Memory underpinnings of decision-making competence: An adult lifespan perspective

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Abstract

Decision-making competence refers to the ability to make judgments and decisions that follow normative criteria of rationality. Here, we review research on memory skills underlying decision-making competence from an adult lifespan perspective. First, we discuss how aspects of decision-making competence are associated with memory skills, and how situational and strategic variations may modulate these relationships. Then, we examine the relationships between age-related differences in decision-making competence and age-related differences in memory skills. Because the relationship between memory and decision making may be reciprocal, we also consider research on how decisions may affect memory. Next, we discuss how decision-making competence may be built and maintained across the adult life span. Finally, we highlight open questions and propose possible future research directions.

Keywords: decision-making competence; memory; cognitive aging; decision support; metacognition; critical thinking

1. What is decision-making competence and why do we need to study it?

Decision-making competence refers to the ability to make good judgments and decisions and is central to obtaining good life decision outcomes (see e.g., Bruine de Bruin et al., 2007; Parker & Fischhoff, 2005). Traditional research on judgment and decision making mostly ignored individual differences but instead focused on how situational variables, like the positive or negative framing of presented information, may affect decision making (Tversky & Kahneman, 2000). Levin (1999) was among the first to point out the need to study individual differences, as well as to understand and improve people's ability to make good judgements and decisions (see also Bruine de Bruin, Del Missier & Levin, 2012). A shift towards assessing individual differences was also motivated by seminal studies that reported positive correlations across decision-making tasks – thus suggesting stable individual-differences (Stanovich & West, 1998; see also Stanovich & West, 2008). Below, we discuss subsequent work that focused on the development and validation of instruments for measuring individual differences in decision-making competence, with performance on several tasks evaluated according to normative criteria for rational decision making.[1]

1.1 Skills underlying decision-making competence

Although decision-making competence refers to the ability to make good judgments and decisions, it has been operationalized in different ways. According to Finucane and Lees (2005), the quality of a decision depends on how well the demands of the task and context fit with decision makers' skills, which may depend on their age, cognitive and affective abilities, memory, and experience. Finucane and Lees (2005) identified five main sets of skills underlying decision-making competence. *Decision structuring* skills support the construction of the decision-problem representation: finding out options and attributes to consider and defining decision consequences and their likelihoods. Other skills include *comprehension* of problem-related information, *information integration* during judgment or choice, *insight*, comprising metacognitive skills, and *affective fluency*,

[1] Normative criteria used to evaluate decision-making competence are usually derived from theories of probability and subjective utility (Stanovich & West, 2008) or population statistics (e.g., Lichtenstein et al., 1978). For normative models in the context of decision-making research, see Keeney and Raiffa (1993), Raiffa et al. (2003), and Edwards (1954).

or the ability to evaluate affectively information in relation to personal goals and preferences and to combine affective and analytical evaluations. Finucane and Gullion (2010) validated a tool for measuring older adults' decision-making competence, using three decision-making tasks focused on *comprehension* of information, *dimension weighting*, which reflects accurate weighting of options' features in line with personal preferences, and *cognitive reflection*, which refers to the metacognitive ability to favor analytic over intuitive processes when needed. In their study, performance on these three decision-making tasks was positively related with measures of short-term memory and associative memory, and negatively related with age.

The tasks comprising Parker and Fischhoff's (2005) youth decision-making competence (Y-DMC) and Bruine de Bruin et al.'s (2007) adult decision-making competence (A-DMC) instruments were introduced as covering four categories of decision-making skills: *belief assessment* or the ability to judge the likelihood of outcomes, *value assessment* or the ability to evaluate outcomes, *information integration* or the ability combine beliefs and values in making decisions, and *metacognition* or knowing the extent of one's abilities. The Adult Decision-Making Competence (A-DMC) instrument includes six decision-making tasks (Table 1), showing good psychometric properties. Its overall score was associated with SES, fluid intelligence, crystallized intelligence (Bruine de Bruin et al., 2007), and some of its component tasks were correlated with age and executive functioning (Bruine de Bruin et al., 2007; Bruine de Bruin, Parker & Fischhoff, 2012; Del Missier et al., 2012, 2013, 2017; see also Parker & Fischhoff, 2005). Moreover, better A-DMC performance was associated with better life decision-making outcomes, as measured with the Decision Outcomes Inventory (DOI), over and above fluid intelligence, crystallized intelligence, and demographics (Bruine de Bruin et al., 2007).[2]

[2] The DOI first asks respondents to indicate whether they have made a specific decision in the last 10 years (e.g., bought a car). For each decision, they are then asked to specify if it had a negative outcome (e.g., they had to spend $500 to fix a car owned for less than half a year). The overall DOI score reflects the number of negative outcomes respondents had avoided out of those they had the opportunity to experience, weighted by the severity of the outcome, using the proportion of participants who reported not experiencing outcomes as a proxy for severity (Bruine de Bruin et al., 2007).

Table 1

A-DMC tasks and corresponding decision-making skills, normative criteria, and scores for performance evaluation (Bruine de Bruin et al., 2007).

<table>
<tr><th>A-DMC Task</th><th>Category of decision-making Skill</th><th>Normative criterion</th><th>Performance Score</th><th>Example item</th></tr>
<tr><td>Resistance to Framing
Judging the value of an option independently of whether its outcomes are described in positive or negative terms (e.g., 75% success rate vs. 25% failure rate)</td><td>Value assessment
Integration</td><td>Consistency in the evaluation of the same options despite variations in their description</td><td>Absolute difference between ratings of related frames</td><td>In a recent confidential survey completed by graduating seniors, 35% of those completing the survey stated that they had never cheated during their college career.

Considering the results of the survey, how would you rate the incidence of cheating at your university?

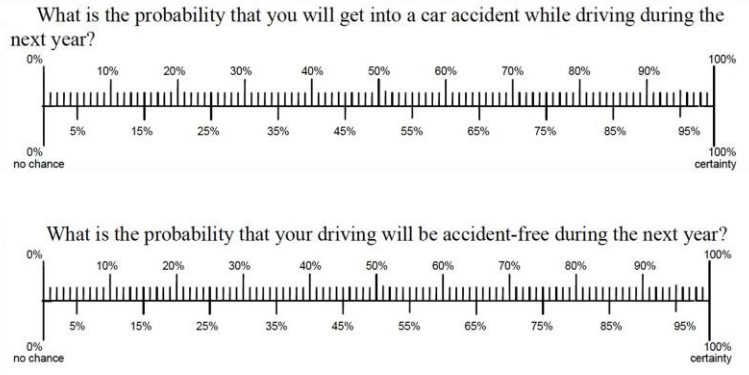
1 2 3 4 5 6
Very low Very high

In a recent confidential survey completed by graduating seniors, 65% of those completing the survey stated that they had cheated during their college career.

Considering the results of the survey, how would you rate the incidence of cheating at your university?

1 2 3 4 5 6
Very low Very high</td></tr>
<tr><td>Applying Decision Rules
Correctly applying predefined strategies for choosing among available options</td><td>Integration</td><td>Accuracy in the implementation of decision rules</td><td>Percent of correct answers</td><td>Features
<table><tr><th></th><th></th><th>Picture Quality</th><th>Sound Quality</th><th>Programming Options</th><th>Reliability of Brand</th><th>Price</th></tr><tr><td>DVD</td><td>A</td><td>2</td><td>5</td><td>5</td><td>5</td><td>$369</td></tr><tr><td></td><td>B</td><td>5</td><td>4</td><td>4</td><td>5</td><td>$369</td></tr><tr><td></td><td>C</td><td>5</td><td>3</td><td>2</td><td>5</td><td>$369</td></tr><tr><td></td><td>D</td><td>3</td><td>5</td><td>2</td><td>2</td><td>$369</td></tr><tr><td></td><td>E</td><td>4</td><td>4</td><td>4</td><td>5</td><td>$369</td></tr></table>Sally first selects the DVD players with the best Sound Quality. From the selected DVD players, she then selects the best on Picture Quality. Then, if there is still more than one left to choose from, she selects the one best on Programming Options.

Which <u>one</u> of the presented DVD players would Sally prefer? _____</td></tr>
</table>

Recognizing Social Norms Knowing how peers evaluate the acceptability of potentially negative behaviors (e.g., stealing)	Belief assessment Value assessment	Accuracy in the perception of group's social norms	Rank correlation between participant's judged proportions (out of 100 people…) and actual proportions endorsing the norms in the sample	Do you think it is sometimes OK … … to steal under certain circumstances? Yes No Out of 100 people your age, how many would say it is sometimes OK … … to steal under certain circumstances? 0 10 20 30 40 50 60 70 80 90 100 No one Everyone
Resistance to Sunk Costs Discontinuing investments into activities despite irrecoverable losses (or sunk costs)	Belief assessment	Accuracy in terms of avoidance of irrecoverable past costs	Average rating across items	You are in a hotel room for one night and you have paid $6.95 to watch a movie on pay TV. Then you discover that there is a movie you would much rather like to see on one of the free cable TV channels. You only have time to watch one of the two movies. Would you be more likely to watch the movie on pay TV or on the free cable channel? 1 2 3 4 5 6 Most likely to watch pay TV Most likely to watch free cable
Consistency in Risk Perception Assessing the likelihood of relative outcomes in ways consistent with probability theory (e.g., the probability of two mutually exclusive and exhaustive options should add up to 100%)	Belief assessment	Consistency of one own's judgments according to the rules of probability	Percent of consistent risk judgments	
Under/Overconfidence Recognizing the strengths and limitations of one's knowledge	Belief assessment Metacognition	Accuracy in the assessment of one own's knowledge	1 – absolute difference between mean confidence and percentage correct in the set of judgments	**Alcohol causes dehydration.** This statement is [True / False]. 50% 60% 70% 80% 90% 100% just guessing absolutely sure

Summarizing insights from previous efforts, Strough et al. (2015) proposed that decision-making competence is supported by deliberative skills such as fluid intelligence, working memory, and executive control, affective skills related to affect and coping, and experiential skills including crystallized abilities and experience. Strough et al.'s (2015) framework considers both the role of the context and the decision maker's individual features including age, gender, personality, and cognitive style (following Finucane & Lees, 2005). Additionally, Strough et al. (2015) highlight the role of motivation, such that individuals who wants to make good decisions may try harder to apply their deliberative, affective, and experiential skills.

2 How are decision-making competence and memory associated across the adult lifespan?

2.1 Memory underpinnings of decision-making competence tasks

In this review, we focus on working memory, episodic memory, semantic memory or knowledge, and implicit/nondeclarative memory, which are deemed as relevant for supporting decision making (Del Missier, Mäntylä, & Nilsson, 2015). Although there is not a perfect match between these aspects of memory and the deliberative, experiential, and affective skills supporting decision-making competence proposed by Strough et al. (2015), working memory has been mainly associated with decisions requiring deliberative skills, episodic and semantic memory with decisions based on experience and knowledge, and implicit/nondeclarative memory with decisions based on intuitive evaluations, including the one based on immediate affective reactions (Del Missier, Mäntylä & Nilsson, 2015). Table 2 summarizes the associations between the memory skills discussed in this section and performance in decision-making tasks.

Table 2

Summary of the associations between performance in decision-making tasks and memory measures.

Memory	Decision-making task	Memory measures
Working memory	• Resistance to Framing* (Del Missier et al., 2013) • Applying Decision Rules* (Del Missier et al., 2013) • Rule-based judgment (Hoffman et al., 2014) • Probability judgment on a focal option (Dougherty & Hunter, 2003) • Sensitivity to expected value (Kray et al., 2021)	• Reading span, n-back • Reading span, n-back • Reading span, operation span, symmetry span • Operation span • Counting span, reading span, symmetry span
Episodic memory	• Recognizing Social Norms* (Del Missier et al., 2013) • Judgment based on retrieval of exemplars (Hoffman et al., 2014) • Judgment based on specific past experiences (Stragà et al., 2017) • Option generation in simple time-pressured tasks (Kaiser et al., 2013)	• Recall of sentences, cued recall of nouns, recognition of nouns • Free recall of pictures, cued recall of numbers, recognition of verbs • Cued recall of movie scenes and their evaluation • Verbal learning and memory test
Semantic memory (or knowledge)	• Resistance to Sunk Costs* (Del Missier et al., 2013) • Resistance to Sunk Costs, two items (Eberhardt et al., 2019) • Real estate decisions with sunk costs (Fennema & Perkins, 2008) • Financial and nonfinancial sunk cost problems (Larrick et al., 1990) • Consistency in Risk Perception* (Del Missier et al., 2013)	• General knowledge test, SRB vocabulary test • Financial experience and literacy measures • Number of college courses in managerial accounting • Training in cost-benefit rules • General knowledge test, SRB vocabulary test

Note. Implicit/nondeclarative memory is missing in the table due to the scarcity of individual-differences studies on its relationship with decision-making competence (see sections 2.1.4 and 4). * Task is part of A-DMC (Table 1).

2.1.1 Working memory and decision-making competence. Working memory supports the temporary maintenance and dynamic updating of task-relevant information, while resisting interference from distractors (Baddeley et al., 2021). Working memory processes may be needed, for instance, for keeping active task-relevant information during the application of decision rules or while mentally comparing decision options.

Performance on two A-DMC tasks seems to be positively related with working memory (Del Missier et al., 2013) even after controlling for individual differences in semantic and episodic memory (Del Missier et al., 2013), or in processing speed and sensory functioning (Del Missier et al., 2017). The first A-DMC task that has been associated with working memory, Resistance to Framing (Table 2), assesses whether participants respond consistently to a positively framed and a negatively framed version of the same decision problems (Table 1). The positive association between working memory and Resistance to Framing may be due to participants with better working memory skills being better able to inhibit the intuitive superficial response triggered by problem framing and to express a more thoughtful evaluation of the options (Del Missier et al., 2013; see also De Martino et al., 2006).

The second A-DMC task that has been associated with working memory, Applying Decision Rules (Table 2), instructs participants to apply decision strategies to choose between options that differ on multiple attributes (e.g., Payne et al., 1993; Table 1). The positive association between working memory and Applying Decision Rules has been explained by the supporting role of working memory during rule application (Del Missier et al., 2017), which requires temporary maintenance of task-relevant information and information integration. This account can also explain the finding that working memory is positively related with the accuracy of judgments based on rules learned from experience (Hoffman et al., 2014; Table 2). In the training phase of Hoffman et al.'s study (2014), participants had to learn how to judge whether comic figures were good or bad catchers of small creatures, and to perform this task they learned a rule based on a linear combination of comic figures' features. In the test phase of this study, participants were asked to judge the catching ability of new

comic figures, which could be predicted by the same information integration rule. Participants who had better working memory skills applied the rule more accurately.

Working memory is also positively related with other decision-making tasks, such as the ability to provide better judgments of probability for a focal option (Dougherty & Hunter, 2003; Table 2). Participants first observed a customer who ordered several menu items. They were then asked to judge the likelihood that a particular menu item, the focal option, would be ordered by the same customer. Participants with better working memory skills provided better likelihood judgments. It was proposed that working memory supports the active consideration of a greater number of alternative menu items potentially ordered by the customer while making the likelihood judgment about the focal menu item (Dougherty & Hunter, 2003).

Working memory span measures have also been found to be positively associated with sensitivity to expected value in a sample of adolescents (Kray et al., 2021; Table 2). Sensitivity to expected value is usually assessed by asking participants to choose between two options for which probabilities of gains and losses are specified. Participants are considered sensitive to expected value if they choose the option with the higher expected value (Parker & Weller, 2015). For instance, participants may be asked to choose between 1 euro for sure and a lottery with a 50% probability of winning 6 euro and a 50% probability of winning nothing. Computing the expected value for the risky option requires combining probabilities and consequences: (50% * 6 euro) + (50% * 0 euro) = 3 euro. Working memory may support this cognitively demanding task (Kray et al., 2021) allowing participants to integrate information and keep in mind the values of the options.

2.1.2 Decision-making competence and episodic memory. Episodic memory supports encoding and retrieval of memory traces for past events (Nyberg & Tulving, 1996; Tulving, 1972). These processes are thought to be involved in judging the likelihood of past events, and in evaluating whether a new event is like an event from the past (Del Missier, Mäntylä & Nilsson, 2015; see also Fiedler; 2000; Thomas et al. 2008). Indeed, episodic memory has been positively associated with performance in Recognizing Social Norms (Del Missier et al., 2013; Table 2). This task involves judging the frequency with which peers believe it is sometimes OK to engage in undesirable

behaviors like stealing (Table 1). Performance may be based on the experience of social norms, as accumulated in episodic memory (Brown, 2002; Haberstroh, 2008; see also Bruine de Bruin, Parker, et al., 2012). In particular, frequency judgments about peers' behaviors may be based on the ability to encode instances of classes of behaviors, like stealing, and to estimate their frequency (Brown, 2002).

In a difficult version of Hoffman et al.'s (2014) judgment task (cf. section 2.1.1; Table 2), participants had to learn how to judge the toxicity of fictitious bugs, based on a combination of the bug's features. Learning a rule was difficult because it required the understanding of a complex multiplicative relationship between the bugs' features. Therefore, participants had to resort to their episodic memory to judge new bugs based on their similarity with previously encountered bugs. Indeed, in this version of the judgment task, participants with better episodic memory skills obtained a better performance.

Another example of episodic memory support for judgment comes from Stragà et al. (2017, Study 2, Table 2). In this study, participants watched a movie and then expressed their future intentions about a minor character of that movie. For example, they were asked how willing they were to see a new movie centered on the minor character. Participants' judgments of future intentions were positively associated with their evaluation of the scenes involving the minor character retrieved from memory.

When judgments and decisions in complex real-word contexts are based on extensive experience and practice, they may involve a combination of recognition processes, based on episodic memory, and procedural skills. Indeed, studies in naturalistic contexts show how the decisions of professionals, such as firefighters, pilots, emergency doctors, often involve recognizing a situation from previous experience and responding based on learned associations with appropriate procedures for that situation (Klein, 1998).

2.1.3 Decision-making competence and semantic memory. Semantic memory is involved when learning and using conceptual knowledge and vocabulary (Nyberg & Tulving, 1996; Tulving 1972). These processes are relevant when judgments and decisions require knowledge (e.g., Li et al., 2015).

For example, individuals may be more likely to make the correct decision to discontinue investments after experiencing "sunk costs" or irrecoverable losses when they have more knowledge about the economic principle to ignore sunk costs (Fennema, & Perkins, 2008; Larrick et al., 1990; Table 2). In the Resistance to Sunk Costs A-DMC task (Table 1), participants are asked to choose between continuing or discontinuing investments into an activity despite irrecoverable losses (Arkes & Blumer, 1985). Participants with better semantic memory skills were better able to avoid sunk costs (Del Missier et al., 2013; Table 2), suggesting that knowledge has a positive role in this task.

Moreover, decision makers may be better at consistently judging probabilities when they have learned probability rules or at least they have an intuitive grasp of them (Stanovich & West, 2008). In line with this view, participants gave more consistent judgments of probability across different scenarios in the Consistency of Risk Perception A-DMC task (Table 1) when they had better semantic memory skills (Del Missier et al., 2013; Table 2), pointing again to the role of knowledge.

Indeed making good decisions requires knowing the rules, strategies, or principles – also referred to as "mindware" (Stanovich & West, 2008). However, in addition to having acquired these rules, strategies, and principles, decision makers also need to understand when these apply, and have the cognitive ability to overcome incorrect alternative responses (Stanovich & West, 2008).

2.1.4 Decision-making competence and implicit/nondeclarative memory. Implicit/nondeclarative memory refers to procedural memory, classical conditioning, and other nondeclarative processes (Baddeley et al., 2020; Nyberg & Tulving, 1996). Intuitive decision-making has been associated with various implicit/nondeclarative processes (Glöckner & Witteman, 2010), such as implicit learning (see also Lieberman, 2000), associative learning, conditioning, basic emotional reactions, and procedural learning[3]. However, to the best of our knowledge, individual-differences studies on the relationship between implicit/nondeclarative memory and decision-making competence tasks are lacking, possibly due to measurement issues (e.g., Hoffman et al., 2014). At a more general level, while correct intuitions can facilitate effective judgment and decision making

[3] According to Kruglanski and Gigerenzer (2011), some judgment heuristics can be applied not only intuitively but also deliberatively, implementing the same rule, depending on the context of application.

(e.g., Queen & Hess, 2010; on normatively correct intuitions see also De Neys, 2012), intuitions may also be wrong (Frederick, 2005; Stanovich & West, 2008). In the latter case, overreliance on intuition instead of deliberation can undermine decision performance, assuming that deliberation is able to produce the right answer without errors, which is also not always the case. Therefore, a key metacognitive aspect of decision-making competence can also be understanding when to trust or block intuition (Finucane & Gullion, 2010; Stanovich & West, 2008; see also section 4).

2.1.5 Reliance on multiple skills and strategy-related changes. Because making judgments and decisions is usually rather complex, multiple skills, beyond memory, may be needed to perform well (see also Strough et al., 2015). As an example, the ability to resist sunk costs has been found to be positively related both to having more knowledge about the sunk cost avoidance principle (Larrick et al., 1990) and to affective aspects such as avoiding rumination about past unrecoverable costs (Bruine de Bruin et al., 2014).

Additionally, the role of memory processes in making judgments and decisions may change with the strategy that is being used, which depends on the specific features of the decision-making task and context (Appelt et al., 2011; Payne et al., 1993). For instance, consider the ability to generate options, which is a fundamental aspect of decision structuring (e.g., Galotti, 2007; Keeney, 2004). One study asked participants to generate options for relatively simple problems in a short time: "You missed your train and have an hour to wait until the next train comes. What could you do?" (Kaiser et al., 2013). The number of generated options was predicted by an episodic memory test, reflecting the ability to retrieve stored information, but not by a test of ideation fluency, which refers to the ability to produce various ideas in response to some preset requirements (Del Missier, Visentini & Mäntylä, 2015). However, when more time was allotted and problems were more complex, ideation fluency was a stronger predictor of the number of valid options than episodic memory (Del Missier, Visentini & Mäntylä, 2015), suggesting a transition from cued recall to more active search and ideation strategies. Similarly, performance on Hoffman et al.'s (2014) judgment task was associated with working memory or with episodic memory, depending on the strategies triggered by the nature of the task (see sections 2.1.1 and 2.1.2; on strategy shifts see also Hoffman et al., 2013).

2.2 Age differences in memory and in decision-making competence

Depending on the task, memory performance may decrease, be maintained, or even increase across the adult life span (Rönnlund et al., 2005; Saltouse, 2014). Working memory (Bopp, & Verhaeghen, 2005) and episodic memory (Park et al., 1996, 2002) both show a negative correlation with age, while implicit memory and procedural memory are relatively spared from age-related declines (LaVoie & Light, 1994; Prull et al., 2000). Semantic memory shows an age-related improvement until the seventies (Salthouse et al., 2003; Salthouse, 2004) despite performance becoming slower (see also Del Missier, Mäntylä & Nilsson, 2015; Salthouse, 2012). However, age-related differences are more accentuated in cross-sectional vs. longitudinal studies (Rönnlund et al., 2005; Salthouse, 2014).

We suggest that, perhaps due to the differential roles of these types of memory, decision-making competence may also decrease, be maintained, or even increase across the adult life span. Older adults perform less well than younger adults on applying decision rules and resisting framing effects (Bruine de Bruin, Parker et al., 2012; Del Missier et al., 2013). Age differences in these abilities can be partially explained by age differences in fluid intelligence and working memory (Bruine de Bruin, Parker et al., 2012; Del Missier et al., 2013; see Table 2). Expected value sensitivity in risky choice, which is positively related with working memory (Kray et al., 2021), is also lower in older adults than in younger adults (Parker & Weller, 2015). Specifically, expected value sensitivity showed an inverted-U-shaped function over the lifespan, among participants aged 5 to 85 years, increasing from childhood to adulthood but then decreasing for the elderly for both risky gains and risky losses (Weller et al., 2011). This finding was interpreted as reflecting the role of the frontal lobe in decision making and its development and degradation over the lifespan (Weller et al., 2011).

In contrast, adult age seems to have no negative correlation with various other tasks measuring decision-making competence, such as the abilities to recognize social norms, provide consistent risk judgments, and resist sunk costs (e.g., Bruine de Bruin, Parker et al., 2012). As we have seen (Table 2), these tasks seem to rely more on episodic or semantic memory. Interestingly, a positive

relationship between age and Recognizing Social Norms was observed after the negative association of age with episodic memory was taken into account (Del Missier et al., 2013). Possibly, this reflects the increased social experience or sensitivity of older participants when providing judgments about other individuals (see also Hess et al., 2005; Peters et al., 2007).

Additionally, adult age may be positively associated with the ability to make decisions that require experience-based knowledge (e.g., Li et al., 2015). Semantic memory, which generally improves across the adult lifespan, may help to improve decisions that require experience-based knowledge (see Table 2). Older adults tend to make better financial decisions than younger adults, perhaps as a result of having learned relevant financial information (e.g., Li et al., 2015). Indeed, people who have learned about the economic sunk-cost principle tend to make better decisions when being faced with sunk costs or irrecoverable losses (Fennema, & Perkins, 2008). Moreover, older adults tend to be better than younger adults at maintaining positive emotions by avoiding focusing on experienced losses, which may further benefit their ability to resist sunk costs (Eberhardt et al., 2019; Strough et al., 2011). This coping tendency may be also enhanced by an age-related increase in loss aversion (see Horn, 2023, for an overview), which may motivate further efforts to defocus from experienced losses (see Bruine de Bruin et al. 2014).

Decision-making tasks that rely on intuition may show no or small age-related differences (see also Queen & Hess, 2010), perhaps because implicit memory processes that support intuition are maintained in older age (e.g., LaVoie & Light, 1994; Prull et al., 2000). However, older adults may rely more on intuition than younger adults even when intuition fails. Indeed, older adults perform worse on Frederick's (2005) Cognitive Reflection Test (Finucane & Gullion, 2010), in which participants must inhibit wrong intuitive responses and generate accurate ones instead. For example, one item asks "A bat and a ball cost $1.10 in total. The bat costs a dollar more than the ball. How much does the ball cost?" The intuitive wrong answer is10 cents, and the right answer is 5 cents.

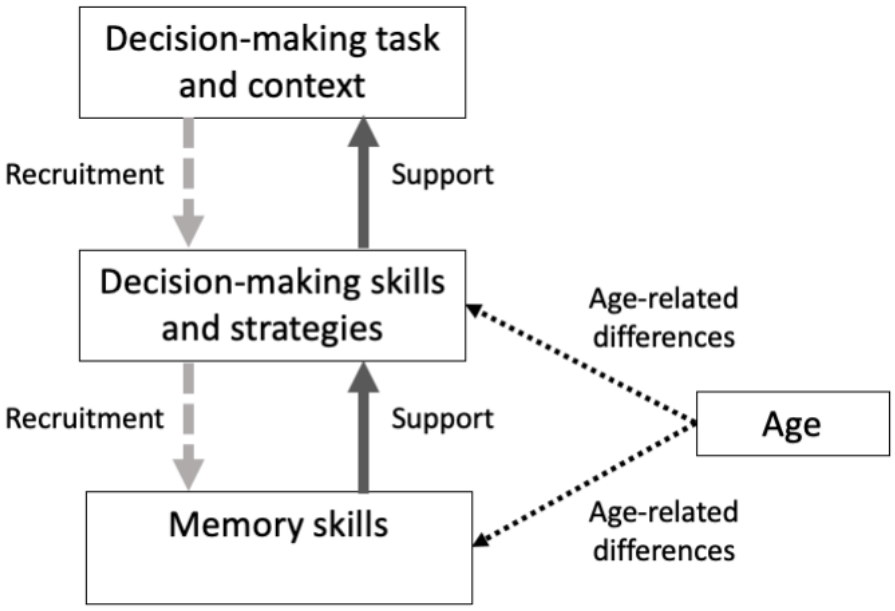
It has been argued that older adults may fare relatively well in daily life due to making adaptive shifts towards more experiential, semantically based, or externally supported strategies (Salthouse, 2012). This idea seems compatible with decision-making studies highlighting that crystallized or

experiential abilities may compensate for the loss of fluid abilities in the aged decision maker (Bruine de Bruin, Parker et al., 2012; Del Missier et al., 2020; Li et al., 2013, 2015). Moreover, older adults may rely less than younger adults on cognitively demanding strategies (e.g., Johnson, 1990; Mata et al., 2007; Mata et al., 2012). While avoiding cognitively demanding strategies may make judgments and decisions easier to execute, it may potentially lead to poorer outcomes when more complex processing is unavoidable (e.g., Mata et al., 2010).

Figure 1 summarizes our view of the relationships between memory, decision-making competence, and age. Individuals may leverage different decision-making skills and strategies to support their decision making, depending on their age, as well as the task and context (see also Payne et al., 1993). These skills and strategies may rely on various memory skills, which may vary with age (see also Strough et al., 2015).

Figure 1

Relationships between decision task and context, decision-making skills and strategies, and memory skills.



2.3 From decisions to memory

Although both theories and evidence suggest that the relationship between memory and decision making is reciprocal, the path from decisions to memory has been explored much less than the path from memory to decision making (Lind et al., 2017). However, the decisions people make may affect their memory (Mather & Johnson, 2000). For instance, people tend to attribute more positive and fewer negative features to chosen options than to foregone options, which is referred to as choice-supportive memory (Mather & Johnson, 2000). A potential explanation of choice-supportive memory is schema-driven processing, which refers to the influence of semantic memory on the episodic recall of options' features. Indeed, participants tend to classify the chosen option as 'good' and the foregone option as 'bad' and this classification biases their memory of the options' features (Lind et al., 2017). Although it has been suggested that choice-supportive memory may be stronger in older adults, findings are mixed (Lind et al., 2017).

Another important topic in the investigation of the relationships between decision-making and memory is the ability to learn from past decisions, which may vary with age (Mata et al., 2011). A meta-analysis of studies on age-differences in risky decision making (Mata et al., 2011) found that older adults performed worse than younger adults when learning how to make repeated risky decisions, like in the Iowa Gambling task and the Balloon Analog Risk Task. In the Iowa Gambling task, participants can make money by repeatedly choosing between four decks of cards that provide them with differential chances of gains and losses (Bechara et al., 1994). In the Balloon Analog Risk Task, participants can make money by pumping balloons as much as possible, but they lose money when balloons pop (Lejuez et al., 2002). Indeed, while older adults tend to perform less well than younger adults' on these decision tasks, they can perform as well as younger when risky decisions were made from written descriptions of probabilities and outcomes (Mata et al., 2011). However, an aforementioned study showed that older adults were less sensitive to expected value than younger adults, even when making risky choices from written descriptions (e.g., Parker & Weller, 2015), and there is a concern that older adults may use only a subset of presented information, perhaps to manage cognitive demands (Weller et al., 2019).

The relationship between decision-making and memory is also evident from studies that investigated the hindsight bias, using the so-called memory design (Pohl, 2007). In this design, participants are initially asked to make a series of judgments (e.g., how many teeth does an alligator have?). Subsequently, participants are presented with the correct answers for some of these items, but not for others. When participants are presented with the questions again and asked to recall their original judgments, their recalled judgments are biased towards the correct answers, if they were provided. One of the possible explanations is that the feedback about the correct answer leads to a to biased reconstruction of the original judgment (Bernstein et al., 2011). Older adults seem to be more affected by the hindsight bias than younger ones (Bernstein et al., 2011; see also Groß & Bayen 2022).

3. Can decision-making competence be built as a core competence and maintained as a specific type of reserve?

There is promising initial evidence that decision-making competence can be strengthened through educational interventions that explain how to make better judgments and decisions (e.g., Jacobson et al., 2012; Rosi et al., 2019; Zwilling et al., 2019). However, individuals also need help with applying what they have learned in concrete real-world contexts (e.g., Larrick, 2004). Transfer of learning to different contexts can be hampered when it is difficult to recognize when a learned rule, principle, or strategy applies (see also Stanovich & West, 2008). Decision aids and help from others may also be provided to support decisions (e.g., Soll et al., 2016), and may be especially beneficial to older adults (see also Hanoch et al., 2011; Salthouse, 2012; Wood et al., 2011).

Once people have learned how to make judgments and decisions, they may be able to maintain it across the life span. Indeed, an American 11-year longitudinal study reported positive correlations between performance on two versions of the Y-DMC battery completed at age 19 and 30, even after controlling for measures of cognitive ability (Parker et al., 2018). Moreover, a longitudinal study that presented three A-DMC tasks to a Swedish sample aged between 60 and 85 years found positive correlations between participants' initial performance and their performance 5 years later, even after controlling sociodemographic variables, crystallized skills, and fluid cognitive abilities (Del Missier

et al., 2020). These findings led Del Missier et al. (2020) to propose the concept of decision-making competence reserve, in line with the idea of cognitive reserve. Cognitive reserve refers to cognitive skills and strategies that allow individuals to cope flexibly and adaptively with the demands of a task in the face of cognitive aging or brain damage (Stern, 2002). Similarly, decision-making competence reserve refers to individuals having an acquired repertoire of strategies and skills specific to judgment and decision making, which allows them to maintain decision-making competence in the face of age-related declines (see also Bruine de Bruin, Parker et al., 2012; Li et al., 2013, 2015; Stanovich & West, 2008).

4. What are the next steps for decision-making competence research?

The findings that we have summarized in the previous sections have led to the accumulation of knowledge about decision-making competence, its relationships with memory as well as other skills, and how those change with age. Studies have been conducted in different countries, with community-dwelling and clinical populations, and with different outcome measures (for a recent review see Bruine de Bruin et al., 2020). However, much remains to be done.

First, we recommend improving the measurement of decision-making competence. Indeed, the range of judgment and decision tasks needs to be expanded. For example, validated measures are needed for decision structuring and affective fluency (see also Finucane & Lees, 2005), in their various facets. Additionally, normed version of decision-making competence tests could also be developed, and further operationalization of some constructs, such as metacognition in decision making, could be attempted.

Second, we recommend additional studies of how different memory skills may contribute to decision-making competence across the adult life span. Especially the role of implicit/nondeclarative memory in decision-making competence has received too little attention. Studies may also look into prospective memory, which may be relevant for the successful implementation of decisions, such as remembering to undergo a scheduled medical check-up, and memory for visuo-spatial information, which may support decisions in visuo-spatial tasks like wayfinding ones.

Third, we recommend developing alternative approaches to evaluating decision-making performance to overcome the potential limits of normative criteria for rationality such as standard expected utility or probability theories. Indeed, rationality can be conceived in different ways, and judgments and decisions seeming irrational from one perspective can be considered rational from another (Chase et al., 1998; Over, 2004). For instance, choosing the best option in a set by deliberating all the information may appear rational, but selecting a suboptimal but satisfying option may be "good enough" when the choice is not very important and the decision-maker has limited time (Simon, 1990). Maximizing one own's utility in the short term may appear rational, but it is clearly not in the context of commons dilemmas like overharvesting (Kopelman et al., 2002). Maintaining consistency between important individual preferences or principles and everyday behavior is not usually considered as a criterion of rationality, but some theorists suggest it should (Nozick, 1994), as well as choosing rationally which goals to pursue (see also Stanovich, Toplak & West, 2008). Finally, something that might look biased in some circumstances, such as using episodic memory for probability or frequency estimation of events (Brown, 1995, 2002; Dougherty et al., 1999), could be adaptive from an ecologic perspective (see e.g., Chase et al., 1998) when memory representations reflect the actual probability or frequency of events.

Fourth, we recommend further investigation of the relationship between decision-making competence, metacognition, and critical thinking. Although these constructs are distinct, there is potentially relevant overlap and interaction (e.g., Butler, 2012; Parker & Fischhoff, 2005; Stanovich, Toplak & West, 2008). Indeed, competent decision making includes appropriate calibration of confidence in one's knowledge (see e.g. A-DMC's Under/Overconfidence task in Table 1), which is an important metacognitive skill. The ability to select the appropriate judgment and decision strategy for the task at hand may represent another aspect that may require appropriate metacognitive skills, although in this case it seems important to distinguish between explicit and implicit selection processes (Payne et al., 1993), with the former more closely related to metacognition. Moreover, the development of the ability to reflect critically on one own's preferences and beliefs, and on their consistency with actual goals and behaviors, seems to represent an important metacognitive aspect of

rationality (Nozick, 1994), not sufficiently addressed by empirical investigations on decision-making competence. We also recommend more investigation of the relationship between decision-making competence and critical thinking. Indeed, critical thinking encompasses a very broad variety of aspects that include logical skills, the ability to evaluate the quality of argumentations, thinking abilities and dispositions, problem-solving abilities, but also aspects that pertain to judgment and decision making (e.g., Ennis, 1993; Halpern, 2003). Interestingly, validation of critical thinking instruments has also adapted and employed instruments developed in the decision-making competence literature like the Decision Outcome Inventory (Butler, 2012). It would be interesting to understand more precisely what the specific contribution of decision-making competence to critical thinking is, and to what extent other facets of critical thinking further contribute to predict real-world decision outcomes.

Fifth, we recommend a greater focus on the relevance of decision-making competence for the real-world. The original validation work showed a positive relation between A-DMC scores and avoidance of negative real-world outcomes (Bruine de Bruin et al., 2007; Parker, Bruine de Bruin & Fischhoff, 2015). Moreover, higher Y-DMC and A-DMC scores have been associated with lower rates of potentially risky and antisocial behaviors, including adolescent delinquency, cannabis use, and early sexual behavior (Parker et al., 2018; Parker & Fischhoff, 2005; Weller, Ceschi & Randolph, 2015; Weller, Moholy, et al., 2015). However, more research on the relationship between decision-making competence and real-word judgment and decision-making outcomes would be useful to fully understand the predictive capacity of existing instruments. This point is especially important to consider in aging populations, who face qualitatively different risks and decisions than much younger cohorts.

5. Conclusion

We hope that our review of decision-making competence research in relation to memory and aging may stimulate further reflection and empirical research. Being able to judge and decide is becoming more and more important in a world that is complex, rapidly changing, and poses many

hard challenges. A critical aspect of decision-making competence in the face of such challenges may involve a better understanding of our strengths and of our limitations as decision makers.

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