Complementary Contributions of Fluid and Crystallized Intelligence to Decision Making Across the Life Span

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Summary

This chapter explores the interplay between fluid intelligence declines and higher levels of crystallized intelligence of older adults as they affect everyday decision-making ability. Specifically, we explore the hypothesis that accumulated knowledge and expertise may help compensate for age declines in fluid cognitive function. The complementary capabilities framework suggests that although age-related declines are inevitable, these declines may be at least partially attenuated on tasks and in domains that are more familiar and practiced. Crystallized intelligence may thereby represent a kind of intellectual capital that circumvents reduced capabilities caused by diminished levels of fluid intelligence. We explore the role of domain-specific knowledge and expertise in context-specific tasks and everyday problem solving, and discuss the practical implications of this research for public policy and for the design of effective decision interventions that can aid decision making among older adults.

Key words: *complementary capabilities, cognitive aging, decision making, fluid intelligence, crystallized intelligence, domain-specific knowledge/expertise*

Better or Worse Off?

In November 2013, 61 percent of voters in New York rejected a proposed amendment to their state Constitution, which would have raised the mandatory retirement age to 80 for judges of the New York Supreme Court and Court of Appeals. Proponents of the amendment had argued that the existing age limit of 70, set after the Civil War, had become outdated in a modern era of antibiotics and cataract surgery, and had led to the unnecessary exclusion of experienced legal experts on the bench. Opponents, meanwhile, were concerned about age-related declines in mental acuity. Thus, behind this debate stood a deeper question: Could these veterans of the law make sound decisions, or would they be encumbered by slower cognitive functioning due to the aging process?

It is an unfortunate, but well documented, fact of life that some cognitive abilities diminish with age. Yet, it is also true that as people get older, they gain more life experience. Whether in their personal or professional lives, people continuously accumulate new knowledge and experience, and recent research indicates that this accumulated life experience may counteract age-related cognitive declines.

This chapter explores the interplay between the fluid cognitive declines in older adults and their higher levels of crystallized intelligence, and how these two factors impact decision-making ability in everyday life. We first review literature on cognitive capabilities across the adult life span, and propose the hypothesis that *experience and accumulated knowledge may help compensate for declining fluid cognitive function* in decision-making across the life span. We then discuss the role of domain-specific experience in context-specific tasks and everyday problem solving. Finally, we close with implications for public policy, particularly for the design of effective decision-making environments for older adults.

Cognitive Capabilities and Decision-Making across the Adult Life span

The concept of aging has long given rise to conflicts in public perception: Although people believe in the adage that age brings knowledge, we also observe that older adults suffer from a decline in many cognitive abilities. Yet, researchers have found mixed evidence regarding older adults' decision-making abilities. While there are many domains in which older adults are worse than younger adults, there are also domains in which they perform as well or better, depending on the type of decision (for a meta-analysis, see Thornton & Dumke, 2005).

What makes a "good" decision? For many decisions, economics prescribes a normatively correct choice. For example, people should never value a 50/50 gamble between $50 and $100 less than they value $50 (yet, they do; Gneezy, List, & Wu, 2006). Even for decisions where individual preferences may affect what is deemed "correct" for the individual, for example intertemporal choices (e.g., a choice between $50 today or $100 in a year), economics suggests that some choices (e.g., $50 today, since $100 in a year provides a 100% interest rate) are suboptimal because they are inconsistent with other available options (e.g., borrowing at a lower interest rate; Frederick, Loewenstein, & O'Donoghue, 2002). On the other hand, it is important to note that decisions may not always be intended to maximize expected or net present utility, but rather to satisfy other criteria, such as minimizing expected loss, or producing a quick resolution.

Some examples of decision-making that seems to worsen with age include the suboptimal choices made when the number of alternative options increases (Besedes, et al., 2010), and excessive risk aversion across certain domains (Qian & Weber, 2008; Mata, Josef, Samanez-Larkin, & Hertwig, 2011; Rolison, Hanoch, Wood, & Liu, 2013). Other research finds that decision-making skills improve with age: For example, older adults make more accurate evaluations of their own knowledge (Kovalchik, Camerer, Grether, Plott, & Allman, 2005), are better at avoiding the influence of irrelevant options on choices (Kim & Hasher, 2005), and better at discontinuing unprofitable investments (Bruine de Bruin, Parker, & Fischhoff, 2012; Strough, Karns, & Schlosnagle, 2011; Strough, Mehta, McFall, & Schuller, 2008). Some of these age-related changes in decision capacity are functional and adaptive, whereas others may lead to decision-making patterns that leave older adults open to suboptimal or even dangerous outcomes. This discrepancy in the literature is puzzling: What might account for the conflicting pattern of the effect of age on decision-making quality?

The concepts of *fluid intelligence* and *crystallized intelligence* are useful in an attempt to reconcile these conflicting views of the effect of aging on decision making. Fluid and crystallized intelligence are two components of general intelligence that were originally identified by Cattell (1971, 1987).

Fluid intelligence (G_f) is defined as reasoning ability, and the ability to generate, transform and manipulate different types of novel information in real time. Cross-sectional and longitudinal comparisons of adults at different ages have shown that a wide range of cognitive capabilities related to fluid intelligence decline steadily across the adult life span, including performance on tasks involving memory, reasoning, and processing speed (e.g, Salthouse, 2004, 2010; Schaie, 1993). In fact, cross-sectional studies of intelligence indicate that the average 60-year-old will have lost more than one standard deviation in fluid intelligence since the time they were twenty (e.g., Salthouse, 2004, 2010). These studies have found that all aspects of fluid intelligence decline nearly linearly with age starting from early adulthood, including processing speed and efficiency (S.-C. Li et al., 2004; Salthouse, 1994, 1996), working memory (McArdle, Ferrer-Caja, Hamagami, & Woodcock, 2002; Salthouse, 1992), attention, and problem solving (Craik & Salthouse, 2000). These declines are especially noticeable when performing complex or novel tasks that require more active processing (Zacks, Hasher, & Li, 2000). This decline in fluid intelligence raises the question of if and how older adults can continue to make good decisions.

One way in which older adults may offset lower levels of fluid intelligence is by relying more heavily on their greater *crystallized intelligence.* Crystallized intelligence (G_c) is defined as an experienced-based knowledge component of intelligence that is acquired through interaction with one's environment. It reflects accumulated knowledge acquired through experience, culture, and prior learning. Crystallized intelligence is the result of accumulated life experiences, and the efficient processing and storage of accumulated information throughout a lifetime (Salthouse, 2004). This form of intelligence is often measured as knowledge, and appears to be linked to education, physical health, and general cognitive competence. It is dependent on a range of influences, including motivation, opportunity, and culture (Horn & Cattell, 1967). Crystallized intelligence thus signifies the acquisition and accumulation of practical experience and knowledge gained from a lifetime of practice dealing with varied tasks, situations, and challenges in everyday life (Glaser, 1984; Rowley & Slack, 2009). Indeed, those mental capabilities that depend most heavily on accumulated knowledge and experience, such as reading comprehension and vocabulary, improve across most of the life span (e.g., Salthouse, 2004). Researchers have also argued that crystallized intelligence is related to components of what may be referred to as *wisdom*, including the ability to view problems from multiple perspectives, accept compromise, and to recognize the limitations of one's own knowledge (Grossmann et al., 2010).

There are multiple ways of measuring cognitive capabilities. To obtain a global measure of crystallized intelligence, the standard practice in psychology is to assess vocabulary, analogies, and general knowledge. In contrast, fluid intelligence abilities are generally measured using cognitive functioning tasks that rely on working memory and abstract reasoning. Some of the differences in the types of standard cognitive tasks commonly used to measure fluid intelligence and crystallized intelligence are presented in Figure 1.

[IFIGURE 1]

Decades of measurement using these tasks consistently support a widely-documented cognitive aging pattern: whereas fluid intelligence declines with age, crystallized intelligence increases across the adult life span into the 60s, after which it plateaus (see Figure 2). The combination of older adults' lower levels of fluid intelligence but higher levels of crystallized intelligence gives rise to the possibility that both forms of intelligence may contribute to the effect of age on decision performance, especially for decision tasks in which both the processing of new information and prior experience can contribute to forming a good decision. In the next section, we turn to the emerging research that has explored the effects of these two types of cognitive capabilities on decision quality.

[FIGURE 2]

Complementary Cognitive Capabilities

The past several years have witnessed an expansion in research on the relationship between cognitive capabilities and aging, and in relating age differences in decision-making to age differences in cognitive capabilities. An emerging theme in this area has been the emphasis on the theoretical importance of compensatory processes in understanding the effects of aging and decision making. That is, although fluid cognitive declines should generally lead to deterioration in decision quality, other capabilities may increase with age to compensate for those declines, partially, completely, or even lead to age-related increases in decision quality. For example, some have suggested that older adults may rely more on affective or experiential processes to make decisions, rather than deliberative cognitive processes (e.g., Peters, Hess, Auman, & Västfjäll, 2007; Strough, Karns, & Scholosnagle, 2011). For tasks where those affective or experiential processes can contribute to good decision making, declining cognitive abilities may therefore be offset by age differences in affective processing or experience with the task. Thus, research on aging and decision making cannot paint a full picture of age differences in decision making without understanding the underlying age-related changes in capability and reliance on these different processes.

One stream of research in this area has recently begun to empirically explore these potential interactions between cognitive and experiential processes, and their net influence on decision-making ability (e.g., Li, Baldassi, Johnson & Weber, 2013; Peters & Bruine de Bruin, 2012; Bruine de Bruin, Parker, and Fischhoff, 2012; Agarwal, Driscoll, Gabaix, & Laibson, 2009; Hansson, Rönnlund, Juslin, & Nilsson 2008). For example, Li and colleagues (2013) explored the possibility that higher levels of crystallized intelligence (i.e., experiential processes) provide an alternate pathway to good decisions, and that this may attenuate the effects of older adults' lower levels of fluid intelligence. Such compensation, which the authors termed the *complementary capabilities hypothesis,* was examined across a wide variety of important decisions from the judgment and decision making literature: *temporal discounting* (how much less people value future consequences), *financial literacy* (understanding financial information and decisions), and *debt literacy* (understanding debt and interest rates). Li and colleagues related performance on these decision-making tasks to standard measures of fluid and crystallized intelligence. Interestingly, older adults performed as well as, or even better than, their younger counterparts in all four decision-making measures. The opposing age differences for fluid and crystallized intelligence with age, together with their positive relationships with decision performance, suggest how age differences in cognitive capabilities may underlay these age differences in decision performance (see Figure 3). For instance, for temporal discounting and financial literacy, the positive effect of age via crystallized intelligence perfectly offset the negative effect of age via fluid intelligence, leading to no net effect of age.

[IFIGURE 3]

Findings from this research are consistent with the hypothesis that crystallized intelligence may represent a kind of *intellectual capital* that circumvents the diminished capabilities due to decreased fluid intelligence. The results lend empirical support to the notion that practical knowledge gleaned from a lifetime of decision-making experience may offset the declining ability to process and manipulate new information.

Importantly, the effect of age on decision quality depends on the *relative importance* of the two types of intelligence required for a particular decision. An increased level of crystallized intelligence may compensate for the negative effect of a deficit in fluid abilities on decision-making – but only in situations in which the task can benefit from existing crystallized knowledge. If crystallized intelligence is a more important determinant of decision performance than fluid intelligence (e.g., filling out a tax return), we might expect older people to perform better than their younger counterparts. The opposite would be true for real-world tasks where fluid intelligence plays a more important role (such as learning how to operate a new smartphone). Finally, when a task depends about equally on fluid and crystallized abilities (such as driving a car, which depends both on driving experience and reaction time), the observed age trajectory might be relatively flat or even inverse-U-shaped.

Research has confirmed that the extent to which experience will attenuate age-related decline depends on the relationship between experience and decision performance on the task of interest. To illustrate, Bruine de Bruin and colleagues (2012) explored the relationships between age, cognitive capabilities, and a range of general decision-making capacities, including resistance to framing effects and under/over-confidence (i.e. the appropriateness of individuals' confidence in their knowledge). The authors determined that for decision tasks in which experience should impact performance (such as consistency in risk perception), task ability *did not decrease* with age. In contrast, for decision tasks in which prior experience should play no role (such as resistance to framing effects), performance *decreased* with age.

In addition to the literature assessing lab-based measures of decision-making, there has been a recent emergence of studies testing the compensating capabilities framework within the context of real-world decision behaviors. Agarwal et al. (2009) studied the relationship between age and financial decision-making using measures of ten different types of credit behavior. The researchers predicted that the life span pattern of financial performance should reflect a trade-off between rising financial experience and declining analytic ability. Consistent with these expectations, the researchers found a U-shaped age-price curve, with middle-aged adults borrowing at lower interest rates and paying fewer late fees compared to both younger and older adults. To better appreciate the magnitude of the effect of age, they found that for home-equity lines of credit, the average 75-year-old paid about $265 more each year compared to the average 50-year-old, whereas the average 25-year-old paid about $295 more. The authors argue that the middle-age peak in performance may be due to younger borrowers having high degrees of cognitive ability but relatively little financial experience, whereas older borrowers maintain a high degree of accumulated financial experience, but decline in their cognitive capacity.

The hypothesis that life span changes in crystallized and fluid intelligence could explain age-related differences in real world financial behaviors was corroborated in a study that combined web-based measures of cognitive ability with field observations of individuals' economic performance (Li et al., 2015). Using a diverse sample of 478 adults between ages 18 and 86, the researchers combined multiple standard measures of crystallized and fluid intelligence with credit scores from a major credit reporting bureaus. Importantly, the researchers collected data on two different types of crystallized intelligence: 1) *domain-general* crystallized intelligence, measured using standard tests of vocabulary and general knowledge (as depicted in Figure 1), and 2) financial *domain-specific* crystallized intelligence, measured using a financial literacy test (Fernandes, Lynch, & Netemeyer, 2014; Lusardi & Mitchell, 2007). (A sample item from this test asks whether stocks, bonds, or savings accounts provides the highest fluctuations in returns over time.) Findings revealed that although the domain-specific measure of crystallized intelligence was positively related to higher credit scores and offset the negative influence of declining fluid intelligence, the measures of *general* crystallized intelligence were not similarly predictive. These results are consistent with the notion that crystallized intelligence may compensate for declines in fluid intelligence, but only for decisions relating to the specific domains in which the person has greater knowledge. Most importantly for public policy, the results suggest that, notwithstanding a general decline in the abilities associated with fluid intelligence, those older adults who possess high domain-specific crystallized intelligence, in the form of accumulated financial knowledge, may be finding an alternative cognitive pathway to making good financial decisions.

Practical Implications: Job Performance

Outside of the laboratory, perhaps the largest body of research examining real-world decision performance across age groups has been in studies of job performance. Because general cognitive capabilities are often a good predictor of performance in most job categories, an older adult who is able to compensate for fluid intelligence deficits should be able to maintain high work performance in life. Much of the research in this field finds no relationship between age and performance, supporting the perspective that crystallized abilities may help to offset cognitive decline across a range of domains in everyday life (McEvoy & Cascio, 1989). Because successful job performance depends both on the processing of new information as well as prior experience, the life span pattern of job performance may reflect the tradeoff between rising prior experience and declining analytic function. What appears to be no relationship between chronological age and performance may actually depend on the relative contribution of fluid and crystallized intelligence on the specific task at hand. However, it is also important to mention that older adults may be able to compensate for cognitive deficits in everyday problem solving using techniques unrelated to expertise. In a recent review, Salthouse (2012) argues that relatively stable levels of functioning in job performance may also reflect the fact that everyday functioning may not require maximal levels of performance, as well as the contributions of non-cognitive traits (e.g., personality) to success.

Practical decision making and the role of domain-specific experience

As we have seen, a growing body of research indicates that increased crystallized intelligence helps mitigate decreases in cognitive ability as measured by fluid intelligence. However, the precise ways in which crystallize intelligence makes this contribution have yet to be fully determined. We know little about which abilities are actually captured by standard measures of general crystallized intelligence (using tests of vocabulary and general knowledge), and how these abilities contribute to good decisions. As such, there is a need for more empirical research on the conceptualization and measurement of crystallized abilities.

Crystallized intelligence may encompass one or more of a number of abilities that contribute to improved decision-making. These components may include (1) *domain-specific knowledge* (i.e., semantic knowledge about a domain), (2) *domain-specific expertise* (i.e., reduced information use and more efficient processing obtained from expert skill in a particular domain), and (3) *domain-general principles* (e.g., improved decision skills gained from years of practice, such as eliminating irrelevant or dominated alternatives in a choice task and identifying redundant information). To illustrate how each component may contribute to decision-making, consider as an example how each contributes to a choice among different health insurance plans: *Domain-specific knowledge* about each type of cost (e.g., premium or deductible) seems essential to making an optimal choice. *Domain-specific expertise* derived from years of experience in choosing healthcare plans could allow one to develop efficient mental short-cuts in estimating annual costs for each plan. Finally, *domain-general principles* may include the ability to simplify decisions by finding redundancy between two dimensions, an ability gleaned from accumulated life experience in making multi-attribute decisions across many domains.

Given the varied components that comprise crystallized intelligence, how might each work to improve decision quality among older adults? Two possible interpretations have been suggested (e.g., Kim & Hasher, 2005). One is the more general domain experience view, which suggests that older adults are generally more skilled at making practical decisions compared with their younger, less experienced counterparts, and that this experience aids decision-making globally across several contexts. In contrast, the domain-specific expertise/knowledge view argues that an older adult will be better in making decisions *only in those specific domains* in which they have greater knowledge or expertise. As we have seen, this latter view was supported by Li et al (2015), who found that domain-specific crystallized intelligence, in the form of financial literacy, offset cognitive declines for financial decision-making. This perspective suggests that age-related cognitive declines may be attenuated by domain-specific experiences in decision tasks that are familiar and highly practiced.

A substantial amount of research has been conducted to find evidence for this type of attenuation across numerous domains. One way in which the domain-specific framework is commonly investigated is by choosing a task on which age-related decline has been documented, and then altering this task so that performance is supported by domain-specific experience (e.g., Soederberg-Miller, 2009). To illustrate, Meinz (2000) tested pianists across a range of experience and ages on measures of music memory and perceptual speed (visually identifying similarities of musical chord pairs), skills that generally decline with age. Results revealed that higher levels of musical experience in the older participants did partially attenuate the negative effects of age on the memory and recall tasks.

Other research suggests that the extent to which experience will offset age-related decline in decision-making depends on the relationship between experience and performance on the task of interest. In a study of marketplace decision-making, Tentori, Osherson, Hasher, and May (2001) observed the product choices made by college students and older adults faced with hypothetical discount cards for supermarket products. Across a series of experiments, the decisions made by the younger group consistently violated the test of regularity, while older adults showed no such tendency. (A decision-maker is considered "irregular" if he would choose B from [A, B, C] but not from [A, B]; i.e. preferring apple in a choice between apple and banana, but banana in a choice among apple, banana and orange). The authors suggested that accumulated shopping experience in grocery stores may train an individual to be cautious of framing effects and other contextual effects in judging the value of products, perhaps even reducing impulsive marketplace purchases. Thus, it is possible that the greater accumulated shopping experience of older adults might act as a buffer against cognitive decline, manifesting in more "regular" choices. However, it should be noted that follow-up work by Kim and Hasher (2005) suggests that a lifetime of experience may result in skilled decision making across a range of topic domains, independent of interest or experience level.

Additional results exploring the role of marketplace expertise are provided by List (2003), who show that increased market experience eliminates an important economic phenomenon known as the endowment effect, whereby people demand a higher price for a product that they own than they would be willing to pay for a product that they do not own. Further, Johnson, Gächter, and Herrmann (2006), demonstrate that consumers who are more knowledgeable about an attribute show lower levels of loss aversion for that attribute. Such findings support that notion that domain expertise may be an important boundary condition for understanding age effects on adults' decisions.

Mechanisms

To understand how older adults use their lifetime of expertise and knowledge to overcome potential problem-solving deficits, it is important to consider some of the proposed mechanisms responsible for this compensation.

First, in order to better understand the mechanisms by which domain-specific experience enhances decision quality, we must also understand how individual, task, and contextual characteristics impact the fit between an individual and the task. Yoon, Cole, and Lee (2009) argue that this "person-context" fit is expected to be highest when specific task and contextual demands do not exceed an individual's basic cognitive capabilities (i.e., fluid intelligence). In these high-fit circumstances where the opportunity for effective decision-making is high, older adults should not feel compelled to adapt their decision processes. In contrast, when the requirements imposed by the task and contexts exceed the cognitive resources available, older adults may feel the need to modify their problem solving strategies. As fit decreases, older adults may begin to rely more on their experience and accumulated knowledge, allowing them to compensate for deficits in cognitive resources resulting from advanced age.

Second, although it seems obvious that increased knowledge is beneficial to the decision-making process, there is a potential problem: Additional knowledge, if not well structured, can make information more difficult to retrieve (McCloskey & Bigler, 1980; Myers, O'Brien, Balota, & Toyofuku, 1984; Radvansky, Spieler, & Zacks, 1993). A good example of this principle is demonstrated in research on the fan effect (Anderson, 1976), in which learning a larger set of facts about a particular category typically *increases* the amount of time it takes to later verify whether any one fact in the category is true (Anderson & Reder, 1999; Lewis & Anderson, 1976). The fan effect is reduced, however, when the facts that one learns are organized into subcategories (McCloskey & Bigler, 1980) – a type of organization that is particularly likely when an individual has expert knowledge in a given domain (Chase & Ericsson, 1981).

Thus, the effect of additional knowledge will depend upon the degree to which knowledge is *well-structured*. Researchers have proposed that with accumulated experience, elements of knowledge become increasingly interconnected and structured, and are integrated with past representations of knowledge to make processing faster and more efficient (e.g., Doane, Sohn, & Jodlowski, 2004). When older adults have vast knowledge to draw upon, representing the long-term product of processing, they may be able to use their highly structured retrieval structures to support decision-making, despite working memory declines and other deficits (Ericsson & Kintsch, 1995; Miller, Cohen, & Wingfield, 2006). In this way, older adults' greater experience in a number of decision-making domains may be related to well-structured memory representations that provide a buffer against their susceptibility to fluid declines.

To understand how this knowledge may lead to more consistent preferences, we have developed a theory that relates memory organization to preference. This model, termed *query theory*, suggests that these failures of memory retrieval may be due to output interference, and that differences in memory search and retrieval should affect decision performance for a number of decision-making phenomena (see query theory and the preferences-as-memory framework; Johnson, Häubl, & Keinan, 2007; Weber et al., 2007). The effects of interference appear to increase with age, such as in short-term memory and Stroop tasks (Hedden & Park, 2001; Spieler, Balota, & Faust, 1996), directed forgetting tasks (Zacks, Radvansky, & Hasher, 1996), and resolving interference from competing memories (Healey, Ngo, & Hasher, 2014). Thus, the role of organization may play an important moderating role in assessing the interplay between aging, increased knowledge and interferences on determining preferences.

A second stream of research, and one that may be highly relevant to the study of context-specific decision making by older adults, has looked at mechanisms employed by "experts" when making decisions within their domain of expertise. This research suggests that the decision-making advantages that experts exhibit can be attributed, in part, to their well-organized knowledge base (e.g., Chi, Glaser, & Farr, 1988), to distinctive encoding processes (Van Overschelde, Rawson, Dunlosky, & Hunt, 2005), and to memory retrieval structures that connect the contents of working memory and long-term memory (Ericcson & Kintsch, 1995). The benefit of having expertise increases as tasks become more challenging, perhaps because these tasks involve processes that are more likely to be automatized (Beilock, Wierenga, & Carr, 2002). The expertise literature also demonstrates that experts tend to rely on less elaborative search when it is advantageous (Ericsson, Prietula, & Cokely, 2007). An analogy between this work and age differences in decision-making can be drawn: Older adults may employ a similarly selective approach to decision-making by not generating strategies that were previously determined to be unproductive. Indeed, a body of work has found that older adults exhibit a tendency to use less information to solve problems, which might reflect their greater expertise (Berg, Meegan, & Klaczynski, 1999; Meyer, Talbot, & Ranalli, 2007; Queen et al., 2012). Related research has also revealed that experts make better decisions in part because of effective attention allocation strategies (Ericsson et al., 2007). Notable examples in this area are studies examining aviation expertise. For example, Morrow et al. (2008) showed that expert pilots spent more time than novice pilots reading cues that were diagnostic for problem solving, which was associated with enhanced decision-making outcomes. Related research found that expert pilots made better decisions than novices in terms of speed and accuracy, as exhibited by their attention strategies in a simulated aviation-environment (Schriver et al, 2008). Further work is needed to investigate whether this mechanism, involving the use of more efficient attention allocation for tasks requiring expertise, is also being employed by older adults when concentrating their attention to familiar, domain-specific tasks. Research that investigates age-differences in eye-tracking performance as a measure of attention may be particularly helpful in investigating this hypothesis further.

Implications for public policy and effective decision environments

The oldest baby-boomers are now in their late sixties, representing the vanguard of an unprecedented, yet highly foreseeable, increase in the country's senior population. The finding that older adults show improved decision-making capacity with increased domain-specific knowledge should be an important consideration for policymakers as they contemplate the future effects of this demographic shift. Further, the hypothesis that the accumulation of knowledge and experience can offset lower levels of fluid intelligence in older adults has important policy implications for the design of effective decision environments and tools for older adults. Accumulating research suggests that there may be multiple pathways that lead to better decision-making, relying on fluid intelligence or crystallized intelligence, or both. To broadly foster optimal decision-making, policy-makers and task-designers should focus on ways to minimize the role of declining fluid intelligence, and maximize the impact of crystallized intelligence among both young adults and older adults.

Maximize Impact of Crystallized Intelligence

As Li et al (2013) note, one way for task designers to enhance the role of crystallized knowledge is by providing decision environments that are analogous to similar environments in which experience already exists, so as to provide a more familiar and meaningful context. The influence of familiar context on task performance has been demonstrated in classic experiments using the Wason selection task, a test of reasoning in which the subject is asked to determine whether a condition rule is being violated (Wason, 1966). The thematic content of some rules elicits a high percentage of logical responses, whereas the content of other rules does not, consistent with the perspective that reasoning may be tied to context-specific experiences for those midlife and beyond (see, for example, Johnson-Laird & Byrne, 1991).

Another means by which to enhance and maintain crystallized intelligence well into our senior years is through education. In addition to the benefits of general education, research also indicates that adults who remain active in a specific domain may show reduced age-related decline compared with those who discontinue engagement in a domain as they increase in age (Meinz, 2000). Older adults may therefore be able to maintain a high level of performance by continuing to accrue relevant experience in their domain of expertise. Research should continue investigating the potential role of the continual availability of new experiences focused on knowledge-based domains for older adults.

With respect to designing better decision-making methods for younger adults, it would be wise to emphasize early training and experience. For example, for those younger adults lacking direct financial experience, various hands-on initiatives for gaining practical financial knowledge, such as effective money management practices, may be an important early start for making sound financial decisions throughout their lives**.** Unfortunately, there is at best mixed empirical evidence supporting the notion that financial education programs actually improve decision-making (Fernandes et al., 2014). For example, in a series of studies on middle-aged adults, a one-time educational survey was not effective in improving 401(k) savings rates relative to a control group (Choi, Laibson, & Madrian, 2011). Thus, it would seem that a targeted lesson is unlikely to have a long-term influence on planning and saving rate behaviors. The complementary capabilities framework suggests that acquired knowledge gained through accumulated experiences, but not necessarily passive learning, may be a key driver in improving financial decision-making.

Minimize Impact of Fluid Decline

At the same time, task designers should consider ways to minimize the impact of declining fluid intelligence among older adults by developing decision-making aids that could compensate for cases where older individuals show deficits or undesirable choice-situation sensitivities in their decision-making. This goal might be accomplished by designing interventions that capitalize on other criteria that influence competencies relevant to decision and choice. For example, task designers could supplement scarce internal working memory with external memory aids to alleviate processing loads for older decision-makers. Other external aids could be provided to older adults to ease the burden on their decreased fluid processing ability, such as a retirement spending calculator for savings and retirement decisions (Brustkern, Denning, & Mayer, 2005).

For task environments in which experience and accumulated knowledge are not particularly helpful, the use of institutional "nudges" to protect older adults and encourage better decisions may be advisable (Agarwal et al., 2009). Nudges can alter decision behavior in a predictable way without forbidding any options (Thaler & Sunstein, 2008), and a growing body of research demonstrates that gentle institutional "nudges" can improve decision making without mandating any specific choice (Johnson et al., 2012). Prominent examples in this literature include automatic enrollment (with the option to opt-out) in 401(k) plans (Choi, Laibson, Madrian, & Metrick, 2002) and organ donation programs (Johnson & Goldstein, 2003). One example of a policy domain in which decision architecture could be used to promote better decisions among older adults is that of Social Security, since almost half of all recipients currently claim their monthly retirement benefits immediately upon eligibility, which significantly reduces their lifetime payments (Muldoon et al., 2008). Suboptimal decision-making in this context may be due to the fact that the claiming choice is inherently complex, requires multiple constraints to be solved simultaneously, and has not been experienced previously. Promisingly, recent research has demonstrated that by encouraging middle-aged and older adults to shift the implicit default from early to later claiming (by altering the order in which participants consider claiming options), the preferred claiming age can be significantly delayed (Appelt, Johnson, Knoll, & Westfall, 2011).

Given the strong evidence for cognitive decline, it would seem that research showing the benefits of aging through increased crystalized intelligence for certain decision-making tasks is important to policy. Direction for the development of interventions that can aid and improve decisions is an increasingly important contribution in an aging society that tries to shift important decisions (e.g., on pension investments and healthcare choices) from government agencies to individuals. Policy makers and task designers should also be mindful of the relative importance that crystallized and fluid intelligence may have on a given task, as this will impact the observed relationship between age and decision-making ability.

Summary

Older adults are faced with an increasing number of important choices that impact their welfare, such as decisions about retirement finances and healthcare. However, lay beliefs about senior decision-making capacity are conflicting: One view sees older people as more knowledgeable; another sees them as suffering from deteriorating cognitive abilities. The complementary capabilities framework suggests that there is not only truth to both views, but proposes a way to help identify when each operates: Although, age-related cognitive declines are to some extent inevitable, the negative effects of these declines may be at least partially attenuated on tasks and in domains that are familiar and highly practiced. That is, the accumulated intellectual capital represented by crystallized intelligence may circumvents reduced capabilities due to diminished levels of fluid intelligence. Having greater experience and acquired knowledge from a lifetime of decision-making may thereby provide older people with another way to make good decisions. Can we really afford to dismiss the value of experienced, domain-specific intelligence? Our senior judiciary may well have an opinion on the matter.

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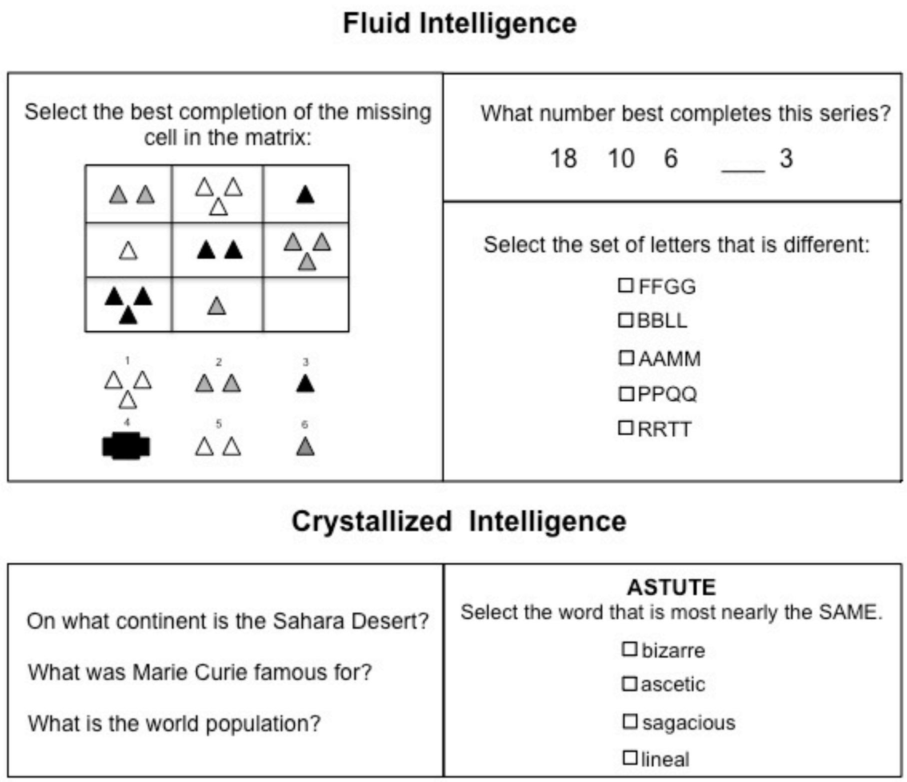
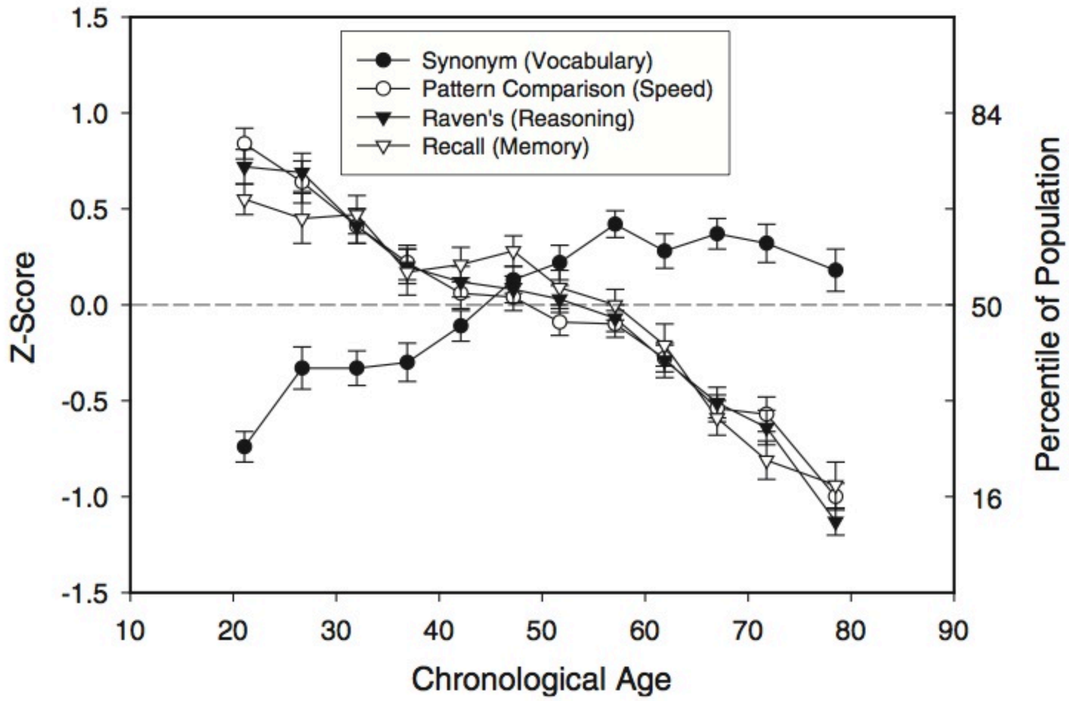
Figure 1.



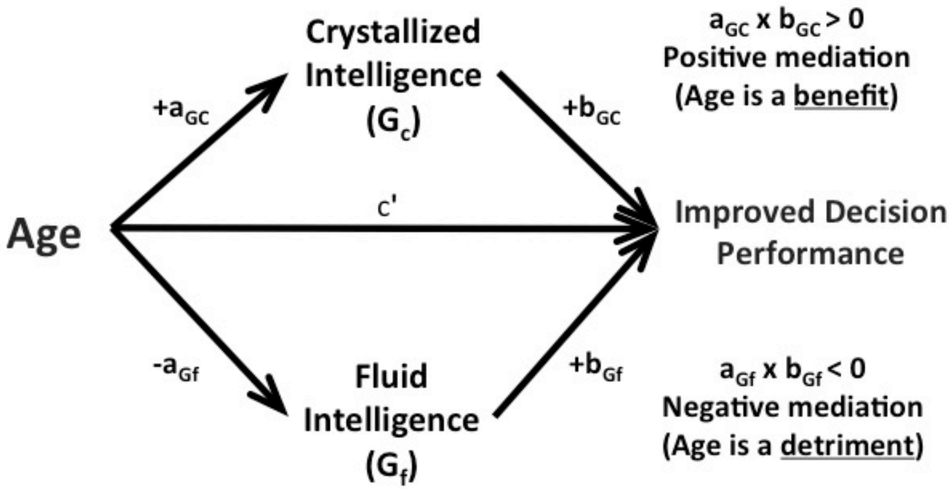
Sample items from five tasks used to measure fluid and crystallized intelligence: Raven's Progressive Matrices, Number Series, Letter Sets, WAIS III-Information, and Shipley Vocabulary.

Figure 2.



Salthouse (2010): Age differences in Fluid and Crystallized Intelligence. Means (and standard errors) of performance in four cognitive tests as a function of age. Each data point is based on between 52 and 156 adults. Copyright © 2010 The International Neuropsychological Society. Reprinted with the permission of Cambridge University Press. doi:10.1017/S1355617710000706.

Figure 3.



Complementary competencies hypothesis of age differences in decision performance as represented as a multiple pathway model from Li et al (2013). As indicated by the positive paths on the right, both G_f and G_c should positively affect decision performance. However, because of opposing age trends (indicated by positive and negative paths on the left), the relationship between age and decision-making requires understanding both pathways to good decisions. Using a notation similar to that of standard mediation analysis, the multiplicative product of age relationships with fluid and crystallized intelligence and their relationships with decision-making shows the indirect effects of age on decision-making ($a_i \times b_i$), and the remaining path as the direct effect (c') of age. Copyright © 2013 by the American Psychological Association. Adapted with permission. The official citation that should be used in referencing this material is Li, Y., Baldassi,

M., Johnson, E. J., & Weber, E. U. (2013). Complementary cognitive capabilities, economic decision making, and aging. *Psychology and aging*, *28*(3), 595.