to guess an answer if they could not think of the appropriate response.

2.2 Results

We start by presenting memory performance in terms of the percentage of correctly recalled items, mean JOLs and ST as a function of age group and item difficulty (related vs unrelated items). Then we will analyse the effects of ST on JOLs as evidence for the CM-process.

Preliminary analyses did not reveal any systematic effects of gender. The data was therefore collapsed across this variable. As a post hoc follow-up on main effects, Scheffé tests were used. The level of significance was set to $p < 0.05$.

Recall. The first column of Table 1 shows the percentage of correct responses. An ANOVA with recall as dependent variable revealed a significant main effect of age group ($F(3,108) = 13.94$; $p < .001$; $\eta^2 = .28$). Post hoc tests clarified that younger adults (79.54%) outperformed children (45.83%), older adults (52.42%; both p's < .001) and adolescents (61.11%; $p < .05$). Furthermore, a main effect of item difficulty was found ($F(1,108) = 278.82$; $p < .001$; $\eta^2 = .72$) which was modified by the interaction between item difficulty and age group ($F(3,108) = 13.67$; $p < .001$; $\eta^2 = .28$). Separate t-tests for each age group revealed that in all age groups, recall was greater for easy items than for difficult ones (all p's < .001). Still, the effect sizes indicated that children (Cohen's d = 1.93), adolescents (d = 1.00), and older (d = 1.44) adults showed a greater difference in recall between related and unrelated items than the younger adults (d = 0.67; cf., Table 1).

Table 1. Recall in %, ST (s) and mean JOLs as a function of age group and item difficulty in Study 1

Age group		Recall (%)	Study time (s)	JOLs
Children				
	Related	65.8 (21.0)	8.1 (5.2)	71.8 (14.9)
	Unrelated	25.9 (20.3)	9.9 (7.5)	48.9 (19.4)
	Overall	45.8 (18.5)	9.0 (6.3)	60.3 (15.5)
Adolescents				
	Related	72.4 (15.6)	8.7 (7.7)	73.7 (13.3)
	Unrelated	49.8 (28.0)	10.5 (8.8)	61.0 (18.3)
	Overall	61.1 (20.7)	9.6 (8.1)	67.3 (14.7)
Younger Adults				
	Related	86.3 (15.9)	9.9 (9.0)	81.6 (12.1)
	Unrelated	72.8 (23.6)	13.9 (9.8)	69.4 (13.7)
	Overall	79.5 (18.9)	11.9 (9.3)	75.5 (11.6)
Older Adults				
	Related	71.4 (24.3)	7.4 (4.7)	75.6 (16.6)
	Unrelated	33.4 (28.5)	10.5 (6.1)	48.6 (25.7)
	Overall	52.5 (24.2)	8.9 (5.2)	62.1 (18.3)

Note. Standard deviations are in parentheses.

Study time. An ANOVA with mean ST as a dependent variable yielded a significant main effect of item difficulty (F(1,108) = 90.48; p < .001; η^2 = .46), with hard items (11.20 s) being studied more extensively than easy ones (8.54 s). This effect was modified by the interaction between item difficulty and age group (F(3,108) = 3.67; p < .05; η^2 = .09). T-tests revealed that the difference in mean ST between related and unrelated items was highest for younger and older adults (both p's < .001), followed by the children and the adolescents (both p's < .01; see Table 1).

Judgments of Learning. In an ANOVA with mean JOLs as a dependent variable a significant main effect of age group was found (F(3,108) = 5.63; p < .001; η^2 = .14) with post hoc tests indicating that younger adults (75.50) gave higher mean JOLs than children (60.34; p < .01) and older adults (62.07; p < .05). Furthermore, a significant main effect of item difficulty (F(1,108) = 137.42; p < .001; η^2 = .56) and a significant interaction (F(3,108) = 5.37; p < .01; η^2 = .13) were found. The interaction reflects the fact that the difference in mean JOLs between related and unrelated items was highest in children (d = 1.34) and older adults (d = 1.23) as compared to adolescents (d = 0.80) and younger adults (d = 0.94; all p's < .001 in t-tests; see Table 1).

Table 2. Mean within-person JOL-ST pearson and ST-recall Gamma correlation as a function of age group in Study 1

Age group	Pearson-correlation JOL-ST	Gamma-correlation ST-recall
Children	-.05 (.29)	-.13 (.29)*
Adolescents	-.04 (.18)	-.11 (.27)*
Younger Adults	-.15 (.22)**	-.21 (.27)**
Older Adults	-.11 (.24)*	-.34 (.32)***

Note. Standard deviations are in parentheses. * p < .05; ** p < .01; *** p < .001.

Cue utilization: Memorizing effort as a cue for JOLs. Most importantly we aimed to examine the relationship between ST and JOLs. For that purpose, we proceeded in analogy with previous work (Hoffmann-Biencourt et al., 2010; Koriat et al., 2009a, 2009b) and calculated Pearson-correlations between ST and JOL for each participant. A negative correlation indicates that shorter studied items received higher JOLs and thus supports the CM-model. The averaged correlations for each age group are depicted in Table 2. For the younger ($p < .01$) and older adults ($p < .05$) correlations were different from zero. An ANOVA with age group as independent variable revealed no significant main effect. In order to substantiate these results, a second procedure adopted from Koriat et al. (2006, 2009a, 2009b) was used. Hence, for each participant JOLs were divided in those above and below the individual median of ST (cf., Figure 1). Mean JOLs above and below this median were calculated and entered in an ANOVA with age group and ST (below and above median) as a dependent variable. A significant main effect of age group ($F(3,108) = 5.54$; $p < .01$; $\eta^2 = .13$) and a significant main effect of ST ($F(3,108) = 21.24$; $p < .001$; $\eta^2 = .16$) occurred. The post-hoc test revealed that younger adults gave higher mean JOLs than children and older adults (s. above). Besides, participants gave higher JOLs for items below the median (69.41) than for items above the median (63.11).

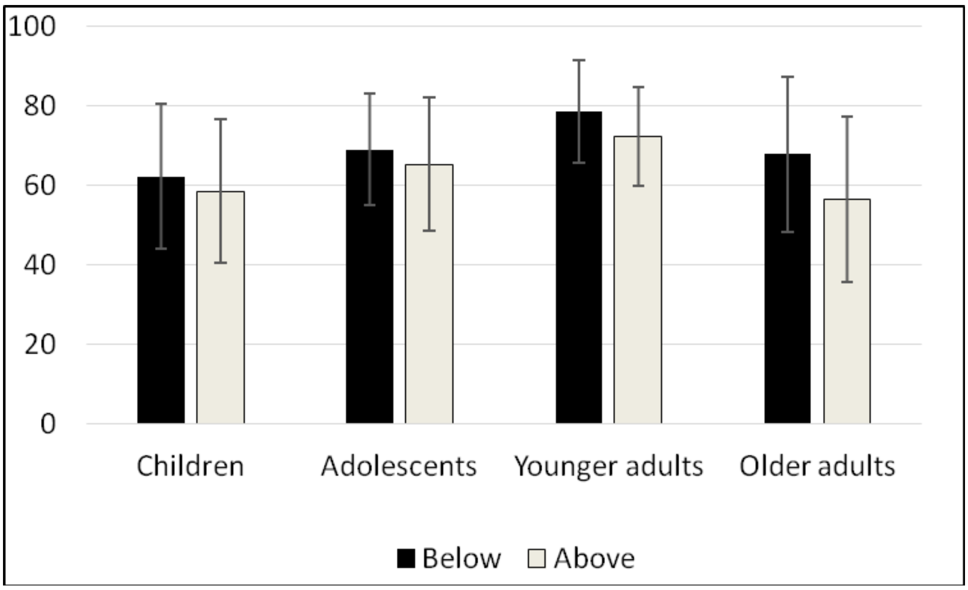

Figure 1. Mean JOLs for below-median and above-median ST as a function of age group in Study 1

Cue validity: *The validity of ST as a predictor of recall*. In order to analyse whether ST predicted later recall, we again drew on existing work by Hoffmann et al. (2010; cf., also Koriat et al., 2009a, 2009b) and calculated Goodman-Kruskal gamma-correlations between ST and recall for each participant. Mean correlations for each age group are depicted in Table 2. All correlations were different from zero ($p < .05$ for children and adolescents; $p < .01$ for younger adults; $p < .001$ for older adults). Shorter ST came along with greater recall. An ANOVA with age group as independent variable revealed a significant main effect of age group ($F(3,108) = 3.50$; $p < .05$; $\eta^2 = .09$). Post hoc tests showed a significant difference between older adults' (-.34) and adolescents (-.11) mean correlations. As a second step, for each participant items were split into those with below and those with above median ST. An ANOVA with age group and ST (below vs. above median ST) as independent and recall as dependent variable was conducted and revealed a significant main effect of a age group ($F(3,108) = 13.77$; $p < .001$; $\eta^2 = .28$), a significant main effect of ST ($F(1,108) = 36.93$; $p < .001$; $\eta^2 = .25$) and a significant interaction between both ($F(3,108) = 4.19$; $p < .01$; $\eta^2 = .10$). The main effect of age group on recall has been analysed with post hoc tests above. The main effect of ST indicates that overall, recall was higher for items below (.65) than above (.54) median ST. T-tests indicated significantly higher recall for items with shorter ST in contrast to items with longer ST for the older age groups (adolescents: $p < .05$; younger and older adults: p's < .001), but not for children (cf., Figure 2).

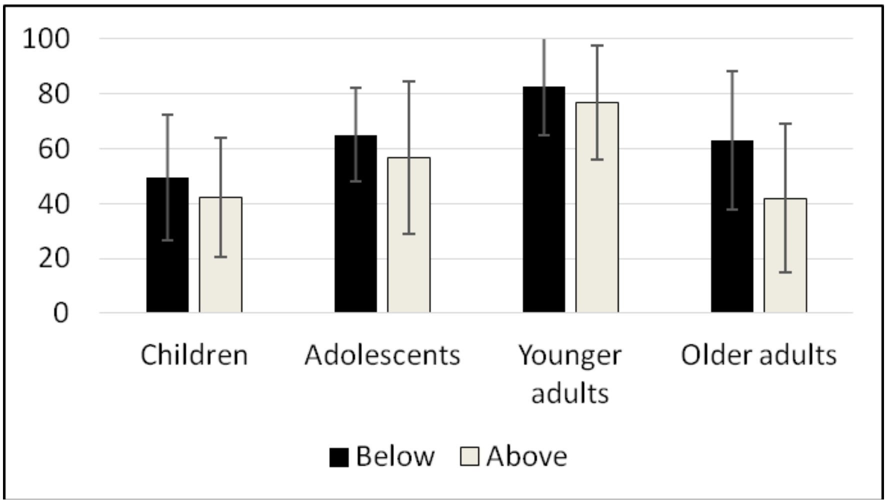

Figure 2. Mean recall in % for below-median and above-median ST as a function of age group in Study 1

2.3 Discussion

The present study aimed at exploring the relationship between metacognitive monitoring and control skills in a broad age range. In particular, we focused on finding evidence for the data-oriented CM-model in a life-span sample. This was achieved by investigating the relationship between ST and size of JOLs. We postulated that the CM-model should be detectable in all age groups but be especially salient in younger adults. An important innovative aspect of our study was its life-span perspective in that four age groups (children in third-grade, adolescents, younger and older adults) were included in the sample. To our knowledge, this study tested data-oriented learning in older adults for the first time.

First, the results show that the experimental conditions operated as expected. We largely managed to balance out baseline difficulty across age groups and experimental conditions with the exception of young adults outperforming the other age groups. Recall rates for related items ranged from .66 to .86. For unrelated items children, adolescents and older adults showed greater difficulty than younger adults, yet in all age groups recall was greater for easy than for difficult items. Additionally, in accordance with the literature adequate metacognitive monitoring performance could be depicted from third grade to older adulthood (Dunlosky & Metcalfe, 2009; Schneider & Löffler, 2016).

In accord with our hypothesis, we found evidence for data-oriented learning in all age groups but also developmental trends. Accordingly, items with higher ST received lower JOLs than items with lower ST in all age groups. This conclusion was substantiated by the results for Pearson correlations between ST and JOLs that took into account the full range of STs for each participant. This analysis revealed evidence in favor of the CM-model for younger and older adults, while results for children and adolescents only showed a tendency towards this direction. Our findings are in accordance with existing data which documents use of the CM-model from third grade on and an increasing association between JOLs and ST until young adulthood (Hoffmann-Biencourt et al., 2010). Yet, the expected differences between third-graders and adolescents could not be detected in Study 1. One possible reason might be that in contrast to existing experiments (cf., Hoffmann-Biencourt et al., 2010; Koriat et al., 2009a) in Study 1 the learning task for adolescents was more challenging than that for third-graders. Possibly, the higher task demands resulted in lower self-regulation performance that were closer to elementary school children's abilities (cf., Schunk & Zimmermann, 1998). As expected the association between ST and JOLs was weaker for older than for younger adults. This might reflect difficulties of older adults in executive functions which makes it more difficult for them to use control processes as a cue for monitoring processes (Pansky et al., 2009).

Additionally, it was analyzed how valid memorizing effort was as a predictor for recall, that is if ST has diagnostic value for JOLs. Gamma-correlations between ST and recall revealed that this is the case for all age groups and shorter ST was associated with greater recall. This effect was most pronounced for older adults. The validity of the memorizing effort heuristic was also reflected when comparing recall for above and below median STs. For adolescents, younger and older adults recall performance increased with shorter ST indicating that the invested effort serves as a valid cue for recall performance. Accordingly, ST seems to gain importance for recall performance with increasing age. Generally, correlations between ST and recall were stronger than those between ST and JOLs, indicating that the validity of ST as a diagnostic cue can be found earlier in life than its use as a cue for the size of monitoring judgements.

In sum, this study for the first time provided evidence for data-oriented processing according to the CM-model in older adults and in a life-span sample. Younger and older adults responded most to the monitoring function of ST. Yet, there is still room for improvement in self-regulation and subsequent monitoring, especially in the two youngest age groups.

Overall, Study 1 added to the literature by showing within one experimental design that participants from middle elementary school age to older adulthood are able to make use of the CM-model. In everyday learning, both the MC- and the CM-model often are probably at play within the same learning task (Koriat et al., 2006). Yet, the literature so far shows only few studies investigating this phenomenon. In order to study the flexible alteration between the MC- and the CM-model within one task goal-oriented learning can be experimentally emphasized by varying the incentive value of different items while data-oriented learning can be operationalized by manipulating item difficulty at the same time. This task design was chosen for Study 2.

3. Study 2

3.1 Introduction

Koriat et al. (2006) showed evidence for goal- and data-oriented learning within one task in young adults: participants gave higher JOLs for items with lower ST if items were of identical incentive value (data-oriented learning) but allocated more ST to items with higher value than with lower value (goal-oriented learning). From a developmental perspective, the interplay of the CM- and MC-model has only been studied for adolescents. To our knowledge, no data exists for elementary school children and older adults. In the only existing study including adolescents, fifth and sixth graders were not able to switch between data- and goal-oriented learning in a pair-associate task; only adolescents in 9^{th} grade were able to do so (Koriat et al., 2014). In fact, younger participants in this study relied more on item difficulty than on incentive value of word pairs, indicating that the CM-model had a greater impact on learning behavior than the MC-model. Although even 6-year-olds are able to control their learning behavior according to item value (Castel, Lee, Humphreys, & Moore, 2011), this seems to be more difficult when item difficulty greatly varies between item pairs. This might be due to the improvement in executive functions during adolescents (Diamond, 2002).

For older adults, Study 1 demonstrated for the first time that they are able to use ST as a cue for JOLs. Yet, clarification is needed for the question whether older adults can flexibly switch between data- and goal-oriented learning within one task. Generally, older adults are able to allocate ST according to the incentive value of items and seem to do so even more than younger adults (Castel, Benjamin, Craik, & Watkins, 2002). Price, Hertzog and Dunlosky (2010) manipulated both incentive value and difficulty of items within one learning task. Here, older adults relied more on item difficulty than on incentive value. This can be explained by the fact that older adults have lower learning goals than younger adults and therefore choose more difficult items independently of their incentive value with low probability (cf., agenda-based-regulation model, Ariel, Dunlosky, & Bailey, 2009). Accordingly, one can expect that for older adults, item difficulty will be a more important cue for ST than incentive value when given the goal to memorize as many word pairs as possible (Price et al., 2010).

We anticipated that both elementary school children and older adults have more difficulties to switch between data- and goal-oriented learning within one task than adolescents and younger adults. For both children and older adults, item-difficulty should be the most salient cue. Thus data-oriented learning should be the more easily detectable than goal-oriented learning in these age groups. In sum, Study 2 aimed to explore the interplay of the MC- and the CM-model within one learning task over a life-time sample for the first time.

3.2 Method

3.2.1 Participants

Again, N = 112 (53 male, 59 female) participants of the same four age groups (n = 28 in each group) and background as in Study 1 took part in the study. Recruitment and recompenses were identical to those in the previous study. Participants' mean ages were 8.14 (SD = 0.36) for the children, 13.07 (SD = 0.81) for the adolescents, 21.89 (SD = 2.59) for the younger adults and 67.18 (SD = 4.78) for the older adults.

3.2.2 Materials and Procedure

The learning items were identical to those in Study 1 with the exception that 12 item pairs were added to younger adults' list in order to further balance baseline differences in memory performance between the age groups. The procedure only differed in one aspect from Study 1: in the learning phase, 50% of the items (25% related and 25% unrelated) were marked with a big star containing a "5"; the other 50% of the items were marked with a smaller star containing a "1". Participants were instructed that they should memorize the items in order to collect as many points as possible. Each correct answer would provide them 1 or 5 point according to the star matched with the item. They were told that they would receive small additional gifts (children and adolescents) or a monetary reward (adults) according to their memory performance to emphasize the importance of the incentive. The JOL- and the recall-phase were identical to Study 1. At the end, the participants were asked to indicate on a 7-point-scale whether it was important to them to achieve as many points as possible (1: "not important at all"; 7: "very important"). In addition, children and adolescents were asked how much they liked the reward (1: "not at all"; 7: "very much").

3.3 Results

We start by presenting memory performance in terms of the percentage of correctly recalled items, mean ST and JOLs as a function of age group, item difficulty (related vs unrelated items) and incentive level. Then we will analyse the effects of ST on JOLs and recall performance. Lastly, the results of the questionnaire on incentives will be reported.

Preliminary analyses did not reveal any systematic effects of gender. The data was therefore collapsed across these variable. As a post hoc follow-up on main effects, Scheffé tests were used. The level of significance was set to p < 0.05.

Recall. The first column of Table 3 shows the percentage of correct responses. The ANOVA with recall as a dependent variable revealed a significant main effect of age group ($F(3,108) = 5.58$; $p < .01$; $\eta^2 = .13$). Post hoc tests clarified that younger adults (75.00%) outperformed children (58.18%; $p < .01$) and older adults (59.08%; $p < .05$). Furthermore, a main effect of item difficulty was found ($F(1,108) = 352.80$; $p < .001$; $\eta^2 = .77$) which was modified by a significant interaction between item difficulty and age group ($F(3,108) = 12.21$; $p < .001$; $\eta^2 = .25$). The difference in recall between related and unrelated items was higher in children ($d = 2.72$) and older adults ($d = 2.46$) than in adolescents ($d = 1.26$) and younger adults ($d = 1.12$; see Table 3). Still, for all age groups recall was higher for related than for unrelated items (all p's < .001 in t-tests). Finally, the main effect of incentive turned out significant ($F(1,108) = 36.92$; $p < .001$; $\eta^2 = .26$): 5 point items (69.59%) were associated with higher recall rates than 1 point items (60.12%).

Table 3. Recall, ST and mean JOLs as a function of age group, item difficulty, and incentive in Study 2

	Recall (%)		ST (s)		JOLs	
	1 pt.	5 pt.	1 pt.	5 pt.	1 pt.	5 pt.
Children						
Related	73.8 (20.0)	88.7 (12.9)	7.2 (2.8)	8.0 (4.3)	71.3 (16.6)	80.4 (15.5)
Unrelated	28.0 (23.6)	42.3 (28.5)	8.2 (3.2)	9.5 (5.3)	41.0 (21.6)	50.9 (22.5)
Overall	50.9 (18.2)	65.5 (16.2)	7.7 (2.6)	8.7 (4.5)	56.2 (17.0)	65.6 (14.9)
Adolescents						
Related	77.0 (19.3)	84.5 (14.0)	7.7 (4.5)	9.4 (5.9)	77.3 (18.8)	83.7 (11.9)
Unrelated	49.6 (31.5)	57.5 (27.2)	11.1 (7.0)	12.4 (7.6)	60.0 (23.9)	65.9 (18.8)
Overall	63.3 (23.3)	71.0 (18.2)	9.4 (5.5)	10.9 (6.6)	68.6 (18.8)	74.8 (13.7)
Younger adults						
Related	84.1 (15.9)	90.2 (15.3)	8.8 (4.1)	11.8 (5.9)	81.2 (15.7)	87.3 (12.8)
Unrelated	56.7 (31.1)	69.1 (26.9)	12.7 (6.4)	15.9 (7.6)	58.1 (24.5)	68.9 (19.8)
Overall	70.4 (22.0)	79.6 (18.6)	10.8 (4.9)	13.8 (6.6)	69.7 (18.0)	78.1 (13.5)

Older adults						
Related	81.6 (18.3)	89.3 (11.3)	5.6 (2.3)	5.9 (2.3)	85.3 (12.8)	84.0 (14.4)
Unrelated	30.4 (25.7)	35.1 (32.8)	8.8 (5.5)	9.3 (4.1)	44.6 (21.6)	45.6 (26.5)
Overall	56.0 (19.0)	62.2 (19.4)	7.2 (3.6)	7.3 (3.1)	65.0 (14.1)	64.8 (17.6)

Note. Standard deviations are in parentheses.

Study time. An ANOVA with mean ST as a dependent variable yielded a significant main effect of age group ($F(3,108) = 6.27$; $p < .01$; $\eta^2 = .15$). In post hoc tests, it was shown that younger adults (12.28 s) studied the items longer than children (8.20 s; $p < .05$) and older adults (7.43 s; $p < .01$). Additionally, the main effect of item difficulty ($F(1,108) = 100.46$; $p < .001$; $\eta^2 = .48$) and the interaction between item difficulty and age group ($F(3,108) = 4.22$; $p < .01$; $\eta^2 = .11$) turned out significant. T-tests revealed that for each age group, the difference in ST between related and unrelated items was significant; however this effect was less pronounced in children (children: $p < .01$; adolescents, younger and older adults: $p < .001$; see Table 3). Furthermore, the ANOVA revealed a significant main effect of incentive level ($F(1,108) = 22.98$; $p < .001$; $\eta^2 = .18$) which was modified by a significant interaction between incentive and age group ($F(3,108) = 3.21$; $p < .05$; $\eta^2 = .08$). Again, t-tests were conducted which showed that only in adolescents ($p < .05$) and younger adults ($p < .001$) the difference in ST between higher and lower valued items was significant (see Table 3).

Judgments of Learning. In an ANOVA with mean JOLs as dependent variable a significant main effect of age group was found ($F(3,108) = 4.60$; $p < .01$; $\eta^2 = .11$) with post hoc tests indicating that children gave lower JOLs (60.90) than younger adults (73.87; $p < .05$). Besides, the ANOVA revealed a significant main effect of item difficulty ($F(1,108) = 263.75$; $p < .001$; $\eta^2 = .71$) and a significant interaction between item difficulty and age group ($F(3,108) = 8.88$; $p < .001$; $\eta^2 = .20$). Although in every age group the difference between related and unrelated items was highly significant (all p's < .001 in t-tests), it was greatest in children ($d = 1.81$) and older adults ($d = 2.24$) as compared to adolescents ($d = 1.02$) and younger adults ($d = 1.18$; see Table 3). Concerning the incentives, a significant main effect ($F(1,108) = 25.78$; $p < .001$; $\eta^2 = .19$) and a significant interaction between incentive and age group $F(3,108) = 3.38$; $p < .05$; $\eta^2 = .09$) were found. T-tests revealed that only the three younger age groups (children and adolescents: p's < .01; younger adults: $p < .001$) gave significantly higher mean JOLs to 5 point than to 1 point items, but not the older adults (see Table 3).

Table 4. Mean within-person JOL-ST Pearson and ST-recall Gamma correlation as a function of age group and incentive level in Study 2

	Pearson correlation recall		**Gamma correlation ST-JOL-ST**	
	1 pt.	5 pt.	1 pt.	5 pt.
Children	-.02 (.32)	-.12 (.32)	-.12 (.37)	-.19 (.46)*
Adolescents	-.18 (.29)**	-.13 (.22)**	-.20 (.37)**	-.19 (.32)**
Younger adults	-.16 (.21)***	-.05 (.24)	-.16 (.44)	-.06 (.36)
Older adults	-.15 (.29)***	-.21 (.28)***	-.27 (.44)**	-.31 (.34)***

Note. Standard deviations are in parentheses. * p < .05; ** p < .01; *** p < .001.

Cue utilization: Memorizing effort as a cue for JOLs. As in Study 1, we aimed to examine the relationship between ST and JOLs by means of Pearson-correlations between both variables for each participant. This time, correlations were computed separately for each incentive level in order to eliminate the impact of goal-orientated processing. Mean correlations are depicted in Table 4. Children's correlations and younger adults' correlations in 5-point items were not different from zero; the other coefficients reached the significance level (adolescents: both p's < .01; younger adults: $p < .001$ for 1-point items; older adults: both p's < .001). A corresponding ANOVA yielded no significant main effects nor interactions. As above, these results were verified by contrasting mean JOLs above vs. below-median ST (see Figure 3). Incentive was included in the ANOVA as additional within-participant factor to keep goal-orientation on a constant level. A part from the significant main effect of age group ($F(3,108) = 4.50$; p

< .01; η^2 = .11) already reported in the JOL section, we found a significant main effect of ST (F(1,108) = 30.30; p < .001; η^2 = .22) with shorter studied items receiving higher JOLs (72.15) and longer studied items receiving higher JOLs (64.93). The main effect of incentive (F(1,108) = 23.81; p < .001; η^2 = .18) and the interaction between incentive and age group (F(3,108) = 3.58; p < .05; η^2 = .09) also have been documented above.

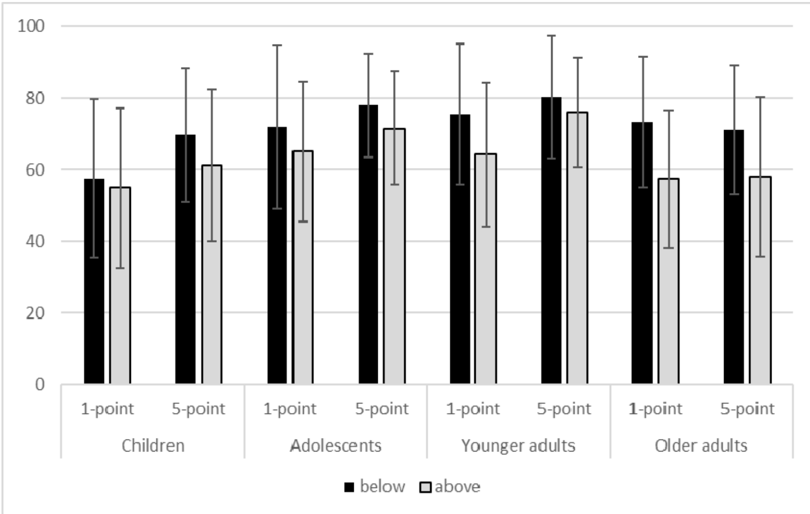

Figure 3. Mean JOLs for below-median and above-median ST as a function of age group and incentive level in Study 2

Cue validity: *The validity of ST as a predictor of recall*. The relationship between ST and recall was analyzed the same way as for Study 1; however, incentive level served as an additional factor. Mean gamma-correlations between ST and later recall for each age group and incentive are depicted in Table 4. In children, only the correlation in 5-point items was different from zero (p < .05); in adolescents and older adults both correlations reached the significance level (5-point items in older adults: p < .001; all other p's < .01); younger adults' correlations were both not different from zero. An ANOVA with age group and incentive as dependent variables revealed no significant main effects nor interactions. Furthermore, recall was calculated for below-median and above-median ST in 1-point items and in 5-point items (see Figure 4). An ANOVA with age group as between-participants factor and ST (below-median vs. above-median) and incentive as within-participant factors yielded a significant main effect of age group (F(3,108) = 5.68; p < .01; η^2 = .14) which has already been reported above in the recall section. Besides, a significant main effect of ST (F(1,108) = 31.62; p < .001; η^2 = .23) was found indicating that shorter studied items received higher recall rates (70.49%) than longer studied items (59.18%). Finally, the significant main effect of incentive (F(1,108) = 34.76; p < .001; η^2 = .24) already documented above was shown again.

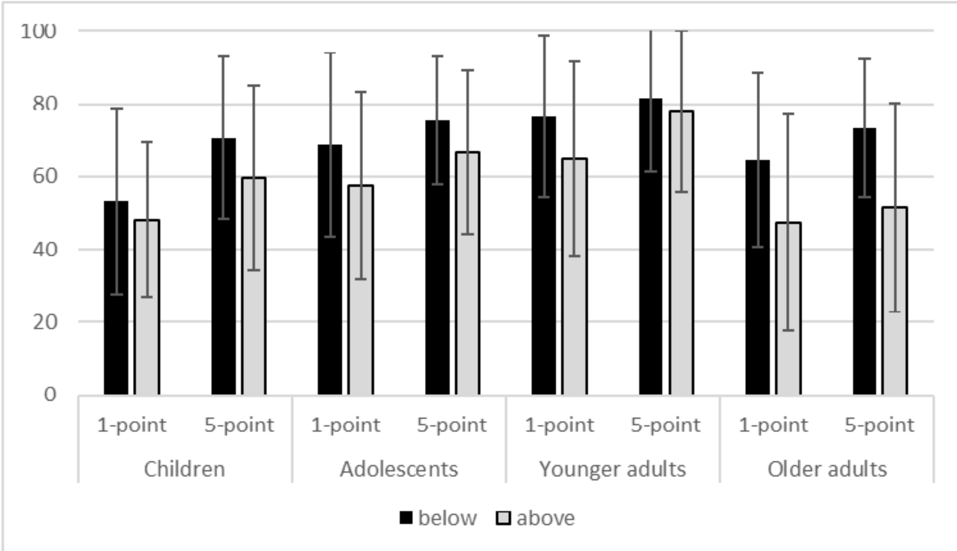

Figure 4. Mean recall in % for below-median and above-median ST as a function of age group and incentive level in Study 2

Questionnaire on incentives. Mean values on the 7-point-scale for question 1 concerning the incentives ("How important was it to you to achieve as many points as possible?") were rather high in each age group (children: M = 5.14; SD = 1.65; adolescents: M = 4.43; SD = 1.85; younger adults: M = 5.15; SD = 1.41; older adults: M = 4.25; SD = 2.27). The correspondent ANOVA with age group as between-participant factor revealed no significant main effect. Concerning question 2 ("How did you like the reward?"), mean values resulted rather high as well (children: M = 5.67; SD = 1.52; adolescents: M = 5.86; SD = 1.16). In a t-test, no significant difference was found between the two age groups.

3.4 Discussion

The first aim of Study 2 was to replicate the findings of Study 1 concerning the CM-model in all four age groups. Secondly, Study 2 was conducted in order to strengthen the still poor data base related to developmental studies on the relation between MC- and CM-processes within one learning task. This seemed important because so far no study has explored the flexible interplay of both processes for older adults and because every-day learning tasks often require the ability to consider both data and goal-oriented learning at the same time.

To account for different learning abilities, task difficulty was adapted to age group. Materials were identical to Study 1, expect the list for younger adults was expanded by 12 items in order to further match memory performance between age groups. Thus, bottom and ceiling effects could be successfully avoided in all age groups and base line difficulty was outbalanced between the age groups. Still, younger adults performed slightly better than the other age groups. The experimental conditions operated as expected: Recall was higher for related than for unrelated items and higher for 5 point than for 1 point items in all age groups.

Manipulation of incentive value was effective as participants of all age groups reported to be motivated to achieve as many points as possible and considered the rewards to be attractive.

Participants of all age groups showed data-oriented learning, that is gave higher JOLs for items with shorter ST than with longer ST. Thus, we were successful in replicating findings from Study 1 which for the first time provided evidence for the CM-model from elementary school age to older adulthood. Correlations between ST and JOLs depicted developmental trends, that is for adolescents, younger adults (only 1-point-items) and older adults but not for elementary school children correlations differed significantly from zero. Especially elementary school children seem to have difficulties with data-oriented learning when goal-oriented learning occurred simultaneously. In all age groups ST was generally a valid predictor for recall performance indicating that shorter studied items received higher recall rates than shorter studied items. Gamma correlations between ST and recall largely confirmed this pattern and were significant for elementary school children (5-point items), adolescents and older adults.

Concerning flexible alteration between goal and data-oriented learning, results show that adolescents and young adults were generally able to apply both the MC- and the CM-model within one learning task (cf., Koriat et al., 2014). In contrast, this posed a greater challenge for elementary school children and older adults. Especially, older adults seemed to rely their JOLs on item characteristics and ST (CM-model) but showed difficulties to achieve as many points as possible at the same time. Elementary school children depicted fewer hints for both goal and data-oriented learning than adolescents and young adults. The necessity to switch between both learning types seems to affect both processes in this age group. This is in line with existing data suggesting that the ability to react to both data and goal-oriented processes at the same time increases with age (Koriat et al., 2014). Possible causes for developmental trends form childhood to young adulthood and from young adulthood to older adulthood seem to differ. While elementary school children might have difficulties to integrate bottom-up and top-down processes (that is inferring from ST to JOLs and vice versa) into a single metacognitive judgment (Koriat et al., 2014), older adults' personal learning goal might hinder their ability to flexibly react to both processes (Ariel et al., 2009). Further research is needed to verify those developmental trends as well as their sources.

4. General Discussion

The results of the two studies presented here indicate that participants from elementary school age to older adulthood are able to use information from control processes to modulate monitoring processes (CM-model). The analyses of JOLs after median-split in both Study 1 and Study 2 showed significant main effects of ST but no significant interaction with age group. Although effect sizes were of medium height (η^2 between .16 and .22) the difference in JOLs for items with shorter and longer ST was not large enough to result in negative correlations between JOLs and ST on item level for all age groups. For elementary school children no correlation was significant, only for younger and older adults nearly all correlations reached significance. For adolescents, mixed results were found: in Study 1 correlations did not reach significance while in Study 2 the correlation between JOL and ST was significant. This is in accordance with existing data concerning developmental trends: From third grade on first evidence for the CM-model is detectable (Koriat et al., 2009) which becomes more stable from 5th grade on (Hoffmann-Biencourt et al., 2010). Both Study 1 and 2 added to the literature by providing evidence for the CM-model in older adults for the first time. No substantial deficits for older adults became evident. Low correlations between ST and JOL in Study 1 could not be replicated in Study 2. Thus it cannot be assumed that older adults generally show disadvantages in the interplay of monitoring and control processes due to deficits in executive functions (Pansky et al., 2009; Souchay & Isingrini, 2004). Further evidence for the stability of the CM-model in older adults derives from the fact that performance did not suffer from simultaneous manipulation of goal orientation in Study 2.

Furthermore, our studies demonstrated age effects for the flexible use of both the MC- and the CM-model within one learning task. Adolescents and younger adults showed the best abilities to do so. Older adults adapted neither ST nor JOLs to item value while elementary school children adapted their JOLs only. These findings cannot be explained by a general deficit concerning the MC-model in these age groups as it has been documented that children and older adults are able to monitor their ST on the basis of monitoring processes (Dunlosky & Connor, 1997; Lockl & Schneider, 2003). A more likely cause appears to be that switching between both models posed difficulties for these age groups (Koriat et al., 2014) as potentially coordinating the use of two cues poses high cognitive demands. Another possible explanation is the higher salience of item difficulty compared to item value (Ariel et al., 2009; Lockl & Schneider, 2004; Price et al., 2010). Further research should aim to investigate the alteration between data and goal-oriented learning with item pairs of identical difficulty in order to make item value more salient (Ariel et al., 2009; Koriat et al., 2006, 2014).

Additionally, for elementary school children no significant correlations between JOLs and ST (CM-model) could be detected. Only the analysis of ST after median-split turned out to be significant in this age group. This pattern of results was confirmed in Study 1 for data-oriented learning and in Study 2 for both data- and goal-oriented learning within one task. Thus, it can be assumed that the sensitivity for data-oriented processes increases after elementary school age (cf., Koriat et al., 2014) and that the interplay between both learning processes also becomes more flexible with age.

In sum, integrating goal-oriented learning (top-down-process) and data-oriented learning (bottom-up-process) within one metacognitive judgement seems to be a complex process (Schneider, 2015). Adolescents and young adults appear to master this task successfully. In contrast, for elementary school children and older adults this appears to be challenging. Yet, generally both age groups are able to apply goal- and data-oriented learning in separate learning tasks. Further research should aim to specify underlying mechanisms of these developmental trends. As our findings represent the first approach using a lifespan sample, our conclusions remain preliminary and require replications with different age groups and different item values. Studies relating goal- and data-oriented learning within one learning task are still scarce, particularly for elementary school children and older adults. This is surprising given that that everyday learning often requires flexible use of both learning processes. Hence expanding our findings to more age groups would allow to account for more fine-grained developmental changes, especially from childhood to adolescence and from younger to older adulthood. Additionally, it would be worth to include individuals with cognitive limitations like mild cognitive inertia or intellectual difficulties in further studies. Overall, the results suggest that, although goal- and data-oriented learning abilities are present over a large age range, especially children and older adults have room for improvement. Thus our findings indicate that exploring the underlying processes of metacognitive abilities is worth to be pursued in future research.

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