Journal of Experimental Child Psychology 237 (2024) 105772

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Active help-seeking and metacognition interact in supporting children's retention of science facts

Michelle Shields, Grai Calabro, Diana Selmeczy *

Department of Psychology, University of Colorado Colorado Springs, Colorado Springs, CO 80918, USA

ARTICLE INFO

Article history:
Received 18 April 2023
Revised 27 June 2023
Accepted 11 August 2023

Keywords:
Help-seeking
Metacognition
Testing effect
Active learning

ABSTRACT

Determining when to ask for help is a critical self-regulated strategy that can benefit children's learning. Despite its importance, we have a limited understanding about the developmental mechanisms that support adaptive help-seeking. In the current preregistered study, predominately White children aged 8 to 13 years (N = 69, n_{girls} = 37) had the option to seek help during an online science learning task. Results revealed that children's ability to adaptively seek help improved throughout childhood and early adolescence. Critically, developing metacognitive skills contributed to greater help-related memory benefits (compared with conditions where help was not previously available). Overall, these findings highlight the role of metacognition in children's ability to adaptively seek and benefit from help during online science learning.

Introduction

Students are continuously tasked with learning new information and developing skills to regulate their learning. Such skills include recognizing when to seek help and what type of help is needed. For example, students may seek help when they are uncertain of the correct answer by asking a teacher for assistance or using a textbook to look up relevant information. However, seeking help might not always be beneficial. If a student is highly confident in the correct answer, then seeking help may be a waste of time or resources and result in limited benefit. Thus, adaptive help-seeking involves

* Corresponding author.
E-mail address: diana.selmeczy@uccs.edu (D. Selmeczy).

https://doi.org/10.1016/j.jecp.2023.105772
0022-0965/

selectively asking for help in a manner that maximizes learning or performance (Nelson-Le Gall, 1981), a skill that has also been shown to correlate with successful academic achievement (Ryan & Shim, 2012; Ryan & Shin, 2011). Despite the growing understanding of the benefits of help-seeking, the development of underlying mechanisms that support these benefits and their impact on long-term learning have been largely unexplored. In the current preregistered study, we examined help-seeking as the decision to seek additional online information during a computer-based science learning task. We investigated whether the opportunity to actively seek help promotes memory retention of learned information compared with conditions where help was unavailable, and the role of metacognition in this process (i.e., the ability to self-reflect on cognitive processes; Nelson & Narens, 1990), in a sample 8- to 13-year-old children. Determining the benefit of help-seeking compared with other learning strategies has potential implications for educators and classroom learning in addition to contributing to theories of self-regulated learning (Karabenick & Berger, 2013).

The development of metacognition and help-seeking

The ability to benefit from help-seeking requires appropriately assessing when help may be most beneficial (Nelson-Le Gall, 1981, 1987). Thus, adaptive help-seeking requires metacognitive monitoring, or the ability to accurately self-reflect on one's knowledge (Nelson & Narens, 1990). Metacognitive monitoring emerges during the preschool years, such that children begin to explicitly report higher levels of confidence when providing correct versus incorrect answers (Ghetti et al., 2013). This relation between confidence and accuracy improves with age (Fandakova et al., 2017). Older children are also more adept at using metacognitive monitoring as a basis for metacognitive control (i.e., self-regulated decision-making), such as determining which items to volunteer toward a reward or restudy for an upcoming test (Hembacher & Ghetti, 2013; Metcalfe & Finn, 2013). Help-seeking is also a type of metacognitive control that relies on appropriate monitoring of one's knowledge to determine when help would be most beneficial (Karabenick & Berger, 2013; Nelson-Le Gall, 1981).

Although metacognitive monitoring and control relations are relevant for help-seeking, only a handful of previous studies have examined whether children's explicit metacognitive judgments (i.e., confidence ratings) play a role in the decision to seek help. For example, previous research demonstrates that preschoolers are more likely to ask for help when they report low levels of confidence during a perceptual task (Coughlin et al., 2014). However, other research shows that first to third graders ask for help similarly regardless of confidence during mathematical problem-solving (Nelson & Fyfe, 2019). Furthermore, whereas fifth graders consistently use metacognitive monitoring to guide help-seeking decisions during vocabulary learning, third graders only do so when provided with reward-based feedback (Nelson-Le Gall & Jones, 1990; Nelson-Le Gall et al., 1990). Overall, these results suggest that the ability to use metacognitive monitoring to guide help-seeking decisions may emerge early during childhood, but the developmental progression of this skill remains unclear. Furthermore, metacognitive monitoring may be domain specific during early childhood (Geurten et al., 2018; Vo et al., 2014), making it important to assess its role in help-seeking across other academic domains. Previous research has often focused on assessing young children's help-seeking during problem-solving (Puustinen, 1998) or vocabulary learning (Nelson-Le Gall & Jones, 1990; Nelson-Le Gall et al., 1990), and therefore we have a limited understanding of how young children seek help during learning of other academically relevant domains (e.g., science learning). In addition, task-based research with younger children often examines help-seeking in social contexts (e.g., seeking help from a peer or researcher) (Nelson & Fyfe, 2019; Nelson-Le Gall, 1987; Nelson-Le Gall et al., 1990), whereas research with adolescence often examines help-seeking in online contexts (e.g., from computer software) (Roll et al., 2011, 2014). The current study sought to contribute to our understanding of how help-seeking progresses from early childhood to early adolescence using an online task, which should allow us to focus on cognitive factors (i.e., metacognition) that contribute to help-seeking while limiting potential social demands.

Importantly, previous research has not directly examined how seeking help benefits long-term retention of information. Therefore, it is unclear under what circumstances and what processes may contribute to knowledge gains associated with seeking help. That is, previous research examining help-seeking behaviors in young children typically used designs that allow children to seek help while

they are completing a task (Nelson-Le Gall, 1987; Nelson-Le Gall et al., 1990; Puustinen, 1998) but do not assess how the opportunity to seek help may affect later retrieval of information. For example, imagine a third-grade student completing a practice worksheet about U.S. state capitals. When she is uncertain about an answer, she asks the teacher for help and, with this help, produces the correct answer. Although this interaction gives us information about whether help was sought and how it contributed to the child's current performance, it does not allow us to understand how the help may affect long-term retention on the final test in the absence of help. Because the retrieval of information often occurs independently and at a later time point, it is important to examine how help-seeking during learning affects long-term retention. Critically, if the development of metacognition plays a key role in adaptive help-seeking, then we would expect those children with more efficient monitoring–control relations (i.e., children who are better at using confidence to guide when they seek help) may also benefit more from having help available. Thus, in the current study, we investigated how the opportunity to actively seek help benefited long-term retention compared to other conditions where help was not available and the potential role of metacognitive development in this process.

Active help-seeking and retrieval practice

Help-seeking may be beneficial for long-term memory retention because it allows students to take an active part in their learning. Active learning practices include activities that engage students in the learning process, such as allowing for elaboration, inquiry, discussion, and self-regulation, and have been shown to improve classroom performance compared with passive learning strategies, such as simply listening to information (Freeman et al., 2014; Lombardi et al., 2021). Lab-based studies have also observed benefits from active learning practices (Markant et al., 2016). For example, 5- to 11-year-olds who chose how they studied to-be-learned information performed better on a later memory test compared with children who were assigned study schedules by researchers (Ruggeri et al., 2019). Furthermore, this benefit of active learning was observed only in older children, suggesting that the ability to effectively implement active strategies might not develop until middle childhood (Metcalfe & Finn, 2013; Ruggeri et al., 2019). Help-seeking can also be considered a form of active learning given that individuals make self-regulated decisions regarding how to seek help, what type of help to seek, and how to integrate help (Karabenick & Gonida, 2017). However, previous research has not examined how the opportunity to seek help may benefit memory retention compared with other more passive conditions, such as simply restudying information or taking a test without the opportunity to engage in help-seeking.

Although the opportunity to engage in help-seeking is predicted to increase retention compared with conditions where self-regulated help-seeking does not occur, retrieval practice (i.e., the effortful process of independently retrieving an answer) has also been shown to be a powerful learning tool (Rowland, 2014). Research with both adults and children demonstrates that taking a test improves learning more than restudying information (i.e., the testing effect) (Fazio & Marsh, 2019; Karpicke & Roediger, 2008), and this benefit is due to tests encouraging generation and strengthening of distinct retrieval cues (Lehman et al., 2014; Rowland, 2014). Active help-seeking, or volitional control over when to seek help, may also benefit retention compared with independent retrieval by increasing task engagement (Vaughn & Kornell, 2019), improving metacognition (Fisher & Oppenheimer, 2021), and/or increasing the incorporation of feedback (Winstone et al., 2016). Thus, we examined whether the opportunity to engage in help-seeking improves retention more than retrieval practice in the absence of help.

In addition to examining how the availability of help affects memory performance, we also assessed what types of help children sought. Seeking instrumental help, such as hints, is considered more adaptive because it provides scaffolded information that supports continued thinking about how to arrive at the answer. In contrast, seeking expedient help, such as the answer, is considered less adaptive because it allows children to complete the question without further engagement (Nelson-Le Gall, 1981). Children's ability to implement and recognize what types of strategies would be most beneficial for learning develops throughout early and middle childhood (Schneider, 2015; Schneider et al., 2004). Consistent with this literature, previous research demonstrated that fifth graders are more likely to seek instrumental help (i.e., hints) as opposed to expedient help (i.e., answers) when com-

pared with third graders during vocabulary learning (Nelson-Le Gall, 1987). Although seeking instrumental help is considered more adaptive than seeking expedient help, seeking expedient help may be appropriate in certain contexts, such as when one has very low confidence or no knowledge of the correct answer (Nelson-Le Gall et al., 1990). Critically, this previous research has not investigated how seeking different types of help influences long-term retention of learned information, and therefore we have limited knowledge of how actively choosing to seek different types of help relates to later memory performance.

The current study

The current research examined help-seeking behaviors in 8- to 13-year-old children. We selected this age range based on previous research suggesting developmental improvements in active learning (Ruggeri et al., 2019), metacognition (Fandakova et al., 2017), and help-seeking (Selmeczy, Ghetti, et al., 2021) during middle childhood. To examine help-seeking behaviors, we used a remote computer-based memory task during which children were asked to remember science facts about animals for an upcoming test. After encoding animal facts, children took a practice memory test. During the practice test, children were presented with an image of an animal and indicated their level of confidence in their ability to correctly recall the associated fact. Critically, participants then experienced three within-participant conditions across trials (i.e., Help Available, No Help Available, and Restudy trials). During Help Available trials participants could seek help, during No Help Available trials participants provided a response in the absence of help, and during Restudy trials participants simply restudied the animal fact. During the Help Available trials, help could be sought in the form of an answer *or* a hint. Hints were categorical cues that indicated the general category of the animal fact (i.e., eyes, move, or eat) based on previous research suggesting that category cues effectively promote memory performance in younger children (Kobasigawa, 1974). Children then completed a final memory test in the absence of help approximately 24 hours later.

We aimed to examine several questions. First, we examined whether children were adaptive in their help-seeking behaviors and whether this improved with age. We predicted that older children would prefer to seek hints more than answers, consistent with previous research demonstrating a similar pattern in children during vocabulary learning (Nelson-Le Gall, 1987). We also explored whether children's confidence would guide the type of help they sought, with the prediction that children would be least confident when seeking answers compared with hints. Critically, we investigated the relation between metacognitive monitoring and control during help-seeking more broadly and examined whether children were less confident when they elected to seek help (regardless of type of help) compared with not seeking help. Based on previous research, we predicted that confidence would guide children's decision to seek help in older children but that this pattern may be dampened or not present in younger children (Nelson-Le Gall et al., 1990).

Second, we examined whether the opportunity to actively seek help led to greater long-term retention than answering in the absence of help or restudying information. We predicted that final test performance (completed without help) would be greater during conditions where children had the earlier opportunity to seek help compared with when no help was provided or information was restudied. In addition, we predicted that this benefit from active help-seeking would be greater in older versus younger children. These predictions were based on previous research suggesting that active self-regulation of learning improves recall compared with passive strategies and that this benefit increases with age (Ruggeri et al., 2019). Moreover, given research demonstrating that children benefit from retrieval practice (Fazio & Marsh, 2019), we predicted that children would perform better on the final test when earlier retrieval occurred, including Help Available and No Help Available conditions, compared with restudying information. We also examined whether children performed better on the final test when seeking earlier hints compared with answers, with the prediction that hints may be associated with increased retention given that they are considered a more beneficial form of help (Nelson-Le Gall, 1981).

Third, we examined whether individual differences in metacognitive ability, measured as the relation between metacognitive monitoring and control, were related to the benefit achieved from earlier help-seeking. That is, we should observe help-related improvements in retention if children sought

help when it was most beneficial for their learning (e.g., when they were uncertain and would have answered incorrectly without help). In contrast, children are less likely to benefit from help if they sought help when it was not useful (e.g., regardless of confidence or when they were certain and would have answered correctly even without help). Thus, we predicted that those children whose confidence better guided when they chose to seek help during the practice test would have greater help-seeking-related performance gains on the final test. This prediction is consistent with previous research demonstrating that metacognitive monitoring contributes to children's ability to benefit from memory hints during recognition (Selmeczy & Ghetti, 2019) and that older children are more effective at using metacognitive monitoring to guide their study decisions in order to benefit their memory performance (Metcalfe & Finn, 2013).

Method

Transparency and openness

This study was preregistered (https://osf.io/mb8ug/) https://osf.io/mb8ug/?view_only=4e2aa8f99b2c42f39e9e8493429458df. Data and materials are available at https://osf.io/3d9tx/ https://osf.io/3d9tx/?view_only=d779b9ca8a9c4e45a912ef3cfc16751c. The memory task is available to preview at https://app.gorilla.sc/openmaterials/458815. Data were analyzed using R Version 4.2.0 (R Core Team, 2022).

Participants

A priori power analysis was conducted to determine the appropriate sample size (N = 68) to detect a medium effect (f = .18) for the interaction between condition (Help Available, No Help Available, or Restudy) and age group (younger or older) (α = .05, $1 - \beta$ = .90). Our final sample included 69 children aged 8 to 13 years (n_{girls} = 37; M_{age} = 10.82 years, SD = 1.60). An additional 12 children were collected and excluded due to reporting a developmental disorder the day of the study (n = 2), parental involvement during the task (n = 3), technical difficulties (n = 4), deciding to stop the task (n = 2), or being outside of our recruitment age range the day of the study (n = 1).

Participants' race was reported as 63.77% White, 7.25% African American, 14.49% Asian, 11.59% multiracial, and 2.9% not reported. Ethnic background was reported as 8.7% Hispanic, 88.4% not Hispanic, and 2.9% not reported. Participants' reported family income was distributed as less than $20,000 (2.9%), greater than $20,000 but less than $40,000 (5.8%), greater than $40,000 but less than $60,000 (13%), greater than $60,000 but less than $90,000 (8.7%), more than $90,000 (65.2%), and not reported (4.3%).

Participants were compensated with a $15 electronic gift card per each 60-min session for total compensation of $30. Participants were recruited through paid online Facebook advertisements distributed to U.S. residents. Participants were also recruited through flyers distributed to local public schools and our research lab's participant pool database. The study was approved by the university's ethics review board.

Materials

Stimuli

Picture stimuli were obtained from a validated set of color line-drawn images (Cycowicz et al., 2001). We created 42 animal facts (6 practice trials used during instructions and 36 task trials) consisting of specific information about animals' movement (e.g., "Elephants move without bending their knees"), eating (e.g., "Ostriches eat pebbles to help break up their food"), or eyes (e.g., "Rabbits' eyes are open when they sleep"). Each sentence consisted of the animal's name, fact category, and fact information. Facts across each category (move, eyes, or eat) were created for each animal and counterbalanced across three orders that were randomly assigned to participants. Each participant was randomly presented with 36 unique animal facts (12 facts in each category).

Receptive vocabulary

The NIH Toolbox (http://www.nihtoolbox.org) Picture Vocabulary Task measured receptive vocabulary skills and was used as a descriptive measure of our sample.

Procedure

Participants were asked to complete two 1-hr remote sessions. Sessions took place ~24 hr apart given previous literature suggesting that the effects of retrieval practice are more robust after a delay (Roediger & Karpicke, 2006). The remote synchronous study sessions were held using Zoom video conferencing, and the task was presented through Gorilla Experiment Builder (https://gorilla.sc). Participants were asked to share their screen during the session to allow researchers to observe that participants were on task. The memory task consisted of three phases: an *encoding* phase, a *help* phase, and a *final test* phase (see https://app.gorilla.sc/openmaterials/458815). All instructions for the memory task were presented through audio recordings to allow participants to complete the task independently. During the memory task, researchers turned off their audio and video feed and communicated with children only if they had questions or were off task (e.g., opened another webpage). Participants completed 6 practice trials to ensure their understanding of the task.

Session 1

During Session 1, participants completed the encoding and help phases of the memory task. During the encoding phase (see Fig. 1A), participants were presented with 36 trials consisting of a picture of an animal, a category icon (i.e., for move, eyes, or eat), and the animal fact. After presenting an animal fact for 6100 ms, participants indicated whether they knew the fact before the study session in order to maintain engagement. The yes/no response option was displayed for 2500 ms, followed by a 250-ms fixation before moving to the subsequent trial.

During the help phase (see Fig. 1B), participants were presented with a picture of an animal and asked to indicate what they learned about the animal. Participants were told that this phase was a practice test and should be used to continue their learning of the animal facts for a final test that would occur approximately 24 hr later. At the beginning of each trial, participants were asked to indicate how sure they were that they remembered the fact about the displayed animal using a 3-point pictorial confidence scale (Hembacher & Ghetti, 2014). The 3-point confidence scale was used to ensure comprehension even by the youngest children in our sample; similar scales have been used in other studies with similarly aged children (Fandakova et al., 2017). Following confidence ratings, animal stimuli were randomly assigned to one of three different conditions: Help Available (20 trials), No Help Available (8 trials), or Restudy (8 trials). There were a greater number of Help Available trials in order to ensure that we would have a sufficient number of trials to compare conditions during which participants elected to seek help compared with not seek help. During Help Available trials, participants had the option to ask for help in the form of a hint or an answer or to provide a response without asking for help. When participants chose help in the form of a hint, they were presented with the category icon and audio recording reminding them what kind of fact they learned (e.g., "You learned this animal eats . . ."). When participants chose help in the form of the answer, they were presented with the category icon and audio recording of the full fact (e.g., "You learned . . . penguins eat their food while swimming"). After help was presented, a text box appeared and participants were asked to type in their response. Participants could also decide not to seek help and provide an answer without selecting any help. During No Help Available trials, participants were asked to type their response and had no help option available. During Restudy trials, participants saw and heard the fact they learned without being asked to respond.

We ensured that all children were presented with facts the same number of times and were re-exposed to the full animal fact during the help phase. In the No Help Available condition, participants were always re-exposed to the full fact after providing their response. In the Help Available condition, participants were re-exposed to the full fact after providing a response when they did not seek help or sought help in the form of a hint. When help was sought in the form of the answer, participants were already re-exposed to the full fact through the help and therefore they simply moved on to the next trail after providing their response. In the Restudy condition, participants were simply re-exposed to

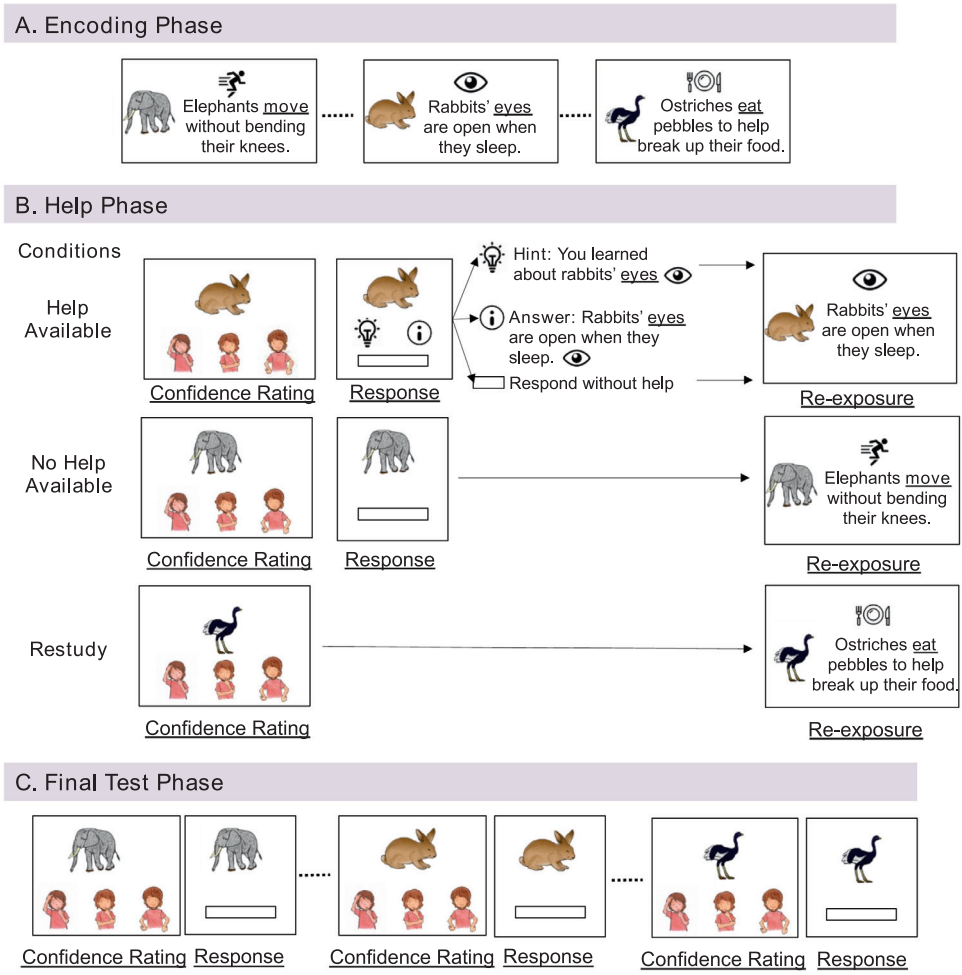

Fig. 1. Experimental task design. (A) During the encoding phase, participants were serially presented with animal facts across three categories (move, eyes, and eat). (B) During the help phase, participants completed a practice test during which they needed to recall the animal facts from the encoding phase. The help phase consisted of the Help Available condition (help could be sought in the form of a hint or an answer), the No Help Available condition (answer was provided in the absence of any help), and the Restudy condition (fact was simply presented). After providing a response in the Help Available and No Help Available conditions, participants would be exposed to the full fact again (except for trials during which help was sought in the form of an answer given that the full fact was already re-presented). (C) Approximately 24 hr later, participants completed a final memory test in the absence of help.

the full fact without requiring a response. Thus, this ensured that each fact was fully viewed twice throughout the task, once during the encoding phase and once during the help phase.

Immediately after the memory task, participants were administered the NIH Toolbox Picture Vocabulary Task. Researchers administered the task via iPad by holding the device up to the web camera and selecting picture choices based on participants' verbal responses (as instructed in the NIH Toolbox remote manual).

Session 2

Session 2 occurred ~24 hr after the first session. During Session 2, participants completed a final memory test (Fig. 1C). For the final memory test, participants were randomly presented images of each studied animal and were asked to answer what they learned about the animal in the absence of help. Before answering, participants were asked to report their confidence using a 3-point confidence scale. After the final test, participants completed a self-reported help-seeking questionnaire (see online supplementary material, analyses of this measure is included in the supplementary results section). Participants also completed additional cognitive tasks assessing individual differences in executive functioning that were used for exploratory analyses and are not reported.

Data processing

Response coding

A codebook was created to code free response answers as either accurate (1) or inaccurate (0) (see supplementary material). Two researchers independently coded blinded response data for accuracy and had an inter-rater reliability of κ = .80 (p < .001). On items where discrepancies occurred, researchers held discussions to come to an agreed-on final accuracy code for each response.

Main measures

Help-seeking proportions. The overall proportion of times help was sought was calculated as the number of times help was sought (hints + answers) divided by the total Help Available trials. The proportion of times hints were sought was calculated by dividing the number of times hints were sought by the total number of times help was sought (hints + answers).

Average confidence. Average confidence was calculated during the help phase and compared across conditions where children did not seek help versus sought help and when seeking hints versus answers.

Metacognitive score. Metacognitive scores measured the relation between metacognitive monitoring (i.e., confidence) and the metacognitive control (i.e., the decision to seek help). Individual differences in metacognitive scores were measured as a difference score in average confidence when help was not sought minus when help was sought during the help phase.

Average memory performance. Memory performance was calculated using average free recall accuracy (based on the response coding scheme described above) and compared across conditions for the final test phase (Help Available, No Help Available, and Restudy conditions) and the help phase (Help Available and No Help Available conditions; see supplementary results section in supplementary material).

Help-related memory benefit. Help-related memory benefits were measured as the difference in final test accuracy between the Help Available and No Help Available conditions.

Results

Preregistered analyses are reported as confirmatory. As stated in our preregistration, age was median split into younger (<10.73 years) and older (≥10.73 years) groups for ease of interpretation. These age groups are also consistent with known periods of developmental differences in metacognition, such that there is a marked change around 8 to 10 years in children's ability to use metacognition to guide decision-making compared with younger children (Hembacher & Ghetti, 2013; Selmeczy & Ghetti, 2019; Selmeczy, Kazemi, et al., 2021), but metacognitive monitoring also continues to improve beyond 10 years into early adolescence (Fandakova et al., 2017). However, we also confirmed that results replicated when treating age as continuous. Additional or post hoc analyses are reported as exploratory.

Preliminary analysis

Receptive vocabulary

Standardized receptive vocabulary scores had a mean of 107.19 (*SD* = 14.30), did not significantly differ across age groups (p = .61), and were significantly higher than the standardized population score of 100, $t(56)$ = 3.79, p < .001.Thus, our sample exhibited higher than average receptive vocabulary. Note that 12 children were missing scores due to limited ability to share iPads between researchers during COVID-19 restrictions.

Main analyses

Frequency of help-seeking

Exploratory analysis examined developmental differences in the overall proportion of times help was sought (including both hints and answers). Younger children (*M* = .42, *SD* = .25) sought significantly more help than older children (*M* = .27, *SD* = .17), $t(67)$ = 2.98, p = .004, p_{Bonf} = .008, Cohen's d = 0.72. However, this finding was no longer significant when controlling for memory performance (using help phase accuracy during No Help Available trials), p = .06, suggesting that younger children sought more help in part due to lower memory performance. Additional exploratory correlational analysis also demonstrated that children who had lower memory accuracy when no help was available during the help phase sought more help overall (r = −.41, p < .001, p_{Bonf} < .001). Thus, our task was appropriate in soliciting help-seeking behaviors, and the frequency of help-seeking was associated with children's memory ability in the absence of help. We also verified that children performed better when help was available versus not available during the help phase, demonstrating that children appropriately integrated sought help (see supplementary results section in supplementary material).

Critically, our research was interested in examining whether there were developmental differences in the types of help children sought (hints or answers), and therefore we examined the proportion of times children sought hints when seeking help. Proportion values higher than .50 indicate a preference toward hints, whereas values lower than .50 indicate a preference toward answers. Confirmatory analysis demonstrated that older children sought a significantly higher proportion of hints (*M* = .69, *SD* = .37) compared with younger children (*M* = 0.48, *SD* = .28), $t(66)$ = 2.66, p = .009, Cohen's d = 0.65, with older children favoring seeking hints and younger children seeking hints and answers similarly. This finding remained significant even when controlling for memory accuracy (using memory accuracy during No Help Available trials in the help phase; Fig. 1B), p = .03, suggesting that this developmental difference in types of help sought occurred even when accounting for differences in memory performance. Thus, overall, older children were more likely to seek help in the form of hints compared with younger children.

Confidence and help-seeking decision

We examined whether children used their confidence to guide their decision to seek help during the help phase of the task. A confirmatory analysis was conducted examining confidence during the Help Available condition using a 2 × 2 mixed analysis of variance (ANOVA) including a within-participant factor of help decision (help sought or help not sought) and a between-participant factor of age group (older or younger) (see Fig. 2). Results revealed a significant interaction between help decision and age group, $F(1, 66)$ = 7.38, p = .008, η_p^2 = .10. Both age groups had similar and low confidence when electing to seek help (younger: *M* = 1.38, *SD* = 0.31; older: *M* = 1.37, *SD* = 0.37), p = .90, p_{Bonf} = 1.00, Cohen's d = 0.03. When electing not to seek help, older children (*M* = 2.72, *SD* = 0.27) had significantly higher confidence compared with younger children (*M* = 2.49, *SD* = 0.43), p = .008, p_{Bonf} = .02, Cohen's d = 0.66. This interaction remained significant when including memory accuracy during No Help Available trials in the help phase as a covariate, $F(1, 66)$ = 5.49, p = .02, η_p^2 = .08, suggesting that individual differences in memory accuracy did not account for this age-related difference. Additional preregistered analyses also confirmed that children had higher confidence for correct versus incorrect answers when no help was available during the help phase (see supplementary results). Overall, these results suggest that children appropriately sought help when experiencing low confi-

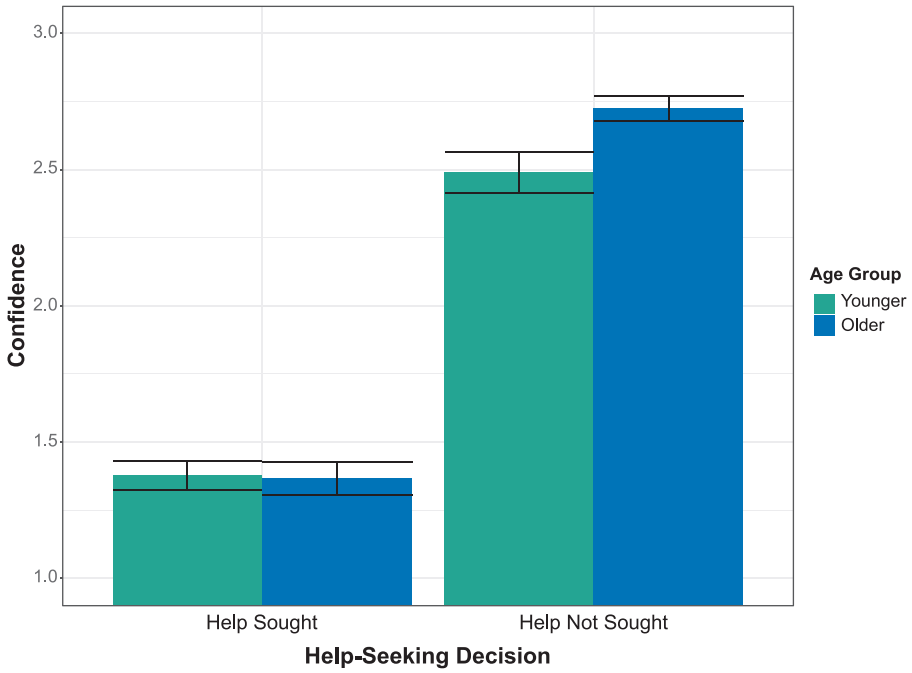

Fig. 2. Confidence as a function of help-seeking decision and age group. Confidence was measured during the help phase as a function of the decision to seek help (help sought or help not sought) and age group (younger or older children). Error bars represent ±1 standard error around the mean.

dence and did not seek help when experiencing high confidence. However, older children were more efficient in using their confidence to guide their help-seeking decisions, such that they were more confident when electing not to seek help compared with younger children.

Exploratory analysis examined whether confidence differed as a function of help type (answers or hints). Because some children always sought one help type, we conducted a multilevel trial-level regression to avoid case-wise deletions. We predicted confidence using random effects of participant and fixed effects of help type (0 = answer, 1 = hint), age group (0 = younger, 1 = older), and their interaction. Results revealed a significant main effect of help type, $b = .31$, $p \leq .001$, 95% confidence interval (CI) [.18, .43], such that confidence was lower when children sought answers compared with hints. No other effects were significant ($ps > .43$). Thus, children used confidence to guide what type of help they sought and were more likely to seek answers when less confident.

Final test memory performance

Confirmatory analysis was used to examine final test accuracy using a 3 × 2 mixed ANOVA including a within-participant factor of help phase condition (Help Available, No Help Available, or Restudy) and a between-participant factor of age group (older or younger) (see Fig. 3). Results revealed a main effect of age group, $F(1, 67) = 8.62$, $p = .005$, $\eta_p^2 = .11$, such that older children ($M = .70$, $SD = .22$) performed better than younger children ($M = .58$, $SD = .22$). The main effect of condition was also significant, $F(2, 134) = 5.49$, $p = .005$, $\eta_p^2 = .08$, such that performance was significantly higher during the Help Available condition ($M = .67$, $SD = .19$), $p < .001$, $p_{Bonf} < .001$, Cohen's $d = 0.46$, and the No Help Available condition ($M = .66$, $SD = .25$), $p = .04$, $p_{Bonf} = .13$, Cohen's $d = 0.25$, compared with the Restudy condition ($M = .59$, $SD = .24$). The Help Available and No Help Available conditions did not significantly differ from each other, $p = .52$, $p_{Bonf} = 1.00$. The interaction between age group and condition was not significant ($p > .64$). Consistent with our predictions, children performed better during the final test under conditions where earlier retrieval practice occurred (Help Available and No Help Available)

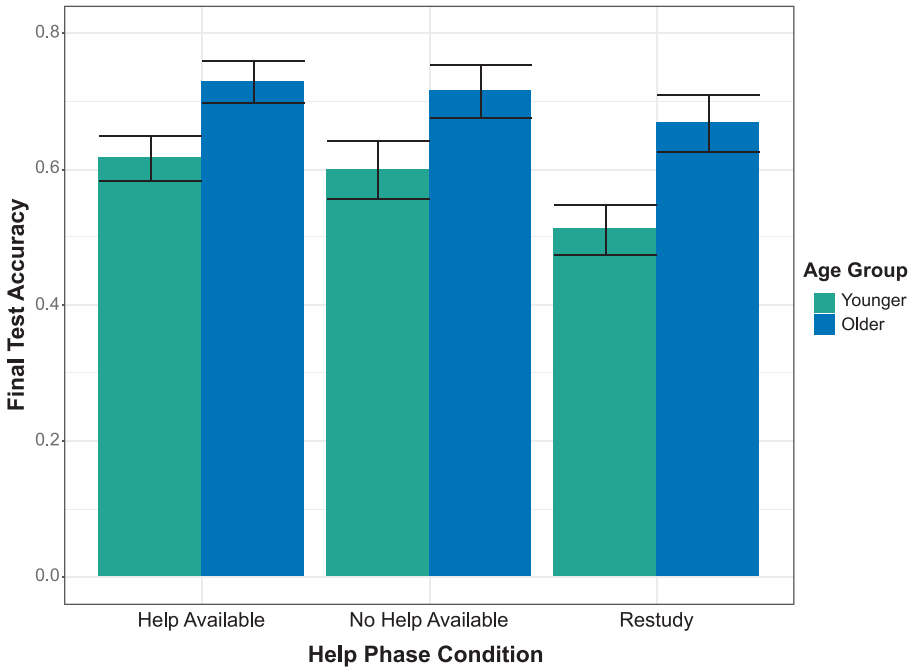

Fig. 3. Final test accuracy as a function of help phase condition and age group. Final test accuracy was measured as a function of help phase condition (Help Available, No Help Available, or Restudy) and age group (younger or older children). Error bars represent ±1 standard error around the mean.

compared with the Restudy condition. However, in contrast to our predictions, children performed similarly when earlier help was available versus not available, and this pattern was similar across age groups. Thus, having the option to actively seek help did not improve retention to a greater extent than the benefit of retrieval practice in the absence of help.

Confirmatory analyses also examined whether final test performance was greater under conditions where help was previously sought in the form of a hint compared with an answer. Using a multilevel trial-wise logistic regression analysis, we predicted final test accuracy using random effects of participant and fixed effects of help type (0 = answer, 1 = hint), age group (0 = younger, 1 = older), and their interaction. No significant effects emerged ($ps > .14$), suggesting that final test accuracy did not differ as a function of whether children elected to seek hints compared with answers during the help phase.

Individual differences in help-related memory benefit and metacognitive scores

Although children on average did not benefit on the final test from having earlier help available compared with no help available, we examined whether individual differences in this benefit may be associated with metacognition. That is, we predicted that children with higher metacognitive ability (measured as the difference in confidence when electing to not seek help vs. seek help during the help phase) would also be more likely to benefit from earlier available help on the final test (measured as the difference in final test accuracy between the Help Available and No Help Available conditions). To examine this, we conducted a confirmatory regression analysis predicting the benefit from available help (Help Available minus No Help Available final test accuracy) using main effects of age group (0 = younger, 1 = older), metacognitive score (help not sought minus help sought help phase confidence), and their interaction. Results revealed a significant interaction between age group and metacognitive score, $b = .33$, $p = .02$, $p_{Bonf} = .06$, 95% CI [.05, .61], such that the relation between the benefit from available help and metacognitive scores was significantly positive in older children ($r = .55$, $p < .001$) but not in younger children ($r = -.08$, $p = .65$) (see Fig. 4). This interaction did not

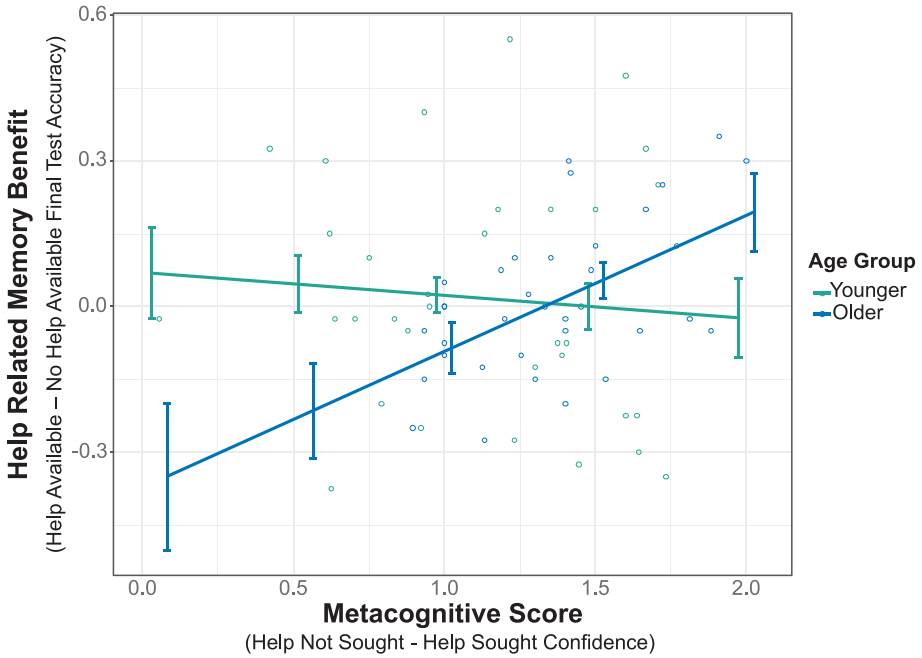

Fig. 4. Relation between the help-related memory benefit and metacognitive scores as a function of age group. Help-related memory benefits were measured as the difference in final test accuracy between the Help Available and No Help Available conditions. Metacognitive scores were measured as the relation between monitoring and control and were calculated as the difference in confidence when electing to not seek help versus seek help during the help phase. Points represent individual data. Lines represent estimates from the regression model. Error bars represent 95% confidence interval around the mean.

emerge when examining metacognition as the difference in confidence for correct versus incorrect answers when help was not available during the help phase (i.e., metacognitive monitoring only; see supplementary results). In addition, this interaction also did not emerge when predicting the benefits of retrieval practice only (i.e., difference between final test performance for the No Help Available and Restudy conditions) (see supplementary results). Thus, the benefit of earlier help-seeking for memory retention was related to older (but not younger) children's ability to appropriately use confidence as a basis to seek help.

Discussion

Adaptively asking for help is a critical skill that children must develop to maximize their learning and requires determining when to ask for help, what type of help to ask for, and how to integrate help (Karabenick, 2003; Nelson-Le Gall, 1981). However, we have a limited understanding of the mechanisms that support help-seeking during childhood and how the opportunity to seek help compares with other types of learning conditions. In the current study, we investigated 8- to 13-year-olds' help-seeking behaviors during an online science fact learning paradigm and the role of metacognition in this process. In addition, we compared children's long-term retention of facts when help was available with conditions where help was not available or information was simply restudied. Overall, our results revealed key findings regarding the benefit and development of help-seeking.

Children engaged in several adaptive help-seeking behaviors. Children who had lower memory performance asked for more help, suggesting that children's level of knowledge plays a role in the frequency of help-seeking. This finding is consistent with previous research demonstrating that children with lower domain knowledge are more likely to seek task-based help during problem-solving and

vocabulary tasks (Nelson-Le Gall, 1987; Newman & Schwager, 1995). Furthermore, older children were more likely to ask for hints compared with answers, suggesting that older children were better at seeking help that is considered more beneficial for learning (i.e., instrumental help), replicating previous research using other cognitive tasks (Nelson-Le Gall et al., 1990). Although seeking hints is often considered more adaptive for long-term learning, there are several social, motivational, and cognitive factors that can influence help-seeking behaviors (Karabenick & Berger, 2013). For example, older children may have enjoyed receiving hints more than younger children or may have potentially considered seeing the answer as a form of cheating. Future research should examine what social and motivational factors may influence help-seeking behaviors above and beyond cognitive variables such as confidence. Furthermore, we did not observe a significant difference on final test performance as a function of help type, suggesting that seeking hints in our current task did not correlate with better long-term retention than seeking answers.

There are several reasons that may contribute to why we did not observe improved retention when seeking hints compared to answers. First, we chose to use hints in the form of category cues given previous research demonstrating that category cues can increase memory performance in children (Kee & Bell, 1981; Kobasigawa, 1974). However, previous research often used semantic category cues (e.g., providing the cue word *fruit* when studying words such as *banana, apple,* and *grapes*), whereas our study used ad hoc cue categories for complex facts. As a result, the category cues used in our study may have been less effective. Critically, in the current study we could only examine the correlation between help type and memory retention because participants could choose what type of help they sought. Follow-up studies could increase the potential effectiveness of hints (e.g., categorical hints with stronger semantic associations) and randomly assign different types of help to determine their causal effects on learning. Future research could also further vary the levels of support provided by help (e.g., providing a hint, the first half of the answer, or the answer) to further investigate what level of help is most beneficial. In addition, all trials required an initial confidence assessment. Thus, this encouraged children to engage in a retrieval attempt prior to electing to seek help, and there may be little additional benefit of encouraging another immediate retrieval attempt with hints. Indeed, previous research demonstrates that engaging in metacognitive judgments improves memory performance in children (Zhao et al., 2022), and future research should directly compare whether the benefit of retrieval-enhanced learning is greater than engaging in metacognitive assessments.

Children were also effective at using metacognition to guide their decision to seek help. Across age groups, children reported lower confidence when they elected to seek help versus not seek help and when seeking help in the form of answers compared with hints. These results suggest that children use metacognitive monitoring to guide when to seek help and what type of help to seek. Critically, we also observed developmental improvements, such that older children were more confident when they elected not to seek help compared with younger children. These results suggest that with age children become more efficient at using confidence as a basis for their decision to seek help and are more confident when they elect not to seek help. Overall, these results are consistent with research suggesting that developmental improvements in help-seeking continue into middle childhood (Nelson-Le Gall et al., 1990).

Importantly, we observed that older children's ability to use confidence as a basis for when to seek help correlated with how much they benefitted from active help-seeking during the final test. That is, older children who were more likely to selectively seek help based on their confidence were the most likely to experience learning gains from help. In contrast, this relation was not observed in younger children, which suggests that younger children's less efficient use of confidence to elect when to seek help also limited individual differences in help-related learning gains. These results highlight the importance of metacognitive development, specifically the relation between monitoring and control, as a factor in children's ability to benefit from self-regulated learning strategies. Future research can further investigate the direct role of metacognition in active learning by experimentally increasing metacognition (e.g., through feedback; van Loon & Roebers, 2020) and examining whether improvements in self-regulated learning are also observed.

When comparing different learning conditions, results revealed that children's retention was higher during conditions where retrieval practice occurred (Help Available and No Help Available conditions) compared with restudying information (Restudy condition). The existing literature is mixed

on whether adults and older children benefit more from retrieval practice compared with younger children (Fazio & Marsh, 2019). In our current task, we did not observe any age-related differences in the benefit of retrieval practice, consistent with research suggesting that retrieval practice benefits may occur automatically and be less affected by developmental differences in explicit strategy use (Fritz et al., 2006). In addition, we did not observe higher retention when help was available versus unavailable. Instead, as described previously, we observed that the ability to improve from available help was related to individual differences in metacognitive ability in older children. Taken together, these results suggest that retrieval practice is effective at increasing memory retention in children, but the ability to also benefit from available help is related to individual differences in metacognitively guided help-seeking.

There are several areas of limitations in the current research. Although we statistically controlled for developmental differences in memory accuracy in our analyses, there was a significant overall increase in memory performance between our younger and older age groups. Critically, relatively high final test accuracy, especially apparent in older children, may have limited our ability to observe large benefits of retrieval-enhanced learning and the opportunity to seek help. Previous research suggests that level of task difficulty may play an important role in retrieval-enhanced learning, such that the magnitude of the testing effect may be larger during more difficult tests (Pyc & Rawson, 2009; Rowland, 2014). Thus, future research would benefit from lowering and matching memory accuracy across age groups through experimental methods (e.g., increasing or decreasing encoding time) to disentangle the role of age and memory-related improvements in active and retrieval-enhanced learning as well as the relation between metacognitive monitoring and control. Our current study also examined memory retention across a relatively short delay period (∼24 hr). Future research would benefit from longer delays between study and testing conditions that are more representative of academic contexts.

In conclusion, our research demonstrates that children engage in adaptive help-seeking during early and middle childhood when learning science information. However, children's help-seeking abilities improve, such that older children are more likely to seek instrumental help and use metacognitive monitoring to guide when they should or should not seek help compared with younger children. Furthermore, only older children with high metacognitive skills experienced memory benefits from active help-seeking decisions. These results suggest that researchers and educators should consider metacognitive development in children's ability to appropriately seek and benefit from help-seeking during learning.

Data availability

Registration and data are available at Open Science Framework: https://osf.io/3d9tx/.

Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.jecp.2023.105772.

References

Coughlin, C., Hembacher, E., Lyons, K. E., & Ghetti, S. (2014). Introspection on uncertainty and judicious help-seeking during the preschool years. *Developmental Science, 18*(6), 957–971. https://doi.org/10.1111/desc.12271.

Cycowicz, Y. M., Friedman, D., Snodgrass, J. G., & Duff, M. (2001). Recognition and source memory for pictures in children and adults. *Neuropsychologia, 39*(3), 255–267. https://doi.org/10.1016/s0028-3932(00)00108-1.

Fandakova, Y., Selmeczy, D., Leckey, S., Grimm, K. J., Wendelken, C., Bunge, S. A., & Ghetti, S. (2017). Changes in ventromedial prefrontal and insular cortex support the development of metamemory from childhood into adolescence. *Proceedings of the National Academy of Sciences of the United States of America, 114*(29), 7582–7587. https://doi.org/10.1073/pnas.1703079114.

Fazio, L. K., & Marsh, E. J. (2019). Retrieval-based learning in children. *Current Directions in Psychological Science, 28*(2), 111–116. https://doi.org/10.1177/0963721418806673.

Fisher, M., & Oppenheimer, D. M. (2021). Harder than you think: How outside assistance leads to overconfidence. *Psychological Science, 32*(4), 598–610. https://doi.org/10.1177/0956797620975779.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America, 111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111.
Fritz, C. O., Morris, P. E., Nolan, D., & Singleton, J. (2006). Expanding retrieval practice: An effective aid to preschool children's learning. *Quarterly Journal of Experimental Psychology, 60*(7), 991–1004. https://doi.org/10.1080/17470210600823595.
Geurten, M., Meulemans, T., & Lemaire, P. (2018). From domain-specific to domain-general? The developmental path of metacognition for strategy selection. *Cognitive Development, 48*, 62–81. https://doi.org/10.1016/j.cogdev.2018.08.002.
Ghetti, S., Hembacher, E., & Coughlin, C. A. (2013). Feeling uncertain and acting on it during the preschool years: A metacognitive approach. *Child Development Perspectives, 7*(3), 160–165. https://doi.org/10.1111/cdep.12035.
Hembacher, E., & Ghetti, S. (2013). How to bet on a memory: Developmental linkages between subjective recollection and decision making. *Journal of Experimental Child Psychology, 115*(3), 436–452. https://doi.org/10.1016/j.jecp.2013.03.010.
Hembacher, E., & Ghetti, S. (2014). Don't look at my answer: Subjective uncertainty underlies preschoolers' exclusion of their least accurate memories. *Psychological Science, 25*(9), 1768–1776. https://doi.org/10.1177/0956797614542273.
Karabenick, S. A. (2003). Seeking help in large college classes: A person-centered approach. *Contemporary Educational Psychology, 28*(1), 37–58. https://doi.org/10.1016/s0361-476x(02)00012-7.
Karabenick, S. A., & Berger, J.-L. (2013). Help seeking as a self-regulated learning strategy. In H. Bembenutty, T. J. Cleary, & A. Kitsantas (Eds.), *Applications of self-regulated learning across diverse disciplines: A tribute to Barry J. Zimmerman* (pp. 237–261). Information Age Publishing.
Karabenick, S. A., & Gonida, E. N. (2017). Academic help seeking as a self-regulated learning strategy. In P. Alexander, D. Schunk, & J. Greene (Eds.), *Handbook of self-regulation of learning and performance* (pp. 421–433). Routledge.
Karpicke, J. D., & Roediger, H. L. (2008). The critical importance of retrieval for learning. *Science, 319*(5865), 966–968. https://doi.org/10.1126/science.1152408.
Kee, D. W., & Bell, T. S. (1981). The development of organizational strategies in the storage and retrieval of categorical items in free-recall learning. *Child Development, 52*(4), 1163–1171. https://doi.org/10.2307/1129502.
Kobasigawa, A. (1974). Utilization of retrieval cues by children in recall. *Child Development, 45*(1), 127–134. https://doi.org/10.2307/1127758.
Lehman, M., Smith, M. A., & Karpicke, J. D. (2014). Toward an episodic context account of retrieval-based learning: Dissociating retrieval practice and elaboration. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*(6), 1787–1794. https://doi.org/10.1037/xlm0000012.
Lombardi, D., Shipley, T. F., Astronomy Team Biology Team Chemistry Team Engineering Team Geography Team Geoscience Team & Physics Team (2021). The curious construct of active learning. *Psychological Science in the Public Interest, 22*(1), 8–43. https://doi.org/10.1177/1529100620973974.
Markant, D. B., Ruggeri, A., Gureckis, T. M., & Xu, F. (2016). Enhanced memory as a common effect of active learning. *Mind, Brain, and Education, 10*(3), 142–152. https://doi.org/10.1111/mbe.12117.
Metcalfe, J., & Finn, B. (2013). Metacognition and control of study choice in children. *Metacognition and Learning, 8*(1), 19–46. https://doi.org/10.1007/s11409-013-9094-7.
Nelson, L. J., & Fyfe, E. R. (2019). Metacognitive monitoring and help-seeking decisions on mathematical equivalence problems. *Metacognition and Learning, 14*(2), 167–187. https://doi.org/10.1007/s11409-019-09203-w.
Bower, G. (1990). *Metamemory: A theoretical framework and new findings* (Vol. 26). Academic Press.
Nelson-Le Gall, S. (1981). Help-seeking: An understudied problem-solving skill in children. *Developmental Review, 1*(3), 224–246. https://doi.org/10.1016/0273-2297(81)90019-8.
Nelson-Le Gall, S. (1987). Necessary and unnecessary help-seeking in children. *Journal of Genetic Psychology, 148*(1), 53–62. https://doi.org/10.1080/00221325.1987.9914536.
Nelson-Le Gall, S., & Jones, E. (1990). Cognitive–motivational influences on the task-related help-seeking behavior of black children. *Child Development, 61*(2), 581–589. https://doi.org/10.1111/j.1467-8624.1990.tb02802.x.
Nelson-Le Gall, S., Kratzer, L., Jones, E., & DeCooke, P. (1990). Children's self-assessment of performance and task-related help seeking. *Journal of Experimental Child Psychology, 49*(2), 245–263. https://doi.org/10.1016/0022-0965(90)90057-f.
Newman, R. S., & Schwager, M. T. (1995). Students' help seeking during problem solving: Effects of grade, goal, and prior achievement. *American Educational Research Journal, 32*(2), 352–376. https://doi.org/10.3102/00028312032002352.
Puustinen, M. (1998). Help-seeking behavior in a problem-solving situation: Development of self-regulation. *European Journal of Psychology of Education, 13*(2), 271–282. https://doi.org/10.1007/bf03173093.
Pyc, M. A., & Rawson, K. A. (2009). Testing the retrieval effort hypothesis: Does greater difficulty correctly recalling information lead to higher levels of memory? *Journal of Memory and Language, 60*(4), 437–447. https://doi.org/10.1016/j.jml.2009.01.004.
R Core Team (2022). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing.
Roediger, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science, 17*(3), 249–255. https://doi.org/10.1111/j.1467-9280.2006.01693.x.
Roll, I., Aleven, V., McLaren, B. M., & Koedinger, K. R. (2011). Improving students' help-seeking skills using metacognitive feedback in an intelligent tutoring system. *Learning and Instruction, 21*(2), 267–280. https://doi.org/10.1016/j.learninstruc.2010.07.004.
Roll, I., Baker, R. S. J. D., Aleven, V., & Koedinger, K. R. (2014). On the benefits of seeking (and avoiding) help in online problem-solving environments. *Journal of the Learning Sciences, 23*(4), 537–560. https://doi.org/10.1080/10508406.2014.883977.
Rowland, C. A. (2014). The effect of testing versus restudy on retention: A meta-analytic review of the testing effect. *Psychological Bulletin, 140*(6), 1432–1463. https://doi.org/10.1037/a0037559.
Ruggeri, A., Markant, D. B., Gureckis, T. M., Bretzke, M., & Xu, F. (2019). Memory enhancements from active control of learning emerge across development. *Cognition, 186*, 82–94. https://doi.org/10.1016/j.cognition.2019.01.010.
Ryan, A. M., & Shim, S. S. (2012). Changes in help seeking from peers during early adolescence: Associations with changes in achievement and perceptions of teachers. *Journal of Educational Psychology, 104*(4), 1122–1134. https://doi.org/10.1037/a0027696.

Ryan, A. M., & Shin, H. (2011). Help-seeking tendencies during early adolescence: An examination of motivational correlates and consequences for achievement. *Learning and Instruction, 21*(2), 247–256. https://doi.org/10.1016/j.learninstruc.2010.07.003.
Schneider, W. (2015). *Memory development from early childhood through emerging adulthood.* Springer International. https://doi.org/10.1007/978-3-319-09611-7.
Schneider, W., Kron, V., Hünnerkopf, M., & Krajewski, K. (2004). The development of young children's memory strategies: First findings from the Würzburg Longitudinal Memory Study. *Journal of Experimental Child Psychology, 88*(2), 193–209. https://doi.org/10.1016/j.jecp.2004.02.004.
Selmeczy, D., & Ghetti, S. (2019). Here is a hint! How children integrate reliable recommendations in their memory decisions. *Journal of Experimental Child Psychology, 177*, 222–239. https://doi.org/10.1016/j.jecp.2018.08.004.
Selmeczy, D., Ghetti, S., Zheng, L. R., Porter, T., & Trzesniewski, K. (2021). Help me understand: Adaptive information-seeking predicts academic achievement in school-aged children. *Cognitive Development, 59*. https://doi.org/10.1016/j.cogdev.2021.101062 101062.
Selmeczy, D., Kazemi, A., & Ghetti, S. (2021). Developmental differences in subjective recollection and its role in decision making. *Child Development, 92*(6), e1308–e1325. https://doi.org/10.1111/cdev.13611.
van Loon, M. H., & Roebers, C. M. (2020). Using feedback to improve monitoring judgment accuracy in kindergarten children. *Early Childhood Research Quarterly, 53*, 301–313. https://doi.org/10.1016/j.ecresq.2020.05.007.
Vaughn, K. E., & Kornell, N. (2019). How to activate students' natural desire to test themselves. *Cognitive Research: Principles and Implications, 4*(1), Article 35. https://doi.org/10.1186/s41235-019-0187-y.
Vo, V. A., Li, R., Kornell, N., Pouget, A., & Cantlon, J. F. (2014). Young children bet on their numerical skills: Metacognition in the numerical domain. *Psychological Science, 25*(9), 1712–1721. https://doi.org/10.1177/0956797614538458.
Winstone, N. E., Nash, R. A., Parker, M., & Rowntree, J. (2016). Supporting learners' agentic engagement with feedback: A systematic review and a taxonomy of recipience processes. *Educational Psychologist, 52*(1), 1–21. https://doi.org/10.1080/00461520.2016.1207538.
Zhao, W., Li, B., Shanks, D. R., Zhao, W., Zheng, J., Hu, X., ... Yang, C. (2022). When judging what you know changes what you really know: Soliciting metamemory judgments reactively enhances children's learning. *Child Development, 93*(2), 405–417. https://doi.org/10.1111/cdev.13689.