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Metamemory and Cognitive Aging

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Summary and Keywords

Metamemory is defined as cognitions about memory and related processes. Related terms in the literature include metacognition, self-evaluation, memory self-efficacy, executive function, self-regulation, cognitive control, and strategic behavior. Metamemory is a multidimensional construct that includes knowledge about how memory works, beliefs about memory (including beliefs about one's own memory such as memory self-efficacy), monitoring of memory and related processes and products, and metacognitive control, in which adaptive changes in processing approaches and strategies may be contemplated if monitoring of memory processes (encoding, retention, retrieval) indicates that alternative strategies may be required. Older adults generally believe that their memory has declined and that, on average, they have less control over memory and lower memory self-efficacy than young and middle-aged adults. Many but not all aspects of online memory monitoring are well preserved in old age, such as the ability to discriminate between information that has been learned versus not learned. A major exception concerns confidence judgments concerning whether recognition memory decisions are correct; older adults are more prone to high-confidence memory errors, believing they are recognizing something they have not encountered previously. The evidence regarding metacognitive control is more mixed, with some hints that older adults do not use monitoring to adjust control behaviors (e.g., devoting more time and effort to studying items they believe have not yet been well-learned). However, any age deficits in self-regulation based on memory monitoring or adaptive strategy use can probably be addressed through instructions, practice, or training. In general, older adults seem capable of exerting metacognitive control in memory studies, although they may not necessarily do so without explicit support or prompting.

Keywords: metamemory, cognition, goal-directed action, monitoring, metacognitive control

Definition: Metamemory as a Concept

Metamemory is a multifaceted psychological construct that is used to understand how people regulate their own cognition and goal-directed action in service of creating and accessing information held in memory (Dunlosky & Metcalfe, 2009; Hertzog & Hultsch, 2000; Nelson, 1996; Tarricone, 2011). There is a wide array of phenomena that fall under this term. For instance, when searching semantic memory for "facts" (declarative knowledge), one could wonder: Do I know that information? Is the information that comes to mind "accurate"—is it what I was looking for? A different metamemory concept is knowledge about learning strategies; what types of approaches for learning "work for me" in situations like the one I am now experiencing? Yet another different concept is whether I am likely to be successful in remembering information; am I good at remembering recently acquired information, such as the name of someone I meet?

One domain of metamemory concerns knowing about knowing: that is, knowledge about how the mind operates, its processes, states, and products. Metamemory knowledge includes strategies for regulating learning, remembering, and problem solving. Early treatments of metamemory in developmental psychology emphasized how accurate knowledge could guide learning of new information (e.g., Flavell, 1979; Perlmutter, 1978).

Another facet of metamemory is beliefs about one's own memory, including beliefs about efficacy or capacity and personal control over memory. Early research about metamemory in adulthood and old age emphasized the importance of considering beliefs people had about themselves and their ability to remember, including memory self-efficacy, perceived control over memory, and related constructs (e.g., Berry, 1999; Miller & Lachman, 1999) and how accurate these beliefs are in capturing individual differences in memory (Beaudoin & Desrichard, 2011; Hertzog & Pearman, 2014).

Cognitive psychologists studying metamemory have emphasized the mechanisms of monitoring memory and memory-related processes and how such monitoring can lead to effective self-regulation of learning and remembering (Nelson, 1996; Nelson & Narens, 1990). The core idea is that accurate monitoring of current cognitive states and processes can lead to better adaptation of strategies to achieve higher levels of learning and memory performance. Recently, cognitive perspectives have had increasing influence on research evaluating development of metamemory across the lifespan, including old age (Hertzog & Shing, 2011). Often, control over memory is achieved through the implementation of strategies for encoding and retrieval.

Metamemory Beliefs and Knowledge

Early developmental research established that children between the ages of 6 and 10 show remarkable growth in their understanding of cognition and how it functions and that this knowledge translates into more effective use of strategies for learning and remembering (Schneider & Pressley, 2013). In the 1980s, scientists developed questionnaires that enabled investigations into what adults of different ages believe to be true about their memories (e.g., Crook & Larrabee, 1990; Dixon, Hultsch, & Hertzog, 1988; Gilewski, Zelinski, & Schaie, 1990). Dixon and colleagues'

Metamemory in Adulthood (MIA) instrument contains scales that assess knowledge about memory (MIA Task) and use of strategies to support memory in everyday life (MIA Strategy). Research with the MIA in the United States and other countries shows that older adults are as knowledgeable about basic features of memory and memory effects as younger adults (Hertzog & Hultsch, 2000).

An important issue for metamemory research is whether older adults possess knowledge about strategies that benefit memory and whether they use that knowledge to guide spontaneous strategy use (Dunlosky & Hertzog, 2000; Hertzog & Dunlosky, 2004; Hertzog & Dunlosky, 2006). Creating new associations (e.g., learning the new phone number of a friend) often benefits from using strategies designed to mediate the association. Strategies can vary from mere repetition of the associated information to more difficult but effective ones, such as the use of interactive imagery (Kausler, 1994; Richardson, 1998). For example, if presented with the word pair SPIDER-CHAIR, one might visualize an image of a spider weaving a web between the legs in a chair. Earlier work in the 20th century indicated that older adults were less likely to spontaneously produce imagery and linguistic mediators (Kausler, 1994), although the age difference seems to be narrowing in recent historical time (e.g., Dunlosky & Hertzog, 2001). Current cohorts of older adults may be more knowledgeable about the benefits of such strategies and emphasize the importance of mediator generation and retrieval without instruction or prompting.

Hertzog and colleagues studied acquisition of knowledge about strategy effectiveness in such tasks. Typically, older adults and younger adults are instructed to use an effective associative encoding procedure (interactive imagery) as well as an ineffective procedure (simple repetition) to learn verbal paired associates. Both age groups learn that imagery is the more effective strategy, as reflected in changes in strategy effectiveness ratings before and after task experience. However, older adults do not show the same degree of quantitative separation of effectiveness ratings before and after task experience as young adults (Price, Hertzog, & Dunlosky, 2010), and they are not as likely to shift to self-chosen use of the interactive imagery strategy after structured strategy experience in an associative learning task (Hertzog, Price, & Dunlosky, 2012). Older adults may also be less likely to adopt effortful strategies in other tasks, such as the keyword mnemonic for learning new vocabulary words (Brigham & Pressley, 1988). The reasons that older adults may avoid using strategies they know could be effective are at present unclear. Nevertheless, knowledge of the strategy's existence is certainly not equivalent to having confidence that one has mastered the strategy or personally can benefit from using it.

Beliefs About Self as Rememberer

Questionnaire results indicate that older adults report lower levels of self-assessed memory ability (e.g., the MIA Capacity scale) and control over memory (e.g., the MIA Locus scale). Similar findings have emerged from other questionnaires. There is explicit evidence for convergent validity of measures of memory ability and memory concerns across different questionnaires (e.g., Hertzog, Hultsch, & Dixon, 1989; Jopp & Hertzog, 2007).

Bandura's theory of self-efficacy and control has been evoked to interpret findings on self-rated memory and has inspired task-specific measures of memory self-efficacy (Berry et al., 1989). These measures ask people to predict and rate performance in a particular task: for example, "How confident are you that you can recall 10 words from this 30-word list?" Questionnaire measures of perceived memory ability are related to but are not the same as task-specific predictions (Hertzog, Dixon, & Hultsch, 1990). Low memory self-efficacy, or low perceived control over memory, correlates with a number of phenomena, including reduced use of encoding strategies (Berry 1999; Hertzog, McGuire, & Lineweaver, 1998; Lachman, 2006; West & Hastings, 2011), avoidance of relying on memory in cognitive tasks (Frank, Touron, & Hertzog, 2013; Hertzog & Touron, 2011), unrealistic and ineffective goal setting and demoralization after goal-pursuit failure (West, Thorn, & Bagwell, 2003), and increased risk for stereotype threat (Hess et al., 2003).

There is ample evidence that memory self-assessments can be inaccurate, including both false overconfidence and underconfidence. Memory self-ratings typically have small, positive correlations with performance on memory tasks (Crumley, Stetler, & Horhota, 2014; Hertzog & Pearman, 2014). Some of the effect may be due to unrealistic task appraisals or expectations—prediction accuracy increases after people perform the task for the first time (Hertzog, Dixon, & Hultsch, 1990). Furthermore, memory self-assessments may not predict memory in the everyday ecology, even when they do predict standard memory tasks (e.g., Hertzog, Park, Morrell, & Martin, 2000; West, 1988). Memory training interventions for older adults often include a component on restructuring negative beliefs (e.g., pessimism) about one's own memory ability, including low memory self-efficacy (Stigsdottir-Neely, 2000; West, Bagwell, & Dark-Freudeman, 2008). Belief restructuring appears to be important for encouraging older adults to benefit from mnemonics training.

Memory Stereotypes About Aging

People believe that memory declines in old age (see Hummert, 2011, for a review). Older adults are at risk for experiencing performance-degrading stereotype threat during memory assessments (Barber & Mather, 2014). Low memory self-efficacy has been linked to negative stereotypes about aging and memory in general (e.g., Lineweaver & Hertzog, 1998; Lineweaver et al., 2009). However, explicit memory self-efficacy beliefs may have less effect on cognitive performance than implicitly activated age-stereotypes about memory (Levy, 1996, 2009). The relationship of negative memory stereotypes to older adults' memory performance is both subtle and complex. For instance, older adults motivated by avoiding possible losses may be more vulnerable to stereotype threat effects, perhaps due to anxiety about possible failure, than older adults with more positive approach-based motivations (Barber, 2017).

Metacognitive Monitoring

Metacognitive monitoring refers to the online assessment of states of the cognitive system. A major question is the extent to which cognitive systems are penetrable by attempts to attend to their current states and status. For instance, Storm and Hickman (2015) showed that people are unaware of the process by which solutions to compound remote associate problems are generated (e.g., what is the word that has a strong association with the following three items: cream, frost, tea).[1] People arrive at problem solutions via a process largely inaccessible to awareness. This also seems to be a general feature of monitoring of memory processes. One has no direct access to the contents of memory; instead, monitoring is limited to sampling indirect cues about what is accessible in memory by observing input processes (e.g., how items were studied) and evaluating what they can retrieve from memory (e.g., Koriat, 1995, 1997, 2000). Memory monitoring can be based on accessing multiple available cues, including feelings of familiarity or "intuitions," in addition to more tangible phenomena, such as the fluency of retrieval or the experience of explicit recollection of evidence (Metcalfe, 2000). Indirect rather than direct access can be regarded as a consequence of a modular mind (e.g., Fodor, 1983), with a central nervous system that has evolved to enable complex control over physical and mental operations by processing ensembles that can operate, to varying degrees, automatically and autonomously of the central executive (Shallice & Burgess, 1991) and the experienced self.

What empirical methods can be used to assess memory monitoring? Metamemory researchers typically ask people to make explicit judgments, often framed as subjective confidence, about current states or the likelihood of future outcomes (e.g., Castel, 2008). The judgments can then be used to determine how the nature of the task and its stimuli influence judgments, or how accurate the judgments are in forecasting future memory outcomes. Explicit judgments enable reliance on verifiable empirical phenomena rather than relying on introspections that may not correspond to monitoring processes (Nelson, 1996). A desirable constraint on the invention of such judgments is that they bear some correspondence to metacognitive monitoring that may actually occur when people are engaged in learning and remembering.

Types of Metamemory Judgments

Metamemory research has focused on a limited number of judgments thought to correspond to possible monitoring processes (Dunlosky & Metcalfe, 2009; Nelson & Narens, 1990). Ease of learning (EOL) judgments involve pre-study assessments of how difficult it will be to learn new information before it has been studied. Judgments of learning (JOLs) inquire about how well information has been learned after it has been studied. Feeling of knowing (FOK) judgments ask people to evaluate whether they will recognize information that they just attempted (perhaps unsuccessfully) to recall. Retrospective confidence judgments (RCJs) ask individuals to assess the accuracy of information that comes to mind after a retrieval search generates candidate answers (e.g., is my recognition memory decision correct or incorrect?). Many other judgments could be and have been constructed (e.g., McCabe & Soderstrom, 2011). One caveat is that an experimenter-invented judgment may not correspond to the monitoring requirements in a task environment or to the spontaneous monitoring behavior of individuals. Nevertheless, the foundational premise is that the empirical behavior of metacognitive judgments reveals insights about how monitoring can be influenced by experimentally manipulated variables (e.g., stimulus properties, processing instructions, task constraints). Sensitivity of judgments to such variables helps identify the cues people may use to construct the judgments. Metamemory researchers also focus on (1) aggregate under- or over-confidence (differences of mean judgments from predicted memory success), (2) calibration, or gradations in mean memory performance as a function of degree of judgment confidence, or (3) resolution, an index of metamemory accuracy, assessed by within-person correlations (across items) of judgments with memory outcomes. This chapter emphasizes resolution as a measure of judgment accuracy.

Use of explicit judgments as empirical evidence immediately raises issues about the construct validity of these judgments as indices of monitoring processes. Any internal states targeted by monitoring can produce judgment cues, but the observer must map accessible evidence onto the rating scale. The scaling process can introduce systematic and random measurement error. Higham and colleagues (Hanczakowski, Zawadzka, Pasek, & Higham, 2013; Higham, Zawadzka, & Hanczakowski, 2016) have shown that binary (yes/no) forced choice feeling-of-knowing judgments diverge from continuous (0–100%) confidence rating scale judgments in predictive accuracy for recognition memory. Such effects can arise because of scaling artifacts, particularly if there are substantial individual differences in observers' mapping of internal states to scaling decisions, or if the grain size of the ordinal differences in a rating scale exceed the number of meaningful ordinal differences in underlying states based on the available cues for monitoring internal states. One reason metamemory researchers often compute ordinal Goodman-Kruskal gamma correlations of judgments and memory outcomes to measure resolution is to minimize individual differences in scaling artifacts in assessing judgment accuracy (Nelson, 1984; but see Benjamin & Diaz, 2008).

In aging research one can be concerned that age differences in use of rating scales generates a lack of measurement equivalence (Baltes, Reese, & Nesselroade, 1988) that would confound apparent age differences in monitoring ability with age differences in scaling behavior.

Aging and Memory Monitoring

Hertzog and Hultsch's (2000) review argued that older adults had spared metacognitive monitoring of encoding and retrieval. This hypothesis had been offered earlier by others (e.g., Perlmutter, 1978; Rabinowitz, 1984), but their evidence was not fully based on "best practices" from experimental cognitive psychology regarding how to validate metacognitive judgments. Subsequently, the idea of spared monitoring accuracy has been confirmed in many instances, but it appears to apply more to the monitoring of encoding than to the monitoring of retrieval of recently learned information (Castel et al., 2016; Hertzog & Dunlosky, 2011).

Monitoring of Encoding

Ease of learning judgments (EOLs) are made before an individual starts the process of encoding new information. They measure evaluations that may feed plans for how to learn new information. Adults of different ages appear to be similar in EOL sensitivity and accuracy. For instance, Price and Murray (2012) asked people to rate how difficult it would be to learn the English equivalents of Chinese characters. Actual difficulty is closely related to the complexity of the characters, in terms of number of line strokes per character. Younger and older adults' EOLs were also strongly related to character complexity and hence relatively accurate (see Figure 1). Price, Hertzog, and Dunlosky (2010) found similar age invariance in EOLs for learning Spanish-English vocabulary times varying in difficulty.

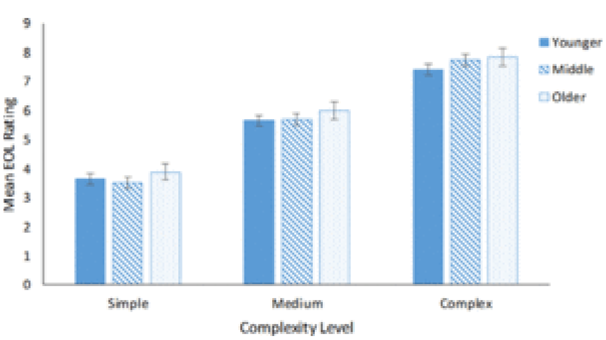

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Figure 1. Ease-of-learning judgments (EOLs) by complexity level. The number of line strokes per Chinese character is closely related to the complexity of the characters themselves. Increases in EOLs were observed for all age groups as a function of figural complexity and normative item difficulty.

Far more empirical evidence is available regarding age differences in JOLs, which are typically obtained immediately after studying information and considered relevant for feeding decisions about whether to continue or cease study or restudy the information at a later time. For instance, in preparing for a later test people may study a list of word pairs such as DOG-SPOON. A JOL would be collected immediately upon cessation of the study trial, prompted by presenting the cue word (e.g., DOG—?) to collect the JOL (similar to a cued recall test).

One important question is the sensitivity of JOLs to different variables and whether this sensitivity varies across age groups. Variables of interest might include manipulated

Source: Price and Murray (2012), reprinted with permission.

features of an experiment, including normative properties of individual stimuli (e.g., whether words are concrete or abstract, high frequency or low frequency, perceptual salience), task features (e.g., presentation durations, concurrent task demands), and person-generated processes (e.g., use of high- versus low-quality encoding strategies, fluency of strategy implementation).

Many cues influence JOL sensitivity. JOLs are affected by the salience of stimulus features that are largely irrelevant to subsequent remembering (e.g., perceptual features such as visual size or auditory loudness; Rhodes & Castel, 2008). They are also sensitive to stimulus properties that actually do influence later remembering, such as associative relatedness. Individuals give higher JOLs to associatively related items (e.g., SUGAR-SALT) than to unrelated items (TABLE-BELL). Associative relatedness is a diagnostic cue, given that it does predict later memory performance (cued recall is higher for related than for unrelated items). Accessing and using diagnostic cues like relatedness improves JOL accuracy.

However, JOLs also ignore or discount other cues that are diagnostic of later remembering. One such feature is an asymmetric direction of associative relatedness of cue-target pairs. For instance, cueing CHEESE with CHEDDAR results in better recall than the converse (i.e., cueing CHEDDAR with CHEESE). However, participants with no prior knowledge of this asymmetry tend to give the same JOL to both items, regardless of which word serves as cue and which serves as target (e.g., Koriat & Bjork, 2006). JOLs have also been shown to be relatively insensitive to instructed encoding strategies varying in normative effectiveness (e.g., Hertzog et al., 2009; Shaughnessy, 1981), and type of memory test (e.g., Touron, Hertzog, & Speagle, 2010; Weaver & Kelemen, 2003). JOLs are also influenced by encoding fluency (i.e., how quickly an item is encoded; see Begg et al., 1989; Hertzog, Dunlosky, Robinson, & Kidder, 2003; Undorf & Erdfelder, 2011) and by retrieval fluency, such as how quickly item-specific details are retrieved (Benjamin, Bjork, & Schwartz, 1998). However, often fluency is not diagnostic of whether the item will be remembered (Hertzog et al., 2003).

Generally speaking, the available evidence indicates little or no difference between adults of different ages in sensitivity or insensitivity of JOLs to different types of available metacognitive cues. For instance, associative relatedness appears to have a similar impact on the JOLs of younger and older adults (e.g., Connor, Dunlosky, & Hertzog, 1997; Hertzog, Kidder, Powell-Moman, & Dunlosky, 2002), and there are usually no age differences in JOL resolution as measured by within-person gamma correlations of JOLs with cued-recall success. Hertzog, Sinclair, and Dunlosky (2010) demonstrated this pattern of effects in a large cross-sectional sample of adults spanning ages 25 to 80. They found robust age differences in associative memory, with an age-x relatedness interaction indicating greater age differences for associatively unrelated word pairs (see Figure 2A). JOLs were affected by relatedness for people of all ages (see Figure 2B).

The most critical evidence concerned the resolution of JOLs. There was no evidence of an age-related deficit in JOL resolution; indeed, for all items (pooling over relatedness), JOL resolution actually increased slightly across the adult age range (see Figure 2C). Clearly, sensitivity to the diagnostic cue relatedness increased aggregate JOL resolution, because—as seen in Figure 2C—computing resolution separately for related and unrelated items lowered the gamma correlations. But in all cases there was little indication of an age-related deficit in JOL accuracy.

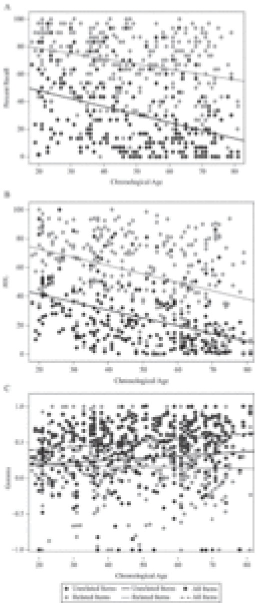

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Figure 2. (A) Cross-sectional age data on associative recall for related and unrelated paired-associate items. Recall was influenced by both relatedness and participant age. (B) Cross-sectional age data on JOLs predicting associative recall for related and unrelated paired-associate items. JOLs were influenced by relatedness (lower JOLs for unrelated items) and decreased with increasing age. (C) Cross-sectional age data on resolution of JOLs (Gamma correlations of JOLs with associative recall) for all items and separately for related and unrelated items.

Source: Hertzog, Sinclair, and Dunlosky (2010). Reprinted with permission.

Note in Figure 2C that resolution was better within the class of unrelated items than within the class of related items. Why? JOLs for both item types were influenced by whether people reported generating a normatively effective mediational strategy (Richardson, 1998), such as interactive imagery or sentence construction, to create the new association. Regardless of whether items were related or unrelated, people gave higher JOLs for items they reported using an effective encoding strategy. Yet strategy use improved unrelated item recall but had little impact on recall of related items. Thus, one reason for the resolution difference between related and unrelated items was that mediator production influenced JOLs for both item types but was diagnostic only for unrelated items (Hertzog et al., 2010).

There is other evidence in the literature indicating age-related sparing in JOL sensitivity and resolution. The delayed-JOL effect (Nelson & Dunlosky, 1991; Rhodes & Tauber, 2011) involves a substantial increase in JOL accuracy after delaying the judgments for a short period of time. Gammas correlations of JOLs and recall can increase from close to zero to .80 after a short delay—a substantial effect. Delaying the JOL apparently allows the outcome of a retrieval attempt to inform the JOL (Nelson, Narens, & Dunlosky, 2004). Connor et al. (1997) showed that older adults produce an equivalent delayed-JOL effect, a finding since replicated in other studies (Rhodes & Tauber, 2011). Older adults are less likely to recall targets during the test, but they give reliably higher JOLs to items they later do recall, leading to equivalent JOL resolution.

Another indication of age equivalence in the monitoring of encoding comes from work on multiple study-test trials, involving repeated opportunities to study items from the same list. Repeated study of a list generates improvements in JOL resolution accompanied by an aggregate underconfidence with practice (UWP; see Koriat, Sheffer, & Ma'ayan, 2002). People apparently rely on remembering past test outcomes as a basis for making JOLs: "I remembered it on the last test, so I will remember it again" (Finn & Metcalfe, 2007, 2008). This memory-for-past-test (MPT) heuristic has similar effects on older and younger adults' JOL resolution across multiple study-test opportunities despite age differences in memory itself (e.g., Hines, Hertzog, & Touron, 2015; Rast & Zimprich, 2009; Tauber & Rhodes, 2012).

One area where there can be age differences in JOL resolution concerns prediction of recognition memory performance. Older adults' recognition memory is often characterized by a larger proportion of correct recognitions associated with a subjective experience of familiarity, as opposed to explicit recollection (e.g., Hay & Jacoby, 1999). Accordingly, younger adults' JOLs appear to be more predictive of recognition memory, particularly of recollection experiences during recognition (Daniels, Toth, & Hertzog, 2009). Toth, Daniels, and Solinger (2011) had older and younger adults study names of actors active in the 1950s and 1990s. Older adults' familiarity with names of 1950s public figures actually reduced JOL resolution because familiarity of unstudied actors' names degraded recognition memory accuracy. Apparently, older adults also overestimate the likelihood of recollection over familiarity experiences in a future recognition test (Soderstrom, McCabe, & Rhodes, 2012). In all these instances, older adults' greater likelihood of familiarity over specific recollection led to reduced accuracy of metamemory judgments.

In summary, the evidence favors relative age sparing in monitoring learning and encoding processes, despite age differences in memory performance itself. This phenomenon has important implications for our understanding of age differences in how monitoring is used to achieve cognitive control (Hertzog & Dunlosky, 2011).

Monitoring After Retrieval Failures

In contrast to monitoring of *encoding*, there is evidence that aging may affect the accuracy of monitoring the *outcomes* of retrieval attempts.

A major type of metacognitive judgments relevant to retrieval monitoring concerns feeling-of-knowing (FOK) judgments. FOKs were created to capture metacognitive states accompanying failed retrieval attempts. If one searches for information believed to be held in memory but cannot find it, is it possible to accurately forecast whether this information can be recovered, or whether it could be recognized (Dunlosky & Metcalfe, 2009). A standard experimental method for studying feeling-of-knowing states is to have individuals attempt to recall information and then make FOK judgments about confidence in the likelihood that the sought information can be recognized if shown on a later recognition test. Researchers can study FOKs for facts or knowledge (information held in semantic memory) or FOKs for recently learned information (held in episodic memory). An example of a semantic FOK task may involve items such as in a trivia game, in which people seek to recall some type of declarative knowledge (e.g., information about famous people, past or current events, geographical information, or scientific facts). Episodic FOK tasks could involve different types of associative learning and memory, such as using interactive imagery for verbal paired associates or name-face associations. This distinction between episodic and semantic memory matters for understanding age differences in FOKs.

Studies of FOKs for knowledge held in semantic memory conducted in the 1970s and 1980s suggested little if any age differences in semantic FOKs (see Hertzog & Hultsch, 2000). These studies preceded the distinctions between sensitivity, overconfidence, and resolution common in metacognitive research today, so studies of age differences in semantic FOK resolution were relatively rare. Butterfield, Nelson, and Peck (1988) showed equivalence in older and younger adults' FOK resolution for unrecalled general knowledge questions. More recent work has reinforced the hypothesis that age spares the resolution of semantic FOKs (e.g., Eakin, Hertzog, & Harris, 2014; Souchay, Isingrini, & Espagnet, 2000; Souchay, Moulin, Clarys, Taconnat, & Isingrini, 2007). One of the reasons for this sparing may be that people of all ages have accurate knowledge about their own mastery of topics or domains of knowledge (e.g., Ackerman & Wolman, 2007). Topic familiarity and accurate self-knowledge can be used to help make more accurate semantic FOKs. However, the retrieval attempt appears to also generate information about availability of specific information in semantic memory for some items more than others, leading to above-chance resolution (Nelson, Gerler, & Narens, 1984). Apparently, older adults are as facile as younger adults in discriminating items they will later recognize, perhaps based on access to related information. For example, after failing to recall the name of George W.

Bush's first secretary of state, but remembering that the office was held by an African American man, may generate a high FOK and also be diagnostic of successful later name recognition (i.e., Colin Powell, in this case).

There are reports of age differences in the accuracy of FOKs for episodic materials, as well as a semantic-episodic dissociation in FOKs. Souchay et al. (2007) found age invariance in judgments concerning questions about art and history facts but a deficit in older adults' FOK resolution for an episodic version of the same materials. Furthermore, the same research group has found that individual differences in episodic FOK resolution are associated with performance on neuropsychological tests of frontal lobe function (Perrotin, Isingrini, Souchay, Clarys, & Taconnat, 2006; Perrotin, Tournelle, & Isingrini, 2008). Given other neuropsychological evidence that young adults with impaired frontal functioning show deficits in FOK accuracy (e.g., Shimamura, 2000) they argued that aging affects frontal lobe function, which in turn impairs a number of processes, such as executive functioning and retrieval monitoring accuracy. However, the hypothesized deficit may not be about metacognitive inferences and monitoring involved in constructing FOKs, per se, but rather an issue of age changes in episodic memory leading to a reduced availability of diagnostic cues for the FOK (Perfect & Stollery, 1993). If an age-related memory deficit reduces access to diagnostic cues, then an intact set of monitoring mechanisms may be shortchanged in information needed to make valid FOKs.

Hertzog, Dunlosky, and Sinclair (2010) assessed FOKs after cued recall for unrelated noun-paired associates using an experimental manipulation that affected the quality of underlying memory representations (what might be termed *memory strength*): the number of item presentations. In a single study-test trial, items were presented once, twice, or four times for study. Multiple study opportunities reinforce the newly created associations, allowing individuals to generate, rehearse, and retrieve mediators for more items. The procedure also involved differential delays between original encoding and subsequent test. A delay is often needed with young adults when high-quality encoding conditions (such as repeated presentations) are implemented because recall and/or recognition performance could be close to ceiling with an immediate memory test, creating insufficient items that are not remembered to enable estimates of FOK resolution. Hertzog et al. (2010) also introduced different delays for younger and older adults so that the age groups could be equated on memory performance. Doing so ensures that any age differences in FOK resolution can be attributed to processes involved in making metacognitive judgments, rather than a memory deficit per se (Dunlosky & Metcalfe, 2009). Hertzog et al. (2010) found that a two-day delay after initial study for older adults equated memory performance at all repetition conditions with memory performance of their younger adults at a seven-day delay. They also ran older adults in a 30-minute delay producing better recall and recognition than achieved by younger adults with a two-day delay.

Hertzog et al. (2010) found no material age deficits for unrecalled items in gamma correlations between FOKs and subsequent recognition memory success. Resolution was best for older adults with a 30-minute delay and quite similar for older and younger adults at two-day and seven-day delays, respectively. Repetition affected resolution for both age groups, affirming that FOK accuracy was influenced by the quality of original encoding for both age groups (see Figure 3). Other studies of age differences in episodic FOKs have typically involved large age differences in memory performance. The age differences found in other studies could be due to age deficits in episodic memory limiting the quality of information available from older adults' memories to inform FOK judgments (see Sacher, Isingrini, & Taconnat, 2013).

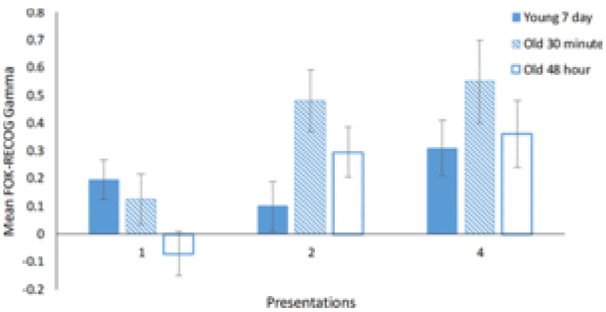

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Figure 3. Mean FOK x Recognition gamma correlations for younger (seven-day delay) and older (30-minute or 48-hour delays) adults as a function of number of presentations at study.

Source: Hertzog, Dunlosky, and Sinclair (2010). Reprinted with permission.

However, the picture is not that simple. Some studies have found appreciable age differences in memory but none in FOK resolution (MacLaverty & Hertzog, 2009; Eakin, Hertzog, & Harris, 2014). In the Eakin and colleagues' study of memory for face-name associations, neither semantic (faces of famous persons) nor episodic (new faces, new names) conditions produced age differences in FOK resolution, contradicting the semantic-episodic dissociation hypothesis about age differences in FOK accuracy. Another difference between studies finding age deficits in FOK accuracy versus those that do not is that the studies finding age differences often include a wider age range, including old-old participants (people as old as 90 years of age) and have also included samples of older adults varying in formal education (see Souchay et al., 2007). One possibility, then, is that the age deficit in FOKs arise only past the age of 80, the upper limit of age in studies in the Hertzog lab. Certainly, the issue is far from settled (see Sacher et al., 2015; Morson, Moulin, & Souchay, 2015).

Another possible explanation of the differing results is that tasks vary in the extent to which original encoding processes result in memory representations that can generate high-quality cues for FOKs when target retrieval search fails. A key hypothesis for accurate FOKs in episodic memory tasks involves what is termed *noncriterial recollection*—explicit remembering of features about the target or the original encoding context (but not recall of the criterion target itself) that is diagnostic of later recognition memory success (Brewer, Knight, Marsh, & Unsworth, 2010). Hertzog, Fulton, Sinclair, and Dunlosky (2014) showed that noncriterial recollection of the original associative encoding strategy (sentence or image mediator) had a significant effect on younger adults' FOKs for unrecalled targets. In that study, mean FOKs, given on a 0 to 100% confidence scale, were 75% for items that participants could recall something about the mediator they had generated and described at the time, contrasted against mean FOKs of 25% without any access to the original encoding strategy. Hertzog, Fulton, and Dunlosky (in preparation) found similar effects of mediator recall on FOKs for older adults.

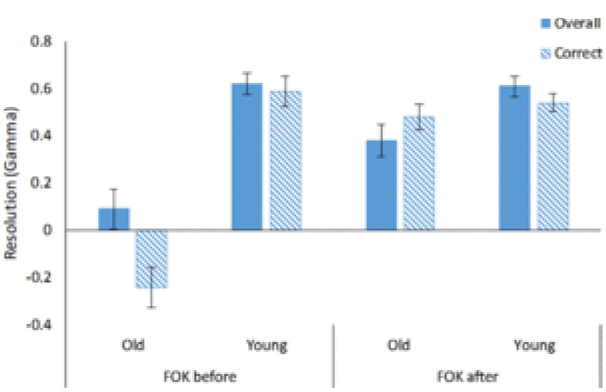

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Figure 4. Feeling-of-knowing (FOK) resolution for younger and older adults when emotional valence is

An important study by Thomas, Bulevich, and Debois (2011) showed that older individuals may have available cues for FOKs that they do not access and that a failure to identify and use these cues may contribute to age differences in FOK resolution. They paired emotional-neutral cue words with positively or negatively valenced emotional target words. After a recall attempt, participants made FOK judgments and were also asked to remember the emotional valence of the targets. These valence judgments had above-chance accuracy, even when targets had not been explicitly recalled—a type of noncriterial recollection. There were age differences in FOK resolution for unrecalled targets when recalled before or after providing the judgment. FOK accuracy, as measured by Goodman-Kruskal gamma correlations, is improved for older adults when individuals are asked to recall the emotional valence of a particular item before giving an FOK.

Source: Thomas et al. (2011). Reprinted with permission.

FOKs were made first, as in standard FOK experiments. However, older adults' gamma correlations were larger when the emotional valence judgment preceded the FOK, greatly attenuating the age difference in FOK accuracy (see Figure 4). When older adults were correct in their valence judgments, age differences were minimized. These results provide compelling evidence that older adults in the standard condition did not access an available diagnostic cue in memory.

In summary, the available evidence provides no clear-cut conclusions regarding age differences in monitoring possible accessibility of information after a retrieval search failure, as captured by FOKs. There is still little indication of an age deficit in monitoring access to information held in semantic memory, despite the fact that old age is associated with increasing likelihood of retrieval blocks or failures during semantic memory search (e.g., Hultsch, Hertzog, Dixon, & Small, 1998). However, some studies found age deficits in FOK accuracy for episodic memory search. Perhaps the fairest summary is that age differences in FOK accuracy can occur but are not inevitable. A plausible hypothesis requiring future tests is that FOK accuracy is most likely to be impaired when conditions constrain availability of noncriterial recollection for older adults, or where available noncriterial recollection that could inform FOKs is not sought by older observers.

Monitoring the Accuracy of Retrieval Products

When information is retrieved from memory, retrospective confidence judgments (RCJs) assess the subjective belief that the retrieval product is actually the information that was the target of the retrieval search. RCJs can be taken after an explicit retrieval search (as in cued recall) or after stimulus-guided verification, as in recognition memory tasks. In an old/new recognition memory task, a single element is presented and participants are asked to judge whether this information was previously encountered. In forced-choice recognition, people are presented with a previously encountered stimulus and one or more companion lures. The task is to choose which stimulus was encountered previously. After recall or recognition responses, RCJs can be collected to assess subjective confidence that the response is correct. RCJs have been widely studied outside of the metacognitive research context given their central importance to understanding response criteria in recognition memory tasks, including signal detection theory (e.g., Wickens, 2002; Wixted, 2007).

It is well known that memory errors (false responses) can be accompanied by erroneous high subjective confidence that the response is correct. For instance, in the Deese-Roediger-McDermott false memory experiment, unpresented lures (e.g., sleep) that are strong associates of a list of related words (e.g., bed, night, nap, alarm) are falsely recalled or incorrectly recognized with high subjective confidence that the lure had been part of the original list (Roediger & McDermott, 1995). Younger and older adults are both susceptible to such illusions. In such instances older adults may have lower resolution of RCJs than younger adults because they do not explicitly seek information that would protect against being lured into errors by misleading evidence (Thomas & Bulevich, 2006). Bulevich and Thomas (2012) showed that older adults showed a larger effect of misleading information on recognition memory and RCJ resolution that was moderated by whether they were forced to respond or allowed to withhold uncertain responses. Their results suggest that older adults' reduced RCJ resolution could be addressed by instructions or training to search for evidence that would reveal the nature of the misinformation.

Other paradigms designed to elicit memory errors are also accompanied by illusory confidence, with older adults being somewhat more likely to evince erroneous high confidence (e.g., Jacoby & Rhodes, 2006). Finally, even in standard recognition memory contexts, older adults may have a greater propensity to high-confidence memory errors (Chua, Sperling, & Schacter, 2009; Dodson, Bawa, & Krueger, 2007; Fandakova, Shing, & Lindenberger, 2013; Shing, Werkle-Bergner, Li, & Lindenberger, 2009; Wong, Cramer, & Gallo, 2012).

Associative recognition tests often contrast intact word pairs at recognition (the same two words paired at study) with rearranged pairs (a new pairing of words from two different pairs seen at study). Age differences in associative recognition are usually localized in rearranged pairs, where older adults may suffer from lower recollection of original associations or be lured by the familiarity of both words given that they had been seen (but not paired together) at study. Older adults may be more vulnerable to memory reconstruction errors (Brainerd & Reyna, 2005; Addis, Wong, & Schacter, 2008), especially because their recognition memory is more likely to be characterized by experiences of familiarity instead of explicit recollection of the original encoding experience and context (e.g., Perfect & Dasgupta, 1997; Guerdoux, Dressaire, Martin, Adam, & Brouillet, 2012; Hay & Jacoby, 1999; Van Ocker, Light, Olfman, & Rivera, 2017). Older adults are reported to be less likely to search for corroborating recollective evidence in recognition tasks and source memory tasks (Bulevich & Thomas, 2012), and are vulnerable to relying on a strong sense of familiarity even when it derives from episodes or sources other than those targeted by a retrieval search or triggered by confrontation with candidate memories (Johnson, 2006).

Studies of RCJs in tasks designed to study recognition memory have often not made contact with methods from the metacognitive literature (e.g., assessing resolution via gamma correlations), but that situation is changing (see Castel, Middlebrooks, & McGillivray, 2016 for a review). The available evidence suggests that RCJ resolution is high in standard associative memory tasks with unrelated verbal paired associates if cued recall is the criterion test (e.g., Dunlosky & Hertzog, 2000; Hertzog et al., 2009). Greater interest focuses on RCJ resolution in recognition memory experiments. There are a number of demonstrations of reduced RCJ resolution for episodic material in older adults (e.g., Kelley & Sahakyan, 2003; Pansky, Goldsmith, Koriat, & Pearlman-Avnion, 2009). As in the case of FOKs, the most unambiguous evidence for age differences in RCJ resolution as a metamemory phenomenon would come from studies that equate age groups on recognition memory accuracy (Dunlosky & Metcalfe, 2009).

Hines, Touron, and Hertzog (2009) presented unrelated concrete noun pairs to older and younger adults with different presentation times (10 s for old, 4 s for young) that equated recognition memory performance for both intact and rearranged pairs. The two groups did not differ in resolution for intact pairs ($M = .64$), but young adults had higher resolution for rearranged pairs, $M = .42$ versus .12, $t(72) = 2.65$, $p < .009$).[2] Dodson, Bawa, and Krueger (2007) also examined age differences in RCJ calibration (i.e., the extent to which RCJs of different magnitudes align with increases in probability of correct recognition) while also controlling for overall level of memory performance with differential item presentation rates. They also found older adults' RCJs to be more poorly calibrated than younger adults' RCJs.

Wong et al. (2012) also controlled on recognition memory performance by dividing attention for some younger adults during encoding. Divided-attention younger adults were then compared to full-attention older adults after selecting a subset of participants in each group equated on memory performance. The recognition test was a two-alternative forced choice procedure, with FOKs scaled from 50% confidence (aligned with the chance probability of correct responding of .50) to 100% confidence. Two embedded recognition discriminations involved color of an instructional font and picture recognition. As seen in Figure 5, older and younger adults both showed higher RCJ resolution for pictures relative to fonts. There were robust age differences in RCJ resolution in the full-attention comparison (left-hand panel) that were reduced but not eliminated by matching on recognition test performance (right-hand panel).

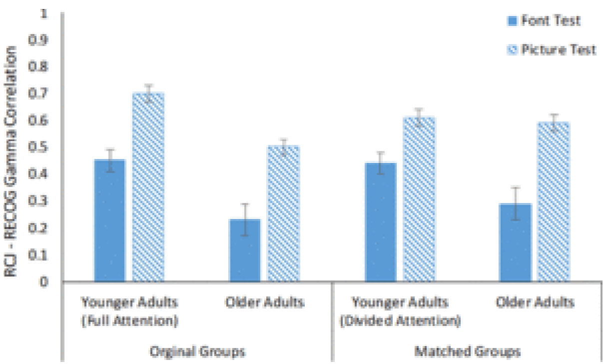

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Figure 5. Mean RCJ x Recognition gamma correlations for older adults and younger adults either at full attention (Original Groups) or in Matched Group (achieved in part by dividing attention of younger adults at study). Participants were tested with a forced-choice test for their memory of both fonts and pictures.

Source: Wong, Cramer, and Gallo (2012). Reprinted with permission.

High-confidence memory errors have been associated with different brain activation signatures (e.g., Fandakova, Lindenberger, & Shing, 2015), that appear to implicate age differences in effective, frontally mediated searches for recollective detail that could overcome familiarity-based memory illusions (Mitchell & Johnson, 2009). In at least some instances, high-confidence errors by older adults can be reduced by a number of different mechanisms, including recollection training (Jennings et al., 2007), use of a distinctiveness heuristic (e.g., Gallo et al., 2006), and even induced stereotype threat (Wong & Gallo, 2016). In the latter instance, it is thought that eliciting concerns about aging and memory causes older adults to be more careful in endorsing previously unstudied items as old. Nevertheless, age differences in resolution for RCJs could have implications for metacognitively grounded strategic control.

Returning to the episodic-semantic distinction, it appears that RCJs for semantic recognition memory tasks show little if any age deficits in resolution (e.g., Eakin et al., 2014; Pliske & Mutter, 1996), although tasks that are explicitly designed to foster false semantic memories have not been used to assess RCJ resolution.

Metacognitive Control

Classically, metacognitive control involves the use of strategies to learn and retrieve information, with ongoing monitoring of the cognitive system to inform learners about progress toward goals and how to adjust strategies to achieve those goals. It can be characterized as part of a larger process of people's self-regulation and adaptive behavior in cognitively demanding situations (see Bjork, Dunlosky, & Kornell, 2013; Kornell & Finn, 2016). A critical feature is the flexible use of cognitive strategies informed by metacognitive monitoring to enhance later remembering. Whereas *monitoring* involves a process of interrogating cognitive processes and products (to the extent this is feasible, given the constraints imposed by modularity of mind and brain), metacognitive *control* is argued to be a process of using monitoring outcomes to affect cognitive control mechanisms in pursuit of performance goals. For instance, older adults seeking to insure that they will remember information they are deliberately trying to learn may choose to focus efforts on studying material they believe they have not yet mastered in previous study attempts, while employing a new and different encoding strategy. Monitoring would be required to estimate degree of mastery (perhaps by a process akin to a judgment of learning), which would then inform strategic control and adaptive changes in strategic behavior (Nelson & Narens, 1990).

Self-Testing as Metacognitive Control

Murphy and colleagues (Murphy, Sanders, Gabriesheski, & Schmitt, 1981; Murphy, Schmitt, Caruso, & Sanders, 1987) conducted some of the first studies of age differences in metacognitive control. Their recall-readiness task required participants to study short lists of words under self-paced conditions with a goal of remembering the entire list in the correct serial order. These word lists exceeded each individual's pre-experimentally determined memory span, requiring that episodic memory be engaged. When participants signaled readiness to recall the list, they were tested. Murphy et al. (1981, 1987) found that older adults were much less likely to remember a complete list than younger adults.

In this task, people can maximize recall by using a simple metacognitive technique: test themselves covertly on the list to make sure they can actually recall it before signaling readiness. This self-testing procedure generates the requisite monitoring that can be used to control study by eliciting additional study when it is needed. Murphy et al.'s younger adults spontaneously used this self-testing strategy, but their older adults did not. Older adults given explicit instructions to use self-testing performed as well as younger adults in list memory, also out-performing uninstructed older adults. These outcomes suggest that older adults could successfully use the self-testing to guide task performance but did not do so spontaneously.

Self-testing can also be applied in other memory-demanding task contexts as long as individuals have sufficient time to use the procedure and then adapt their learning strategies based on self-testing. Maddox and Balota (2012) studied age differences in the spacing of self-testing in a face-name association paradigm. Their younger and older adults were instructed that they should use self-testing up to four times during a retention phase (while also engaging in reading a narrative passage). Spacing the self-tests out over time is the best way to support learning (Bjork et al., 2013). Older and younger adults showed similar patterns of self-test spacing in the standard condition. When explicitly instructed to attempt to space the self-tests out evenly across the retention interval, older adults were less effective at doing so. However, this outcome could reflect age differences in time monitoring accuracy when performing demanding cognitive tasks (e.g., Craik & Hay, 1999; Hertzog, Touron, & Hines, 2007) rather than a deficit in metacognitive control.

Older adults are somewhat less likely to produce these kinds of mnemonic strategies but age differences in strategy production can be remedied by merely informing people about these strategies (e.g., Dunlosky & Hertzog, 2001). What about age differences in self-testing strategies? Dunlosky, Kubat-Silman, and Hertzog (2003) trained self-testing use by older adults in a task using verbal paired associates (pairs of concrete nouns that had no prior associative relation to one another). Dunlosky et al. contrasted standard mnemonic strategy training to a training condition that received both mnemonic strategy training and self-testing training. People were taught to restudy items selectively, focusing their efforts on items they could not remember when they tested themselves using cue cards (for which the cue [e.g., SPIDER] was written on the opposite side of the card to the answer [e.g., CHAIR]). A cue card generates an analog of a well-studied metacognitive judgment: a delayed JOL. Because delayed JOLs are highly accurate for people of all ages, use of the cue cards to determine whether one knows the target generates accurate monitoring that can be used to guide further study behavior.

Learning a long list of words is typically enhanced when people selectively restudy words they have not already remembered during an earlier recall test (Dunlosky & Hertzog, 1998B; Nelson, Dunlosky, Graf, & Narens, 1994). To benefit from self-testing, individuals should generate a delayed JOL using the cards for every item and then use the JOLs to sort items into at least two categories: those that need more study or those that do not. Recall success, and perhaps retrieval with fluent access, would lead to high delayed JOLs (people can monitor retrieval latency to a degree, see Benjamin et al., 1998; Hertzog, Touron, & Hines, 2007; Hines, Touron, & Hertzog, 2009). Metacognitive control would involve focusing new study efforts on the items that could not be recalled, or ones that were only recalled with difficulty.

Dunlosky et al. (2003) found that older adults trained to use both mnemonics and self-testing performed better than a group of older adults who were given mnemonic training alone, provided that they were allowed to self-pace their study. Older adults tested with an experimenter-determined order at a fixed presentation rate could not engage in flexible metacognitive control and did not perform better than people given memory strategy training (see also Souchay & Isingrini, 2004). Later research showed that self-testing is sufficiently easy to understand and implement, and that it can be effective using a home-based training manual for self-instruction (Bailey, Dunlosky, & Hertzog, 2010).

Item Selection

Perhaps the simplest form of metacognitive control consists in the selection of items for study when that selection is under participant control. If task constraints permit only a subset of items to be restudied on any trial, will people adjust their selections so as to optimize learning? Nelson and colleagues (e.g., Nelson & Leonesio, 1988) argued that item selection should be sensitive to prior levels of learning. Nelson et al. (1994) addressed this question by having the young adults select items for restudy if they had low confidence in their ability to recall those items. This behavior matched the computer-based selection in rates of learning over trials.

Dunlosky and Hertzog (1997) adopted this procedure from Nelson et al. (1994) to investigate age differences in item selection. People made delayed JOLs to a list of 36 paired-associates and also indicated which 18 items of the 36 they would like to re-study over four additional study-test trials. Previous research on associative learning shows that learning rates are maximized if people restudy items with the lowest level of prior learning. A self-selection condition was contrasted with one in which the computer program selected the 18 items based on the JOLs. Both age groups preferred to restudy items with lower delayed JOLs, and these JOLs were highly accurate. There was a slight tendency for older adults to underperform their peers in the computer-selected study, although this sample difference was generated by a few older persons who chose to restudy the same items. These individuals also rated themselves lower in subjective memory; perhaps they believed that holding on to the few items they had already learned was a better goal than attempting to learn the entire list.

Tullis and Benjamin (2012) ran young and old adults in an associative learning task with a mixed list of 15 concrete-concrete and 15 abstract-abstract noun pairs, collecting JOLs for each item but also asking individuals to select half the items for restudy. These item selections were then honored (presenting the selected items for further study) or dishonored (presenting the unselected items for further study). As in Dunlosky and Hertzog (1997), both age groups selected unlearned items for further study, and item selections correlated equivalently with prior delayed JOLs. However, honoring choices benefited younger adults' subsequent learning (manifested in better recall in the honor condition relative to the dishonored condition). In contrast, there were no differences between these two conditions among older adults. Tullis and Benjamin (2012) argued that this pattern can be interpreted as a failure of metacognitive control in older adults. Older adults may have recalled fewer abstract items (Kausler, 1994) yet still avoided choosing difficult abstract items for future study even though they would benefit more from restudying them.

Other studies have observed older adults' avoidance of difficult items in memory tasks. Kornell and Metcalfe (2006) and Metcalfe (2002) generated a hypothesis called the region of proximal learning (RPL). RPL predicts individual differences in item selection from lists varying in normative difficulty, such as foreign-language vocabulary, and governed by individual differences in current knowledge or mastery. In such instances, Metcalfe has argued against Nelson and Leonesio's (1988) hypothesis that individuals would select any and all as-yet-unlearned items in a new study trial (see Dunlosky & Hertzog, 1998B), opting instead to study the subset of items closest to their level of current mastery (i.e., their RPL).

Older adults may show stronger RPL effects than younger adults. Price, Hertzog, and Dunlosky (2010) directly replicated and extended one of Metcalfe's tasks to study older adults' item selection behavior. They presented individuals with 2 X 3 arrays of Spanish words with normative item-difficulty explicitly labeled in columns (Easy, Medium, Hard) ordered from left to right. These arrays were shown to participants, with the left-hand column explicitly labeled "Easy," the middle-column explicitly labeled "Medium," and the right-hand column labeled "Hard." The arrays displayed only the Spanish word; individuals had to use the computer mouse to click on the word, revealing its English meaning. Both younger and older adults tended to select easier items first, but older adults selected easier words to study in two selection-study cycles. Given that older adults also recalled fewer words, their selection behavior was consistent with RPL. A second experiment crossed experimenter-assigned point values with difficulty. When difficult items were worth more points, a clear age difference in selecting high-value difficult items emerged, with younger adults selecting difficult items but older adults avoiding them. Older adults' avoidance of difficult items was significantly correlated with memory self-efficacy beliefs and working memory. Thus, although older adults' item selection behavior could be construed as RPL-like self-regulation, an alternative (but not mutually exclusive) interpretation is that older adults' lack of confidence in their memory ability caused them to avoid difficult items.

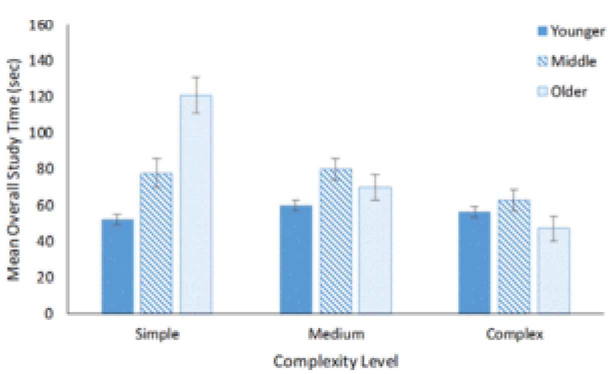

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Figure 6. Study-time allocation as a function of figural complexity in Chinese characters. Whereas middle and

Price and Murray (2012) asked older, middle-aged, and younger adults to learn the English equivalents of 36 unfamiliar Chinese characters, which better controlled for preexperimental knowledge of the language. Figural complexity of the characters was experimentally manipulated by varying the number of line segments. Manipulating figure complexity had a major impact on both recall and EOLs for all three age groups, showing that this variable was both salient to participants and highly diagnostic of actual item difficulty. All age groups tended to study easier items, on average, and avoid harder items, with younger adults' study seems relatively insensitive to character complexity, older adults tend to allocate more study time to simple characters.

Source: Price and Murray (2012), reprinted with permission.

no discernable age differences in this tendency. However, older adults tended to study fewer items and to restudy those items less often than younger adults and middle-aged adults (see Figure 6). Price and Murray (2012) interpreted the patterns of their data as consistent with RPL, although the strongest evidence for that claim came from the study time allocation data reviewed below.

Study Time Allocation

An alternative measure of metacognitive control in multi-trial learning tasks involves allocation of study time (e.g., Nelson, 1993; Nelson & Leonesio, 1988). When a task provides the opportunity to restudy all items, adaptive self-regulation may be reflected in investing more study time in items not already learned.

Dunlosky and Connor (1997) assessed relations between delayed JOLs, recall, and study time at the next study opportunity in younger and older adults. Delayed JOLs and recall both had, as expected, negative gamma correlations with ensuing study time, with a stronger relation for recall than JOLs. However, older adults showed less significant differences in study time between previously recalled and unrecalled items, apparently placing greater emphasis on restudying previously recalled items. Krueger (2012) replicated this finding in a spatial memory task.

The problem with interpreting these correlations as deficits in metacognitive control by older adults is that the optimal restudy schedule for older adults, as contrasted to younger adults, is not actually known. Pyc and Rawson (2009) showed that recall was superior if young adults did not cease studying items after a single successful recall. It may be reasonable for older adults to attempt to continue working with material they may believe could be otherwise forgotten.

In contrast, Hines, Touron, and Hertzog (2009) found little evidence of age differences in study time allocation using a verbal associative recognition task. Hines et al. used different presentation times for older (10 s) and younger (4 s) participants to equate first-trial associative recognition memory performance. The second trial study was self-paced. Their multilevel regression models found that study time at Trial 2 was predicted by Trial 1 recognition-memory accuracy and by Trial 1 recognition-memory confidence judgments (CJs) for both younger and older adults, with minimal age differences in study time allocation. The relationship of CJs to study time, independent of recognition memory performance itself, showed that monitoring affected subsequent control. The age-related similarity in metacognitive control occurred despite the fact that CJs were less accurate for older adults than younger adults.

The differences in design and procedures make it difficult to reconcile the apparently conflicting conclusions about aging and metacognitive control of study time. It is possible that low levels of recall in the older adults for Dunlosky and Connor (1997), combined with the fact that only a subset of items were tested at each trial, fostered a more conservative strategy of a greater emphasis on restudy of recalled items. In contrast, the apparent ease with which associative recognition was achieved may have encouraged older adults to emphasize acquiring previously unrecognized items.

Price and Murray's (2012) study with Chinese-English vocabulary provided strong evidence for age differences in time allocated to study difficult Chinese characters in their grid-selection task. Younger adults and middle-aged adults showed little effect of complexity of the Chinese characters on total study time; older adults, in contrast, showed a clear differentiation, with much more study time devoted to simple items than complex items (see Figure 6). This pattern is consistent with the hypothesis of older adults having a subjective RPL much lower than that of the other age groups. Furthermore, Price and Murray (2012) found that study time allocation was predicted by working memory capacity as well as beliefs about the inevitability of age-related memory decline or concern about Alzheimer's disease.

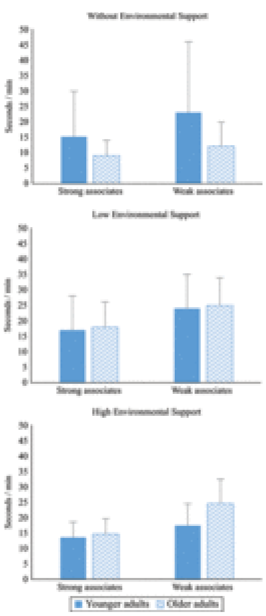

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Figure 7. Study-time allocation in younger and older adults as a function of environmental support and item association. Older adults allocate more study time to weakly associated items with more environmental support.

From Froger et al. (2012), reprinted with permission.

Although study time has been a traditional measure in self-regulated learning research, it is clearly a measure with limited interpretability (e.g., Koriat, Ma'ayan, & Nussinson, 2006) that is influenced by a variety of variables that themselves may be more important than study time, per se, in explaining learning. In particular, what one does with the time allocated is probably more important than the sheer amount of time invested in the effort. High-quality mnemonic strategies, such as interactive imagery and sentence generation (Richardson, 1998), typically require more time to implement than other less-effective strategies such as simple repetition. But even if one spends more time repeating an item than encoding it with imagery, the probability of recall would remain higher for items encoded with high-quality, interactive imagery. Froger, Bouazzaoui, Isingrini, and Taconnat (2012), for example, showed that instructions to use superior interactive imagery and sentence construction strategies affected age differences in cued recall (see Figure 7). Older adults, on the other hand, showed reliable shifts in strategy use toward interactive imagery under self-paced conditions that benefited their recall of weakly associated items that benefit more from the use of effective mnemonics (see Dunlosky & Hertzog, 1998A; Hertzog, Dunlosky, & Sinclair, 2010). The strategy shift produced a dramatic shift in study time for weakly related items for older adults; they allocated more study time to those items after strategy instructions.

Metacognitive Control in Complex Task Contexts

Castel and colleagues have run a series of studies demonstrating that older adults can be selective about items they remember, such as ordering probability of recall of items in a word list to monotonically increase with increases in experimenter-assigned point values (e.g., Castel et al., 2011; see Castel, Middlebrooks, & McGillivray, 2016). Although age differences in overall list recall are still observed, older adults score similarly to younger adults on a selectivity index that captures the degree to which people emphasize learning and then remember high-value over low-value items.

Castel et al. (2013) further showed that older adults' value-directed behavior was strategic, because if the task was structured so as to afford it, they were likely to back-load rehearsal of high-value items as a chunk toward the end of the list. Doing so enabled them to rely on holding the high-value items in working memory and then reporting them first in order to maximize points gained in the task. Metacognitive control appeared to be involved because older adults' use of this strategy and their benefit for attained point value increased in likelihood across multiple tests (Castel et al., 2011, 2013). Castel and colleagues have interpreted these findings as indicating that older adults may know from life experience that they cannot learn the same amount of information as they once did, so they compensate for age changes by emphasizing allocation of effort to remember what is most valuable and important to them.

Age differences in value-directed benefits may depend on the type of memory assessed and how sensitive that form of episodic memory is to age differences. Associative recall and recognition are known to produce substantial age differences (Kausler, 1994; Old & Naveh-Benjamin, 2008). Ariel, Price, and Hertzog (2015) studied value-directed remembering with paired-associate learning while also structuring the task to examine whether individuals will be strategic in item study based on experimenter assigned values. Older and younger participants studied unrelated noun-noun paired-associate items presented in grids, running a mouse over a 2 X 3 matrix of black rectangles to reveal the word pair underneath each rectangle (which was only visible when the mouse pointed to pixels contained within the rectangle). An identical matrix of black rectangles was displayed to the left of the items; this matrix contained the point values for items in corresponding areas. The computer program recorded the sequence of views and the viewing times for each element in the grids. After studying ten consecutively presented grids, participants received a cued-recall test. Ariel et al. (2015) also collected retrospective strategy reports to determine the kinds of associative strategies used for different items.

Older and younger adults searched for point values similarly, starting with a search for value and selectively studying and restudying high-value over low-value items. Both age groups allocated more study time to high-value items, and this time was invested in using effective but demanding associative encoding strategies. Normatively effective strategies were more frequently used for high-value items. Thus, older adults' self-regulatory flexibility was relatively well preserved in that they searched for high-point values and were then selective in the attention paid to items according to their value—in this case, selectively engaged high-quality associative learning strategies. However, unlike a free recall test, the greater effort spent on high-value item encoding did not eliminate age differences in memory for high-value associations. An individual differences analysis indicated that this age-related associative learning deficit was produced by older adults who scored lower in a test of inductive reasoning; older adults high in inductive reasoning showed no deficit in memory for high-value associations. This finding could signify that people higher in inductive reasoning generate higher quality mediators that can eliminate the value-directed deficit.

Conclusions

Metacognition is a fruitful area of research regarding aging and the capabilities of older adults. There is a fascinating dissociation between age deficits in associative learning and older adults' preserved ability to monitor that learning, as measured by JOLs. It also appears that older adults can engage in simple and complex forms of metacognitive control.

Older adults may not believe they are capable of doing so, given tendencies to rate themselves lower in memory and control over memory than young and middle-aged adults. Yet there are at best weak correlations of memory beliefs and memory performance in old age, suggesting that these beliefs could arise from sources such as internalized age stereotypes rather than accurate self-assessments. Hence, restructuring negative beliefs and age stereotypes about memory may be critical when one seeks to help older adults improve memory performance through training (West et al., 2008).

There are a number of demonstrated age differences in learning and memory that can be remediated through metacognitive approaches. Older adults are more susceptible to illusions of memory (false memories), but this tendency can be ameliorated by training older adults to use encoding and retrieval strategies that help them discriminate information they were seeking from lures that come to mind (e.g., Jennings et al., 2007; Lustig & Flegal, 2008). In general, then, it appears that training metacognitive approaches to self-regulation in cognitive tasks (Hertzog & Dunlosky, 2011) and in everyday life (Dunlosky, Bailey, & Hertzog, 2011) has great potential for assisting older adults in minimizing memory deficits and optimizing their everyday memory functioning.

References

Ackerman, P. L., & Wolman, S. D. (2007). **Determinants and validity of self-estimates of abilities and self-concept measures**. *Journal of Experimental Psychology: Applied*, *13*, 57–78.
Find this resource:

Addis, D. R., Wong, A. T., & Schacter, D. L. (2008). **Age-related changes in the episodic simulation of future events**. *Psychological Science*, *19*, 33–41.
Find this resource:

Ariel, R., Price, J., & Hertzog, C. (2015). **Age-related associative memory deficits in value-based remembering: The contribution of agenda-based regulation and strategy use**. *Psychology and Aging*, *30*, 795–808.
Find this resource:

Bailey, H., Dunlosky, J., & Hertzog, C. (2010). **Self-regulation training at home: Does it improve older adults' learning?** *Gerontology*, *56*, 414–420.
Find this resource:

Baltes, P. B., Reese, H. W., & Nesselroade, J. R. (1988). *Life-span developmental psychology: Introduction to research methods*. Hillsdale, NJ: Lawrence Erlbaum Associates.
Find this resource:

Barber, S. J. (2017). **An examination of age-based stereotype threat about cognitive decline: Implications for stereotype-threat research and theory development**. *Perspectives on Psychological Science*, *12*, 62–90.
Find this resource:

Barber, S. J., & Mather, M. (2014). Stereotype threat in older adults: When and why does it occur, and who is most affected? In P. Verhaeghen & C. Hertzog (Eds.). *The Oxford handbook of emotion, social cognition, and problem solving during adulthood* (pp. 302–320). New York, NY: Oxford University Press.

Find this resource:

Begg, I., Duft, S., Lalonde, P., Melnick, R., & Sanvito, J. (1989). **Memory predictions are based on ease of processing**. *Journal of Memory and Language*, *28*, 610–632.
Find this resource:

Benjamin, A. S., Bjork, R. A., & Schwartz, B. L. (1998). **The mismeasure of memory: When retrieval fluency is misleading as a metamnemonic index**. *Journal of Experimental Psychology: General*, *127*, 55–68.
Find this resource:

Benjamin, A. S., & Diaz, M. (2008). Measurement of relative metamnemonic accuracy. In J. Dunlosky & R. A. Bjork (Eds.), *Handbook of metamemory and memory*. New York, NY: Psychology Press.
Find this resource:

Berry, J. M. (1999). Memory self-efficacy in its social cognitive context. In T. M. Hess & F. Blanchard-Fields (Eds.), *Social cognition and aging* (pp. 69–96). San Diego, CA: Academic Press.
Find this resource:

Berry, J. M., West, R. L., & Dennehey, D. M. (1989). **Reliability and validity of the Memory Self-Efficacy Questionnaire**. *Developmental Psychology*, *25*, 701–713.
Find this resource:

Beaudoin, M., & Desrichard, O. (2011). **Are memory self-efficacy and memory performance related? A meta-analysis**. *Psychological Bulletin*, *137*, 211–214.
Find this resource:

Bjork, R. A., Dunlosky, J., & Kornell, N. (2013). **Self-regulated learning: Beliefs, techniques, and illusions**. *Annual Review of Psychology*, *64*, 417–444.
Find this resource:

Brainerd, C. J., & Reyna, V. F. (2005). *The science of false memory*. New York, NY: Oxford University Press.
Find this resource:

Brewer, G. A., Knight, J. B., Marsh, R. L., & Unsworth, N. (2010). **Individual differences in event-based prospective memory: Evidence for multiple processes supporting cue detection**. *Memory & Cognition*, *38*, 304–311.
Find this resource:

Brigham, M. C., & Pressley, M. (1988). **Cognitive monitoring and strategy choice in younger and older adults**. *Psychology and Aging*, *3*(3), 249–257.
Find this resource:

Bulevich, J. B., & Thomas, A. K. (2012). **Retrieval effort improves memory and metamemory in the face of misinformation**. *Journal of Memory and Language*, *67*, 45–58.
Find this resource:

Butterfield, E. C., Nelson, T. O., & Peck, V. (1988). **Developmental aspects of the feeling of knowing**. *Developmental Psychology*, *24*, 654–663.
Find this resource:

Castel, A. D. (2008). **Metacognition and learning about primacy and recency effects in free recall: The utilization of intrinsic and extrinsic cues when making judgments of learning**. *Memory & Cognition*, *36*, 429–437.
Find this resource:

Castel, A. D., Friedman, M. C., McGillivray, S., Flores, C. C., Murayama, K., Kerr, T., & Drolet, A. (2016). **I owe you: Age-related similarities and differences in associative memory for gains and losses**. *Aging, Neuropsychology, and Cognition*, *23*, 549–565.
Find this resource:

Castel, A. D., Humphreys, K. L., Lee, S. S., Galván, A., Balota, D. A., & McCabe, D. P. (2011). **The development of memory efficiency and value-directed remembering across the lifespan: A cross-sectional study of memory and selectivity**. *Developmental Psychology*, *47*, 1553–1564.
Find this resource:

Castel, A. D., Middlebrooks, C. D., & McGillivray, S. (2016). Monitoring memory in old age: Impaired, spared, and aware. In J. Dunlosky & S. K. Tauber (Eds.), *The Oxford handbook of metamemory* (pp. 463–483). New York, NY: Oxford University Press.
Find this resource:

Castel, A. D., Murayama, K., Friedman, M. C., McGillivray, S., & Link, I. (2013). **Selecting valuable information to remember: Age-related differences and similarities in self-regulated learning**. *Psychology and Aging*, 28, 232–242.
Find this resource:

Chua, E. F., Schacter, D. L., & Sperling, R. A. (2009). **Neural correlates of metamemory: a comparison of feeling-of-knowing and retrospective confidence judgments**. *Journal of Cognitive Neuroscience*, 21, 1751–1765.
Find this resource:

Connor, L. T., Dunlosky, J., & Hertzog, C. (1997). **Age-related differences in absolute but not relative metamemory accuracy**. *Psychology and Aging*, *12*, 50–71.
Find this resource:

Craik, F. I. M., & Hay, J. F. (1999). **Aging and judgments of duration: Effects of task complexity and method of estimation**. *Perception* & *Psychophysics*, *61*, 549–560.
Find this resource:

Crook, T. H., & Larrabee, G. J. (1990). **A self-rating scale for evaluating memory in everyday life**. *Psychology and Aging*, *5*, 48–57.
Find this resource:

Crumley, J. J., Stetler, C. A., & Horhota, M. (2014). **Examining the relationship between subjective and objective memory performance in older adults: A meta-analysis**. *Psychology and Aging*, *29*, 250–263.
Find this resource:

Daniels, K. A., Toth, J. P., & Hertzog, C. (2009). **A role for recollection in the accuracy of judgments of learning**. *Psychology and Aging*, *24*, 494–500.
Find this resource:

Dixon, R. A., Hultsch, D. F., & Hertzog, C. (1988). The metamemory in adulthood (MIA) questionnaire. *Psychopharmacology Bulletin*, *24*, 671–688.
Find this resource:

Dodson, C. S., Bawa, S., & Krueger, L. E. (2007). **Aging, metamemory, and high-confidence errors: A misrecollection account**. *Psychology and Aging*, *22*, 122–133.
Find this resource:

Dunlosky, J., Bailey, H., & Hertzog, C. (2011). Memory enhancement strategies: What works best for obtaining memory goals? In P. Hartman-Stein & A. LaRue (Eds.), *Enhancing Cognitive Fitness in Adults* (pp. 3–23). New York, NY: Springer.
Find this resource:

Dunlosky, J., & Connor, L. (1997). **Age differences in the allocation of study time account for age differences in memory performance**. *Memory and Cognition*, *25*, 691–700.
Find this resource:

Dunlosky, J., & Hertzog, C. (1997). **Older and younger adults use a functionally identical algorithm to select items for restudy during multi-trial learning**. *Journal of Gerontology: Psychological Sciences*, *52*, 178–186.
Find this resource:

Dunlosky, J., & Hertzog, C. (1998a). **Aging and deficits in associative memory: What is the role of strategy use?** *Psychology and Aging*, *13*, 597–607.
Find this resource:

Dunlosky, J. T., & Hertzog, C. (1998b). Training programs to improve learning in later adulthood: Helping older adults educate themselves. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 249–275). Mahwah, NJ: Lawrence Erlbaum Associates.
Find this resource:

Dunlosky, J., & Hertzog, C. (2000). **Updating knowledge about encoding strategies: A componential analysis of learning about strategy effectiveness from task experience**. *Psychology and Aging*, *15*, 462–474.
Find this resource:

Dunlosky, J., & Hertzog, C. (2001). **Measuring strategy production during associative learning: The relative utility of concurrent versus retrospective reports**. *Memory & Cognition*, *29*, 247–253.
Find this resource:

Dunlosky, J., Kubat-Silman, A., & Hertzog, C. (2003). **Training metacognitive skills improves older adults' associative learning**. *Psychology and Aging*, *18*, 340–345.
Find this resource:

Dunlosky, J., & Metcalfe, J. (2009). *Metacognition*. Thousand Oaks, CA: SAGE.
Find this resource:

Eakin, D. K., Hertzog, C., & Harris, W. (2014). **Younger and older adults generate similar accuracy of semantic and episodic feeling of knowing for names of faces**. *Aging, Neuropsychology, and Cognition*, *21*, 27–51.
Find this resource:

Fandakova, Y., Lindenberger, U., & Shing, Y. L. (2015). **Maintenance of youth-like processing protects against false memory in adulthood**. *Neurobiology of Aging*, *36*, 933–941.
Find this resource:

Fandakova, Y., Shing, Y. L., & Lindenberger, U. (2013). **High-confidence memory errors in old age: The roles of monitoring and binding processes**. *Memory*, *21*, 732–750.
Find this resource:

Finn, B., & Metcalfe, J. (2007). **The role of memory for past test in the underconfidence with practice effect**. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 238–244.
Find this resource:

Finn, B., & Metcalfe, J. (2008). **Judgments of learning are influenced by memory for past test**. *Journal of Memory and Language*, *58*, 19–34.
Find this resource:

Flavell, J. H. (1979). **Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry**. *American Psychologist*, *34*, 906–911.
Find this resource:

Fodor, J. A. (1983). *The modularity of mind: An essay on faulty psychology*. Cambridge, MA: MIT Press.
Find this resource:

Frank, D. J., Touron, D. R., & Hertzog, C. (2013). **Age differences in strategy shift: Retrieval avoidance or general shift reluctance?** *Psychology and Aging*, *28*, 778–788.
Find this resource:

Froger, C., Bouazzaoui, B., Isingrini, M., & Taconnat, L. (2012). **Study time allocation deficit in older adults: The role of environmental support at encoding?** *Psychology and Aging*, *27*, 577–588.
Find this resource:

Gallo, D. A., Bell, D. M., Beier, J. S., & Schacter, D. L. (2006). **Two types of recollection-based monitoring in younger and older adults: Recall-to-reject and the distinctiveness heuristic**. *Memory*, *14*, 730–741.
Find this resource:

Gilewski, M. J., Zelinski, E. M., & Schaie, K. W. (1990). The Memory Functioning Questionnaire for assessment of memory complaints in adulthood and old age. *Psychology and Aging*, *5*, 482.
Find this resource:

Guerdoux, E., Dressaire, D., Martin, S., Adam, S., & Brouillet, D. (2012). **Habit and recollection in healthy aging, mild cognitive impairment, and Alzheimer's disease**. *Neuropsychology*, *26*, 517–533.
Find this resource:

Hanczakowski, M., Zawadzka, K., Pasek, T., & Higham, P. A. (2013). **Calibration of metacognitive judgments: Insights from the underconfidence-with-practice effect**. *Journal of Memory and Language*, *69*, 429–444.
Find this resource:

Hay, J. F., & Jacoby, L. L. (1999). **Separating habit and recollection in young and older adults: effects of elaborative processing and distinctiveness**. *Psychology and Aging*, *14*, 122–134.
Find this resource:

Hertzog, C., Dixon, R. A., & Hultsch, D. F. (1990). **Relationships between metamemory, memory predictions, and memory task performance in adults**. *Psychology and Aging*, *5*, 215–227.
Find this resource:

Hertzog, C., & Dunlosky, J. (2004). **Aging, metacognition, and cognitive control**. *Psychology of Learning and Motivation*, *45*, 215–251.
Find this resource:

Hertzog, C., & Dunlosky, J. (2006). Using visual imagery as a mnemonic for verbal associative learning: Developmental and individual differences. In T. Vecchi & G. Bottini (Eds.). *Imagery and spatial cognition: Methods, models and cognitive assessment* (pp. 259–280). Amsterdam and Philadelphia: John Benjamins.
Find this resource:

Hertzog, C., & Dunlosky, J. (2011). **Metacognition in later adulthood: Spared monitoring can benefit older adults' self-regulation**. *Current Directions in Psychological Science*, *20*, 167–173.
Find this resource:

Hertzog, C., Dunlosky, J., Robinson, A. E., & Kidder, D. P. (2003). **Encoding fluency is a cue utilized for judgments about learning**. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*, 22–34.
Find this resource:

Hertzog, C., Dunlosky, J., & Sinclair, S. M. (2010). **Episodic feeling-of-knowing resolution derives from the quality of original encoding**. *Memory & Cognition*, *38*, 771–784.
Find this resource:

Hertzog, C., Fulton, E. K., & Dunlosky, J. (2017). *Age differences in accuracy of feeling-of-knowing judgments are connected to noncriterial recollection of original encoding experiences*.
Find this resource:

Hertzog, C., Fulton, E. K., Sinclair, S. M., & Dunlosky, J. (2014). **Recalled aspects of original encoding strategies influence episodic feelings of knowing**. *Memory & Cognition*, *42*, 126–140.
Find this resource:

Hertzog, C., & Hultsch, D. F. (2000). Metacognition in adulthood and aging. In T. Salthouse & F. I. M. Craik (Eds.), *Handbook of aging and cognition* (2nd ed., pp. 417–466). Mahwah, NJ: Lawrence Erlbaum Associates.
Find this resource:

Hertzog, C., Hultsch, D. F., & Dixon, R. A. (1989). **Evidence for the convergent validity of two self-report metamemory questionnaires**. *Developmental Psychology*, *25*, 687–700.
Find this resource:

Hertzog, C., Kidder, D. P., Powell-Moman, A., & Dunlosky, J. (2002). **Aging and monitoring associative learning: Is monitoring accuracy spared or impaired?** *Psychology and Aging*, *17*, 209–225.
Find this resource:

Hertzog, C., McGuire, C. L., & Lineweaver, T. T. (1998). **Aging, attributions, perceived control, and strategy use in a free recall task**. *Aging Neuropsychology and Cognition*, *5*, 85–106.
Find this resource:

Hertzog, C., Park, D. C., Morrell, R. W., & Martin, M. (2000). Ask and ye shall receive: Behavioural specificity in the accuracy of subjective memory complaints. *Applied Cognitive Psychology*, *14*, 257–275.
Find this resource:

Hertzog, C., & Pearman, A. (2014). Memory complaints in adulthood and old age. In T. J. Perfect & D. S. Lindsay (Eds.), *The SAGE handbook of applied memory* (pp. 423–443). London: SAGE.
Find this resource:

Hertzog, C., Price, J., Burpee, A., Frentzel, W. J., Feldstein, S., & Dunlosky, J. (2009). **Why do people show minimal knowledge updating with task experience: Inferential deficit or experimental artifact?** *Quarterly Journal of Experimental Psychology*, *62*, 155–173.
Find this resource:

Hertzog, C., Price, J., & Dunlosky, J. (2012). **Age differences in the effects of experimenter-instructed versus self-generated strategy use**. *Experimental Aging Research*, 38, 42–62.
Find this resource:

Hertzog, C., Sinclair, S. M., & Dunlosky, J. (2010). **Age differences in the monitoring of learning: Cross-sectional evidence of spared resolution across the adult life span**. *Developmental Psychology*, *46*, 939–948.
Find this resource:

Hertzog, C., & Shing, Y. L. (2011). Memory development across the lifespan. In K. Fingerman, C. A. Berg, T. Antonucci, & J. Smith (Eds.), *Handbook of lifespan developmental psychology* (pp. 299–330). New York, NY: Springer.
Find this resource:

Hertzog, C., & Touron, D. R. (2011). **Age differences in memory retrieval shift: Governed by feeling-of-knowing?** *Psychology and Aging*, *26*, 647–660.
Find this resource:

Hertzog, C., Touron, D. R., & Hines, J. C. (2007). **Does a time monitoring deficit influence older adults' delayed retrieval shift during skill acquisition?** *Psychology and Aging*, *22*, 607–624.
Find this resource:

Hess, T. M., Auman, C., Colcombe, S. J., & Rahhal, T. A. (2003). **The impact of stereotype threat on age differences in memory performance**. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *58*, 3–11.
Find this resource:

Higham, P. A., Zawadzka, K., & Hanczakowski, M. (2016). **Internal mapping and its impact on measures of absolute and relative metacognitive accuracy**. In J. Dunlosky & S. Tauber (Eds.), *Oxford handbook of metamemory* (pp. 39–61). New York, NY: Oxford University Press.
Find this resource:

Hines, J. C., Hertzog, C., & Touron, D. R. (2015). **Younger and older adults weigh multiple cues in a similar manner to generate judgments of learning**. *Aging, Neuropsychology, and Cognition*, 22, 693–711.
Find this resource:

Hines, J. C., Touron, D. R., & Hertzog, C. (2009). **Metacognitive influences on study time allocation in an associative recognition task: An analysis of adult age differences**. *Psychology and Aging*, *24*, 462–475.
Find this resource:

Hultsch, D. F., Hertzog, C., Dixon, R. A., & Small, B. J. (1998). *Memory change in the aged*. New York, NY: Cambridge University Press.
Find this resource:

Hummert, M. L. (2011). **Age stereotypes and aging**. In K. W. Schaie & S. L. Willis (Eds.), *Handbook of the psychology of aging* (pp. 249–262).
Find this resource:

Jacoby, L. L., & Rhodes, M. G. (2006). **False remembering in the aged**. *Current Directions in Psychological Science*, *15*, 49–53.
Find this resource:

Jennings, J. M., Dagenbach, D., Engle, C. M., & Funke, L. J. (2007). **Age-related changes and the attention network task: An examination of alerting, orienting, and executive function**. *Aging, Neuropsychology, and Cognition*, 14, 353–369.
Find this resource:

Johnson, M. K. (2006). **Memory and reality**. *American Psychologist*, 61, 760–771.
Find this resource:

Jopp, D., & Hertzog, C. (2007). **Activities, self-referent memory beliefs, and cognitive performance: Evidence for direct and mediated relations**. *Psychology and Aging*, *22*, 811–825.
Find this resource:

Kausler, D. H. (1994). *Learning and memory in normal aging*. San Diego, CA: Academic Press.
Find this resource:

Kelley, C. M., & Sahakyan, L. (2003). **Memory, monitoring, and control in the attainment of memory accuracy**. *Journal of Memory* & *Language*, *48*, 704–721.
Find this resource:

Koriat, A. (1995). **Dissociating knowing and the feeling of knowing: Further evidence for the accessibility model**. *Journal of Experimental Psychology: General*, *124*, 311–333.
Find this resource:

Koriat, A. (1997). **Monitoring one's own knowledge during study: A cue-utilization approach to judgments of learning**. *Journal of Experimental Psychology: General*, *126*, 349–370.
Find this resource:

Koriat, A. (2000). **The feeling of knowing: Some metatheoretical implications for consciousness and control**. *Consciousness and Cognition*, *9*, 149–171.
Find this resource:

Koriat, A., & Bjork, R. A. (2006). **Mending metacognitive illusions: a comparison of mnemonic-based and theory-based procedures**. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 1133–1145.
Find this resource:

Koriat, A., Ma'ayan, H., & Nussinson, R. (2006). **The intricate relationships between monitoring and control in metacognition: Lessons for the cause-and-effect relation between subjective experience and behavior**. *Journal of Experimental Psychology: General*, *135*, 36–69.
Find this resource:

Koriat, A., Sheffer, L., & Ma'ayan, H. (2002). **Comparing objective and subjective learning curves: Judgments of learning exhibit increased underconfidence with practice**. *Journal of Experimental Psychology: General*, *131*, 147–162.
Find this resource:

Kornell, N. & Finn, B. (2016). Self-regulated learning: An overview of theory and data. In. J. Dunlosky & B. Finn (Eds.), *The Oxford handbook of metamemory* (pp. 325–339). New York: Oxford University Press.
Find this resource:

Kornell, N., & Metcalfe, J. (2006). **Study efficacy and the region of proximal learning framework**. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 609–622.
Find this resource:

Krueger, L. E. (2012). **Age-related effects of study time allocation on memory performance in a verbal and a spatial task**. *Educational Gerontology*, *38*, 604–615.
Find this resource:

Lachman, M. E. (2006). **Perceived control over aging-related declines: Adaptive beliefs and behaviors**. *Current Directions in Psychological Science*, *15*, 282–286.
Find this resource:

Levy, B. (1996). **Improving memory in old age through implicit self-stereotyping**. *Journal of Personality and Social Psychology*, *71*, 1092–1107.
Find this resource:

Levy, B. (2009). **Stereotype embodiment: A psychosocial approach to aging**. *Current Directions in Psychological Science*, *18*, 332–336.
Find this resource:

Lineweaver, T. T., Berger, A. K., & Hertzog, C. (2009). **Expectations about memory change across the life span are impacted by aging stereotypes**. *Psychology and Aging*, *24*, 169–176.
Find this resource:

Lineweaver, T. T., & Hertzog, C. (1998). **Adults' efficacy and control beliefs regarding memory and aging: Separating general from personal beliefs**. *Aging, Neuropsychology, and Cognition*, *5*, 264–296.
Find this resource:

Lustig, C., & Flegal, K. E. (2008). **Targeting latent function: Encouraging effective encoding for successful memory training and transfer**. *Psychology and Aging*, *23*, 754–764.
Find this resource:

MacLaverty, S. N., & Hertzog, C. (2009). **Do age-related differences in episodic feeling of knowing accuracy depend on the timing of the judgement?** *Memory*, *17*, 860–873.
Find this resource:

Maddox, G. B., & Balota, D. A. (2012). **Self-control of when and how much to test face-name pairs in a novel spaced-retrieval paradigm: An examination of age-related differences**. *Aging, Neuropsychology, and Cognition*, *19*, 620–643.
Find this resource:

McCabe, D. P., & Soderstrom, N. C. (2011). **Recollection-based prospective metamemory judgments are more accurate than those based on confidence: Judgments of remembering and knowing (JORKS)**. *Journal of Experimental Psychology: General*, *140*, 605–621.
Find this resource:

Metcalfe, J. (2000). **Feelings and judgments of knowing: is there a special noetic state?** *Consciousness and Cognition*, *9*, 178–186.
Find this resource:

Metcalfe, J. (2002). **Is study time allocated selectively to a region of proximal learning?** *Journal of Experimental Psychology: General*, *131*, 349–363.
Find this resource:

Miller, L. M. S., & Lachman, M. E. (1999). **The sense of control and cognitive aging: Toward a model of mediational processes**. In T. M. Hess & F. Blanchard-Fields (Eds.), *Social cognition and aging* (pp. 17–41). San Diego, CA: Academic Press.
Find this resource:

Mitchell, K. J., & Johnson, M. K. (2009). Source monitoring 15 years later: What have we learned from fMRI about the neural mechanisms of source memory? *Psychological Bulletin*, *135*, 638–677.
Find this resource:

Morson, S. M., Moulin, C. J., & Souchay, C. (2015). **Selective deficits in episodic feeling of knowing in ageing: A novel use of the general knowledge task**. *Acta Psychologica*, *157*, 85–92.
Find this resource:

Murphy, M. D., Sanders, R. E., Gabriesheski, A. S., & Schmitt, F. A. (1981). **Metamemory in the aged**. *Journal of Gerontology*, *36*, 185–193.
Find this resource:

Murphy, M. D., Schmitt, F. A., Caruso, M. J., & Sanders, R. E. (1987). **Metamemory in older adults: The role of monitoring in serial recall**. *Psychology and Aging*, *2*, 331–339.
Find this resource:

Nelson, T. O. (1984). **A comparison of current measures of the accuracy of feeling-of-knowing predictions**. *Psychological Bulletin*, *95*, 109–133.
Find this resource:

Nelson, T. O. (1993). **Judgments of learning and study time allocation**. *Journal of Experimental Psychology: General*, *122*, 269–273.
Find this resource:

Nelson, T. O. (1996). **Consciousness and metacognition**. *American Psychologist*, *51*, 102–116.
Find this resource:

Nelson, T. O., & Dunlosky J. (1991). **When people's judgments of learning (JOLs) are extremely accurate at predicting subsequent recall: The delayed-JOL effect**. *Psychological Science*, *2*, 267–270.
Find this resource:

Nelson, T. O., Dunlosky, J., Graf, A., & Narens, L. (1994). **Utilization of metacognitive judgments in the allocation of study during multitrial learning**. *Psychological Science*, 5, 207–213.
Find this resource:

Nelson, T. O., Gerler, D., & Narens, L. (1984). **Accuracy of feeling-of-knowing judgments for predicting perceptual identification and relearning**. *Journal of Experimental Psychology: General*, 113, 282–300.
Find this resource:

Nelson, T. O., & Leonesio, R. J. (1988). **Allocation of self-paced study time and the 'labor-in-vain effect'**. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *14*, 676–686.
Find this resource:

Nelson, T. O., & Narens, L. (1990). Metamemory: A theoretical framework and new findings. In G. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 26, pp. 125–141). San Diego, CA: Academic Press.
Find this resource:

Nelson, T. O., Narens, L., & Dunlosky, J. (2004). **A revised methodology for research on metamemory: Pre-judgment recall and monitoring (PRAM)**. *Psychological Methods*, *9*, 53–69.
Find this resource:

Old, S. R., & Naveh-Benjamin, M. (2008). **Differential effects of age on item and associative measures of memory: A meta-analysis**. *Psychology and Aging*, *23*, 104–118.
Find this resource:

Pansky, A., Goldsmith, M., Koriat, A., & Pearlman-Avnion, S. (2009). **Memory accuracy in old age: Cognitive, metacognitive, and neurocognitive determinants**. *European Journal of Cognitive Psychology*, *21*, 303–329.
Find this resource:

Perfect, T. J., & Dasgupta, Z. R. (1997). **What underlies the deficit in reported recollective experience in old age?** *Memory & Cognition*, 25, 849–858.
Find this resource:

Perfect, T. J., & Stollery, B. (1993). **Memory and metamemory performance in older adults: One deficit or two?** *Quarterly Journal of Experimental Psychology*, *46*, 119–135.
Find this resource:

Perlmutter, M. (1978). **What is memory aging the aging of?** *Developmental Psychology*, *14*, 330–345.
Find this resource:

Perrotin, A., Isingrini, M., Souchay, C., Clarys, D., & Taconnat, L. (2006). **Episodic feeling-of-knowing accuracy and cued recall in the elderly: Evidence for double dissociation involving executive functioning and processing speed**. *Acta Psychologica*, *122*, 58–73.
Find this resource:

Perrotin, A., Tournelle, L., & Isingrini, M. (2008). **Executive functioning and memory as potential mediators of the episodic feeling-of-knowing accuracy**. *Brain and Cognition*, *67*, 76–87.
Find this resource:

Pliske, R. M., & Mutter, S. A. (1996). **Age differences in the accuracy of confidence judgments**. *Experimental Aging Research*, *22*, 199–216.
Find this resource:

Price, J., Hertzog, C., & Dunlosky, J. (2010). Self-regulated learning in younger and older adults: Does aging affect cognitive control? *Aging, Neuropsychology, and Cognition*, *17*, 329–359.
Find this resource:

Price, J., & Murray, R. (2012). **The region of proximal learning heuristic and adult age differences in self-regulated learning**. *Psychology and Aging*, *27*, 1120–1129.
Find this resource:

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*, 437–447.
Find this resource:

Rabinowitz, J. C. (1984). **Aging and recognition failure**. *Journal of Gerontology*, *39*, 65–71.
Find this resource:

Rast, P., & Zimprich, D. (2009). **Age differences in the underconfidence-with-practice effect**. *Experimental Aging Research*, *35*, 400–431.
Find this resource:

Richardson, J. T. E. (1998). **The availability and effectiveness of reported mediators in associative learning: A historical review and an experimental investigation**. *Psychonomic Bulletin* & *Review*, *5*, 597–614.
Find this resource:

Rhodes, M. G., & Castel, A. D. (2008). **Memory predictions are influenced by perceptual information: Evidence for metacognitive illusions**. *Journal of Experimental Psychology: General*, *137*, 615–625.
Find this resource:

Rhodes, M. G., & Tauber, S. K. (2011). **The influence of delaying judgments of learning on metacognitive accuracy: A meta-analytic review**. *Psychological Bulletin*, *137*, 131–148.
Find this resource:

Roediger, H. L., & McDermott, K. B. (1995). **Creating false memories: Remembering words not presented in lists**. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*, 803–814.
Find this resource:

Sacher, M., Isingrini, M., & Taconnat, L. (2013). **Effects of aging and divided attention on episodic feeling-of-knowing accuracy**. *Acta Psychologica*, *144*, 258–263.
Find this resource:

Sacher, M., Landré, L., & Taconnat, L. (2015). **Age-related differences in episodic feeling-of-knowing arise from differences in memory performance**. *Memory*, *23*, 119–126.

Find this resource:

Schneider, W., & Pressley, M. (2013). *Memory development between two and twenty*. Mahwah, NJ: Lawrence Erlbaum Associates.
Find this resource:

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Belmont, CA: Wadsworth.
Find this resource:

Shallice, T. I. M., & Burgess, P. W. (1991). **Deficits in strategy application following frontal lobe damage in man**. *Brain*, *114*, 727–741.
Find this resource:

Shaughnessy, J. J. (1981). **Memory monitoring accuracy and modification of rehearsal strategies**. *Journal of Verbal Learning and Verbal Behavior*, *20*, 216–230.
Find this resource:

Shimamura, A. P. (2000) **Toward a cognitive neuroscience of metacognition**. *Consciousness & Cognition*, *9*, 313 –323.
Find this resource:

Shing, Y. L., Werkle-Bergner, M., Li, S. C., & Lindenberger, U. (2009). **Committing memory errors with high confidence: Older adults do but children don't**. *Memory*, *17*, 169–179.
Find this resource:

Soderstrom, N. C., McCabe, D. P., & Rhodes, M. G. (2012). **Older adults predict more recollective experiences than younger adults**. *Psychology and Aging*, *27*, 1082–1088.
Find this resource:

Souchay, C., & Isingrini, M. (2004). **Age related differences in metacognitive control: Role of executive functioning**. *Brain and Cognition*, *56*, 89–99.
Find this resource:

Souchay, C., Isingrini, M., & Espagnet, L. (2000). **Aging, episodic memory feeling-of-knowing and frontal functioning**. *Neuropsychologia*, *14*, 299–309.
Find this resource:

Souchay, C., Moulin, C. J. A., Clarys, D., Taconnat, L., & Isingrini, M. (2007). **Diminished episodic memory awareness in older adults: Evidence from feeling-of-knowing and recollection**. *Consciousness and Cognition*, *16*, 769–784.
Find this resource:

Stigsdotter Neely, A. (2000). Multifactorial memory training in normal aging: In search of memory improvement beyond the ordinary. In R. D. Hill, L. Bäckman, & A. Stigsdotter Neely (Eds.), *Cognitive rehabilitation in old age* (pp. 63–80). New York: Oxford University Press.

Find this resource:

Storm, B. C., & Hickman, M. L. (2015). **Mental fixation and metacognitive predictions of insight in creative problem solving**. *Quarterly Journal of Experimental Psychology*, *68*, 802–813.

Find this resource:

Tarricone, P. (2011). *The taxonomy of metacognition*. New York: Psychology Press.

Find this resource:

Tauber, S. K., & Rhodes, M. G. (2012). **Multiple bases for young and older adults' judgments of learning in multitrial learning**. *Psychology and Aging*, *27*, 474–483.

Find this resource:

Thomas, A. K., & Bulevich, J. B. (2006). **Effective cue utilization reduces memory errors in older adults**. *Psychology and Aging*, *21*, 379–389.

Find this resource:

Thomas, A. K., Bulevich, J. B., & DuBois, S. (2011). **Context affects feeling-of-knowing accuracy in younger and older adults**. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *37*, 96–108.

Find this resource:

Toth, J. P., Daniels, K. A., & Solinger, L. A. (2011). **What you know can hurt you: Effects of age and prior knowledge on the accuracy of judgments of learning**. *Psychology and Aging*, *26*, 919–931.

Find this resource:

Touron, D. R., Hertzog, C., & Speagle, J. Z. (2010). **Subjective learning discounts test type**. *Experimental Psychology*, *57*, 327–337.

Find this resource:

Tullis, J. G., & Benjamin, A. S., (2012). **Consequences of restudy choices in younger and older learners**. *Psychonomic Bulletin & Review*, *19*, 743–749.

Find this resource:

Undorf, M., & Erdfelder, E. (2011). **Judgments of learning reflect encoding fluency: Conclusive evidence for the ease-of-processing hypothesis**. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *37*, 1264–1269.

Find this resource:

Van Ocker, J. S., Light, L. L., Olfman, D., & Rivera, J. (2017). **Effects of repetition on age differences in associative recognition**. *Memory*, *25*, 350–359.

Find this resource:

Weaver, C. A., III, & Kelemen, W. L. (2003). **Processing similarity does not improve metamemory: Evidence against transfer-appropriate monitoring**. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*, 1058–1065.
Find this resource:

West, R. L. (1988). Prospective memory and aging. In M. M. Grunebberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory: Current research and issues: Clinical and educational implications* (Vol. 2, pp. 119–125). New York: Wiley.
Find this resource:

West, R. L., Bagwell, D. K., & Dark-Freudeman, A. (2008). **Self-efficacy and memory aging: The impact of a memory intervention based on self-efficacy**. *Aging, Neuropsychology, and Cognition*, *15*, 302–329.
Find this resource:

West, R. L., & Hastings, E. C. (2011). **Self-regulation and recall: Growth curve modeling of intervention outcomes for older adults**. *Psychology and Aging*, *26*, 803–812.
Find this resource:

West, R. L., Thorn, R. M., & Bagwell, D. K. (2003). **Memory performance and beliefs as a function of goal setting and aging**. *Psychology and Aging*, *18*, 111–125.
Find this resource:

Wickens, T. D. (2002). *Elementary signal detection theory*. New York, NY: Oxford University Press.
Find this resource:

Wixted, J. T. (2007). **Dual-process theory and signal-detection theory of recognition memory**. *Psychological Review*, *114*, 152–176.
Find this resource:

Wong, J. T., Cramer, S. J., & Gallo, D. J. (2012). **Age-related reduction in the confidence-accuracy relationship in episodic memory: Effects of recollection quality and retrieval monitoring**. *Psychology and Aging*, 27, 1053–1065.
Find this resource:

Wong, J. T., & Gallo, D. A. (2016). **Stereotype threat reduces false recognition when older adults are forewarned**. *Memory*, *24*, 650–658.
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Notes:

(1.) The correct answer is: Ice.

(2.) This outcome was not a focus of the analyses in the original paper, so we report the test result here.

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