AGING AND DECISION MAKING AS MEASURED BY THE SWEDISH VERSION OF THE ADMC BATTERY

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The aim of this study was to examine age-related differences in decision-making competence. The study is a part of the ongoing Betula project (Nilsson et al., 1997; 2004), and the data included test results from (N, 364) corresponding to the questionnaires with complete responses (>80%) to the items addressed. The Swedish version of the Adult Decision-Making Competence (A-DMC) battery was used. An exploratory factor analysis of the A-DMC data yielded a two-component solution: The A-DMC tasks were divided into Factor 1 (Applying Decision Rules, Resistance to Framing and Consistency in Risk Perception tasks), and Factor 2 (Under/Overconfidence, Resistance to Sunk Costs and Recognizing Social Norms). These two factors showed opposite age effects, where Factor 1 (analytic decision making) declined with age, whereas Factor 2 (heuristic decision competence) was not negatively affected by old age.

As we live today, people are given more and more options to choose among and even more to dismiss. Different situations of varied importance are faced which acquire decision-making skills. Decision-making skills are critical for preserving physical and psychological well-being in older adulthood, which either comprises ages of at least 55 or at least 65 years, (Peters and Bruine de Bruin 2010, in press). Elderly people continue to make everyday life decisions. With advanced age, they have to face new and sometimes more complex decision-making problems, involving instrumental activities of independent living (e.g., managing finances, maintaining a household and taking medications). Despite this, many elderly have reduced physical and cognitive abilities due to their age. For example, in health-related decisions, older adults are not only confronted by far more medical decisions than their younger counterparts, but such decisions tend to involve greater degrees of complications, risks and uncertainties.

A related issue concerns the assessment of decision-making capacity in old adults. What should we do when an older adult, particularly one who is frail, vulnerable or eccentric, begins to make decisions that put the elder or others in danger or that are inconsistent with the person’s long-held values? At what point does decision-making that is affected by a neuropsychiatric disease process no longer represent “competent” decision making? As these social and ethical considerations illustrate, understanding how older adults decide, what are the strengths and weaknesses of their decision processes, and how they can be aided to take better decisions has major applied and social significance.

In the early studies in the field of decision-making competence not much attention was given to developmental changes that occur with aging, changes that can influence decision-making abilities, strategies and capacities. Although decision-making competence is critical for preserving autonomy and well-being in senior years, there are several limitations in the present knowledge of the aging decision makers. First, there are not many empirical studies dealing with this topic, and those that exist are fragmentary, despite its implications for elderly adults’ well-being (for reviews see Finucane et al., 2005; Peters et al., 2000). Moreover, as the majority of earlier aging
research focused on the antecedents and consequences of older adults’ decisions, limited attention was giving to older adults’ decision-making competence (DMC) and to cognitive control functions supporting decisions. As Del Missier et al. (2012) pointed out, relatively little is known about how individual decision-making skills are related to each other, to cognitive abilities, and to real-world outcomes. Also, little is known about how individual decision skills develop across the adult life-span, and how developmental and age-related changes in DMC are related to other higher-order cognitive processes, including prefrontally mediated executive functioning and metacognition (Bruine de Bruin, et al., 2007; Del Missier et al., 2012; Mäntylä et al., 2008; Peters et al., 2007).

Another reason for the scarcity of studies investigating individual differences in decision-making is that past research has only made sporadic attempts to develop and validate measures of individual differences in DMC which is necessary to investigate age-related differences in decision behavior. As an exception, Stanovich and West (1998, 2000, and 2008) conducted the first stream of individual-differences studies involving reasoning and decision making. They found moderate correlations between performance in some tasks (e.g., resistance to overconfidence and hindsight bias) and measures of cognitive ability (fluid intelligence), whereas no such correlations were found for other decision tasks (e.g., avoidance of sunk cost and resistance to framing in between-subjects designs). Following this line of research, Bruine de Bruin et al. (2007; see also Parker & Fischhoff, 2005) developed and validated a battery of decision tasks aiming to measure individual differences in DMC. The decision-making tasks were selected from the judgment and decision-making literature, representing skills relevant to normative theories of decision making.

**Age related differences in decision-making competence**
The A-DMC battery studies the effects of aging on decision making. Its aim is to understand how age-related changes impact older people’s psychological well being, in order to establish what impact these changes have on decision competence in terms of health, medication and other important personal aspects of life. By understanding these changes it will be easier to give appropriate assistance depending on situation and decision-making tasks.

There are two separate views on what decision-making competence (DMC) refers to in the context of old age and decision-making. One view posits that DMC refers to legal or clinical determinations of a person’s ability to make necessary decisions in everyday life (Searight and Hubbard, 1998 in Finucane et al., 2002). Within this view individual differences are measured to provide diagnostics criteria for determination of the “individual's fall on a competence continuum” as stated by Finucane et al., (2002). In a second view competence is seen as a function of aging, focusing on the measure of group differences and examining older adults’ decision-making competence to see how they differ from younger peoples’ (Finucane et al., 2002). Increased research in decision-making science has resulted in better understanding of adult age differences in decision-making and the fact that aging doesn’t only bring about negative changes. It is suggested that decision-making skills dependent on analytic processes decline, others that rely on heuristic modes are preserved.
Decision scientists have proposed different appellations for these two processes, including intuitive versus analytic (Hammond, 1996), heuristic versus analytic (Evans, 1989), reflexive versus reflective (Lieberman, 2003), and System 1 versus System 2 (Kahneman, 2003; Kahneman & Frederick, 2005; Stanovich 1999), deliberative versus affective/experiential (Bruine de Bruin et al., 2007, 2009). Following Bruine de Bruin et al., (2007) these two factors will be referred to as the factor1 (analytic) and factor 2 (heuristic) processes in this present study.

Heuristic modes are described as concrete, contextualized and/or domain specific. They rely on fast automatic processes where thoughts and feelings are produced in a quite effortless manner and spontaneously. Actions of this mode are considered implicit, intuitive, automatic, associative, and fast (Bruine de Bruin et al., 2007, 2009; Del Missier et al., 2012). Analytic modes on the other hand, are considered as abstract, de-contextualized, domain general and rely on slower executive control processes and working memory. In the decision-making process both modes of thought are necessary (Del Missier et al., 2012; Bruine de Bruin et al., 2007, 2009).

Age related deteriorations in cognitive functions include information processing speed, attention, episodic memory (Nilsson et al., 1997) and spatial ability (Light & Zelinski, 1983; Salthouse, 1982). Age-related loss of grey matter in the prefrontal cortex has been related to older adults’ deficits in explicit memory and learning (Peters & Bruine de Bruin, 2011). (e.g., Park et al. 2002) have shown that working memory processes decline with age, as a result older adults process information more slowly and they seem to be less numerate than younger adults. Older adults’ understanding of basic numerical and probabilistic information seems to decrease (Peters et al., 2007). It is proposed that as working memory processes decline in adults, the quality of Decision-making tasks relying on such processes also decline (Peters & Bruine de Bruin, 2011). Bruine de Bruin et al., (2007; 2009) asked participants (aged 18-88) to complete different tasks (e.g. lexicographic, satisfying, equal weights). They presented diverse multi-attribute decision problems, involving choices between DVD players with different features, where the participant had to choose one or more options according to a different decision rule. It was observed that older participants performed more poorly than the younger once. The older participants also showed a greater framing effect. This refers to the phenomenon when choices are altered systematically due to how the language used is formulated or framed (Levin et al., 1988). However, in the same studies they observed that older participants did perform as well or better in the four remaining tasks of the A-DMC battery. This was a bit surprising as these also have been considered as analytic in nature (Bruine de Bruin et al., 2009) and should decline with age. For example, no significant age differences were seen in the ability to consistently judge risks across five different situations or in Recognizing Age-group Social Norms. Older adults showed less of a sunk-cost effect, which is the ability to ignore prior investments that do not affect future decision outcomes (Arkes &Blumer 1985). Further, older participants had more confidence in their knowledge than younger adults, (for a review, see Peters and Bruine de Bruin 2011). Based on these results, the authors hypothesized that these tasks may be dependent on a different strategy, the heuristic one, which becomes better or stay unchanged with growing age. Older people have lived longer and gained greater life experience, they are aware of their own knowledge and its limitations. By using heuristic strategies reliance on fluid cognitive ability is reduced when decisions are made, (Peters and Bruine de Bruin 2011). Therefore heuristic strategies are utilized to
compensate for age related declines in analytic processes. At the same time it was also shown that older adults who utilized heuristic strategies favored information focusing on positive emotions and ignored negative aspects, which according to the authors may affect the decision-making quality negatively (Peters & Bruine de Bruin 2011).

Positive changes in heuristic processing relevant to decision-making include increased specialized knowledge and strategies based on personal experiences (for a review see Peters & Bruni de Bruin 2011). Different aspects of information processing have been studied within the Socio-emotional Selectivity Theory (SST; Carstensen, Isaacowitz, & Charles, 1999). For example, they observed that, depending on how much time one perceives to have, different goals are prioritized. (Löckenhoff & Carstensen, 2004) have shown that with increasing age emotional meaning from life are prioritized over goals that maximize long-term payoffs. Similar goal changes were observed among males with symptomatic HIV infection who didn’t have much time left in life (Carstensen & Fredrickson, 1998). It is assumed that when time in life is limited, people in general, pay more attention to the emotional aspects of situations, they prioritize emotion-focused strategies and prefer emotionally gratifying social contacts over contacts with novel social partners, which enhance the emotional well-being (for a review see Löckenhoff & Carstensen 2004). Older people attend to and remember positive information better than negative information, and that with growing age the autobiographical memory becomes more positive (Charles, Mather, & Carstensen, 2003; Mather & Carstensen, 2003). In a longitudinal study by (Field 1981) participants were asked about their childhood, as they became older, the answers became more positive. In another study by Kennedy et al., (2004) nuns were asked to recall personal information about physical and mental health which they had reported 14 years earlier, in the control conditions where the nuns hadn’t received instructions to focus either on their current emotions or give as accurate responses as possible, the older nuns evaluated the past as more positive than the younger nuns (for a review see Kennedy et al., 2004).

In earlier studies attempts were made to connect different decision making tasks with a cognitive control (e.g. Del Missier et al., 2012; Hinson, Jameson, & Whitney, 2003; Frederick, 2005; Shiv & Fedorikhin, 1999; Mäntylä et al., in press). But, rather than focusing on specific control processes, they tended to focus on high-level mechanisms. In their attempt to shed light on this problem, Del Missier et al., (2012) carried out a study and could show a significant relationships between three executive functions (shifting, updating and inhibition) and two of the A-DMC battery tasks, Applying Decision Rules and Consistency in Risk Perception were observed. Still, the remaining tasks of the A-DMC battery (Resistance to Framing, Recognizing Social Norms, Under/overconfidence, Resistance to Sunk Costs) remain to be linked to specific control processes. Despite their findings the present knowledge concerning different decision making tasks and cognitive control are still fragmentary and unclear. Therefore in this present study we include cognitive measures aiming at clarifying which control processes the remaining A-DMC battery could be associated with.

In line with recent research, the present study aimed to investigate DMC across the adult lifespan by examining the structure of the DMC construct, as measured by the Swedish version of the A-DMC (Marklund & Mäntylä, 2008). Specifically, a central goal of the study was to clarify whether DMC should be considered as a multidimensional measure,
comprising the six subcomponents of the A-DMC battery. Based on earlier studies, the DMC was considered in terms of a two-component model, with analytic and heuristic decision making as the primary factors. Specifically, following the findings of Del Missier et al. (2012) it was hypothesized that the analytic factor would comprise the A-DMC tasks of Applying Decision Rules, Resistance to Framing and Consistency in Risk Perception, respectively. The DMC tasks Under/Overconfidence, Resistance to Sunk Costs and Recognizing Social Norms were expected to comprise the heuristic component.

Provided that DMC can be considered as a higher-level construct (e.g., a two- or a three-component model), another central aim of the study was to examine age-related differences in each of these components. Following earlier study, it was hypothesized that age differences in decision making would be accentuated in analytic decision making, and eliminated in tasks that are believed to tap heuristic decision competence.

Method

The present study is a part of the Betula project, a longitudinal Prospective Cohort Study on memory, health, and aging (Nilsson et al., 1997; 2004). At present, four waves of data collection have been completed. A fifth round of data collecting, T5, was initiated in 2008 and completed in 2010 (Nilsson et al., 2004). The data used in the present study was from this fifth wave.

Participants
Recruitment of participants began by randomly obtaining names from the population registry in Umeå, a city in northern Sweden with around 130,000 inhabitants. The number of males and females selected for inclusion reflected the proportion of males and females in each age cohort of the population. At the recruitment stage all of the participants were screened for dementia, sensory impairments, mental retardation and a native tongue other than Swedish (see Nilsson et al., 1997, for further details concerning recruitment and inclusion criteria). The participants underwent an extensive health assessment at the first test occasion. One week later they returned and performed different cognitive tests. The two test occasions lasted for about two hours. All participants that completed the cognitive test session received the A-DMC questionnaire and were asked to answer it at home and then return it by mail.

The age span of participants in this study was 25-80 years old (mean age=60.82, standard deviation=13.80). Of the questionnaires sent out >80% were returned with complete responses to the items addressed, which corresponded to 364 individuals. The rest were considered dropouts, mainly being described as belonging to one of three different subgroups: the largest subgroup did not return the questionnaire, for unknown reasons; other persons provided partial responses, and were not considered; an additional subset of the individuals returned the questionnaire unfilled. Some provided a reason for their unwillingness to complete any of the questions (e.g., lack of time or interest) but the majority did not.
Materials and Procedure

The Swedish version of the A-DMC battery is composed of six tasks: applying decision rules, resistance to framing, under/overconfidence, resistance to sunk costs, consistency in risk perception, and recognizing social norms. In 2008, Marklund and Mäntylä translated the A-DMC questionnaire into Swedish. At that time it was also subjected to a psychometric evaluation involving a large sample of young and middle-aged adults. Bruine de Bruin et al. (2007; and Parker & Fischhoff, 2005) demonstrated that the A-DMC battery has good internal consistency, in terms of correlations among component tasks, and acceptable validity, in terms of correlations with real-world decision outcomes.

Applying Decision Rules (ADR). ADR in the A-DMC task estimates the ability of the participants to apply decision rules of varying complexity. The participants are presented with 10 different decision problems containing several attributes that must be weighed against each other. The problems may for instance involve choices between DVD players with different features (such as picture quality). For each problem, participants are asked to select one or more options according to a different decision rule (lexicographic, satisfying, equal weights, etc.), from a table presenting numeric ratings of features. The scores then represent the proportion of responses across items that are in accordance with the normatively correct answers that would be the result of unwavering application of the decision rules.

Consistency in Risk Perception (CRP). This A-DMC task is devised to determine ability of the participants to act according to the rules of probability theory when judging the likelihood of dangerous events. Ten such events are described, and participants are asked to assess how probable it is that each event could happen in 1 year’s time (e.g., how likely is it that you will be in a car accident while driving during the upcoming year?). After this the same events are presented a second time, but the participants are now asked to judge the probability of their occurring within the next 5 years (e.g., how likely is it that you will be in a car accident while driving during the upcoming 5 years?). The participants expressed their judgments by ticking a graduated ruler that displays a scale from 0% (no chance) to 100% (certain). Consistency in risk perception is then evaluated by examining the congruence of the participants’ judgments with three principles: (i) the judged probabilities of the same event in different time frames should be consistent (e.g., the probability of being in a car accident could not be greater in 1 year’s time than in 5 years’ time), (ii) the judged probability of a subset event cannot exceed that of its superset event (e.g., the probability “of dying in a terrorist attack during the next year” cannot be greater than the probability of dying “from any cause—crime, illness, accident, and so on—during the next year”), and (iii) the judged probabilities of complementary events should add up to 100% (e.g., probability of moving “your permanent address to another state some time during the next year” and probability of keeping “your permanent address in the same state during the next year”). The proportion of these principles successfully passed (on a total of 20) by the participants is then the basis for evaluating their performance.

The under/overconfidence task. This is a task requiring metacognitive abilities, measuring the accuracy of participants’ confidence judgments. The task consists of 34 true-false questions, and immediately after answering each question, participants state
how sure they are of their answer on a scale ranging from 50% (just guessing) to 100% (absolutely sure). Their performance is then measured in terms of absolute discrepancy from perfect calibration, varying between 0 and 1 (0 = absolute discrepancy, 1 = perfect calibration).

Resistance to Framing. This task measures whether the subject’s answers are affected by irrelevant changes in the description of the problems. This task is limited to valence framing problems, specifically risky-choice framing and attribute framing. A 6-point scale is used which, since it lacks a midpoint, forces respondents to express a relative preference between options. There are seven risky-choice framing tasks, and all are presented in two formally equivalent gain and loss versions, each having a safer option and one that is more of a gamble. For example, the first problem concerns a pesticide threatening the lives of 1,200 endangered animals. In the gain version, the participant may choose between (a) saving 600 endangered animals for sure and (b) a 75% chance of saving 800 animals, and a 25% chance that no animals will be saved. The corresponding loss frame presents a choice between (a) losing 600 animals for sure and (b) a 75% chance of losing 400 animals, and a 25% chance of losing 1,200 animals.

Also, seven attribute framing items are included, in which participants are asked to give positive or negative ratings to differently described versions of seven equivalent scenarios (glass half-full/half-empty), like judging the effectiveness of a condom with a 95% success rate or a 5% failure rate. The two frames (positive and negative) appear in separate sets with different item orders and are separated by other A-DMC tasks. Performance is measured by the mean absolute difference between ratings for the loss and the gain versions of each item.

Resistance to sunk costs. This task of the A-DMC measures the ability to ignore prior investments when making financial decisions. Normatively, one should ignore past, unrecoverable expenditures, and only possible future consequences should be reflected by one’s decisions. The task consists of 10 items, using a rating scale ranging from 1 (most likely to choose [the sunk-cost option]) to 6 (most likely to choose [the normatively correct option]). Performance is measured by calculating the average rating across the 10 items.

Recognition of social norms. This task is unaltered from the Y-DMC (Parker & Fischhoff, 2005), it concerns social norms that apply to all ages, and measures how accurately the participants assess peer social norms. First participants choose whether or not “it is sometimes OK” to engage in a list of 16 undesirable behaviors, like stealing for instance. Later in the test battery, the participants are asked to estimate how many “out of 100 people your age” would support each behavior. The first answers provided the actual percentage of participants endorsing each of the 16 behaviors. This percentage could then be compared to each individual participant’s estimation of how many other people their age would endorse the different behaviors. Performance can then be measured (using a rank-order correlation, from -1 to +1) by comparing the actual percentages with each participant’s estimated percentage of their peers’ behavior.

Cognitive measures
In addition to the A-DMC tasks cognitive measures were included in the analysis aiming to identify the relationships between aspects of decision-making competence and
executive functioning. Further, to identify which and how the tasks of the A-DMC battery rely on different aspects of executive functions. The tests comprised measures of processing speed and visuo-spatial ability. Three indicators of processing were included to form a composite score (z-values): Letter-digit substitution test, is a modified version of the Digit Symbol Substitution Test (Salthouse & Babcock, 1991; Wechsler, 1981). The test comprises a reference table of nine letter-digit pairings. Below the reference table, letters appear randomized in rows with blank boxes beneath. Participants are required to write down the digits in the empty boxes according to the reference table. Following a brief practice trial, participants were allotted 60s to complete as many letter digit pairings as possible, number of correct pairings serving as the dependent measure (max = 125). The second indicator was Letter comparison (Salthouse & Babcock, 1991) which requires the participant to indicate whether pairs of letter strings (consisting of three, six, or nine letters) are the same or different. Correct decisions during a 30-second trial were the dependent measure (max = 21). Finally, the Pattern comparison task (Salthouse & Babcock, 1991) required the participants to indicate whether pairs of pattern/line drawings were the same or different. The number of correct decisions during a 30-second trial was used as the dependent measure (max = 30). Wechsler Adult Intelligence Scale-Revised (Wechsler, 1981), is designed to measure cognitive ability in adults. The test consists of six verbal subtests (Information, Comprehension, Arithmetic, Digit Span, Similarities, and Vocabulary) and five performance subtests (Picture Arrangement, Picture Completion, Block Design, Object Assembly, and Digit Symbol). Visuo-spatial ability was assessed through the employment the Block Design subtest of WAIS-R to measure spatial ability in everyday life. This subtest involves the manipulation of cubes to match a series of patterns provided on pictures and presented in ascending order of difficulty (maximum number of cubes = 9, and maximum score = 52). In this present study the inclusion of the Block Design test was motivated by the fact that this test may be regarded to reflect generally (fluid) ability. The cognitive reference tasks were administered during one of two test sessions which lasted 1.5 and 2 hours for each participant (for a complete test list, and more information about the Betula battery and reliability measures see or contact Nilsson et al., 1997; Nilsson, 1999; and Rönnlund and Nilsson, 2006a; 2006b).

Results

To examine the structure of the DMC construct, the A-DMC data was submitted to an exploratory factor analysis (table1). In this table, the test results of younger participants are given beneath the heading 1, while the results of the older participants are found under the heading 2. This analysis yielded a two-component solution with the Applying Decision Rules, Resistance to Framing and Consistency in Risk Perception constituting factor1 (analytic) scores. Factor 2 (heuristic) comprised the DMC tasks Under/Overconfidence, Resistance to Sunk Costs and Recognizing Social Norms. The two factors explained 80% of the total variance.
Table 1
Factor Loadings for the Principal Factor Analysis of the A-DMC Data

<table>
<thead>
<tr>
<th>A-DMC task</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applying Decision rules</td>
<td>.66</td>
<td>.24</td>
</tr>
<tr>
<td>Resistance to Framing</td>
<td>.59</td>
<td>-.04</td>
</tr>
<tr>
<td>Consistency in Risk Perception</td>
<td>.62</td>
<td>-.01</td>
</tr>
<tr>
<td>Recognizing Social Norms</td>
<td>.39</td>
<td>.61</td>
</tr>
<tr>
<td>Under/Overconfidence</td>
<td>.09</td>
<td>.60</td>
</tr>
<tr>
<td>Resistance to Sunk Costs</td>
<td>-.31</td>
<td>.67</td>
</tr>
</tbody>
</table>


In table 2 descriptive statistics for the six task measures of the A-DMC battery is shown. Under the heading 1, the test results of younger participants is given, while the results of the older participants are found under the heading 2. Higher scores represent better performance in a particular task. Thus it can be seen that younger participants performed better in Applying Decision Rules than older participants, while older individuals performed better in the task Resistance to Sunk Costs.

Table 2
Descriptive statistics of A-DMC components

<table>
<thead>
<tr>
<th>A-DMC component</th>
<th>1</th>
<th>2</th>
<th>M</th>
<th>Mdn</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applying Decision rules</td>
<td>.67</td>
<td>-.09</td>
<td>.75</td>
<td>.80</td>
<td>.16</td>
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<tr>
<td>Resistance to Framing</td>
<td>.56</td>
<td>-.27</td>
<td>3.91</td>
<td>3.93</td>
<td>.53</td>
</tr>
<tr>
<td>Consistency in Risk Perception</td>
<td>.60</td>
<td>.37</td>
<td>.79</td>
<td>.80</td>
<td>.12</td>
</tr>
<tr>
<td>Recognizing Social Norms</td>
<td>.34</td>
<td>.53</td>
<td>.60</td>
<td>.64</td>
<td>.20</td>
</tr>
<tr>
<td>Under/Overconfidence</td>
<td>.49</td>
<td>-.31</td>
<td>.89</td>
<td>.91</td>
<td>.08</td>
</tr>
<tr>
<td>Resistance to Sunk Costs</td>
<td>-.04</td>
<td>.77</td>
<td>4.58</td>
<td>4.60</td>
<td>.63</td>
</tr>
</tbody>
</table>

Note. Adult Decision-Making Competence (A-DMC) components are scored so that higher numbers reflect better performance.

Table 3 shows the bivariate correlations among the A-DMC component scores, as they are affected by age. Significant relationships were found between the Applying Decision Rules, Resistance to Framing, Consistency in risk perception and Under/overconfidence of the A-DMC battery. It can also be seen that the strongest correlations were positive (e.g. if Applying Decision Rules decreases, then so does Resistance to Framing).

Table 3
Correlations among A-DMC component scores

<table>
<thead>
<tr>
<th>A-DMC Components</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applying Decision rules</td>
<td>-</td>
<td>.21**</td>
<td>-</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Resistance to Framing</td>
<td>.21**</td>
<td>-.04</td>
<td></td>
<td></td>
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<tr>
<td>Consistency in Risk</td>
<td>.10</td>
<td>.05</td>
<td>.15**</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognizing Social</td>
<td>.04</td>
<td>.10*</td>
<td>.05</td>
<td>.09</td>
<td>-.09</td>
<td>-</td>
</tr>
<tr>
<td>Under/Overconfidence</td>
<td>.17**</td>
<td>.10*</td>
<td>.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance to Sunk Costs</td>
<td>.00</td>
<td>-.08</td>
<td>.10</td>
<td>.09</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. ** p<.01. * p<.05. (p = two-tailed)

Age-related differences in decision-making competence
In the second step of analysis, age-related differences in decision competence were examined by relating each participant's factor scores to age. These analyses showed selective effects in that the bivariate (Pearson) correlation between age and analytic scores was highly significant (r = -.37, p< .001). This negative association suggests an
age-related decline in the cognitively demanding analytic aspects of decision-making competence. By contrast, the correlation between age and heuristic scores was positive ($r = .15, p < .01$), suggesting that the more experientially-oriented decision competence increased with age.

Table 4
Regression analysis on A-DMC competence

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
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<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
<td></td>
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<td>Block 1</td>
<td>Gender</td>
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<td>1.23</td>
<td>-.02</td>
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<tr>
<td></td>
<td>Education</td>
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<td>.16</td>
<td>-.05</td>
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<tr>
<td></td>
<td>MMSE</td>
<td>.58</td>
<td>.40</td>
<td>.06</td>
</tr>
<tr>
<td></td>
<td>Block design</td>
<td>-.43</td>
<td>.08</td>
<td>-.30</td>
</tr>
<tr>
<td></td>
<td>Speed</td>
<td>-7.79</td>
<td>.89</td>
<td>-.48</td>
</tr>
<tr>
<td>Block 2</td>
<td>Gender</td>
<td>-.33</td>
<td>1.20</td>
<td>-.01</td>
</tr>
<tr>
<td></td>
<td>Education</td>
<td>-.09</td>
<td>.15</td>
<td>-.02</td>
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<td>MMSE</td>
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<td>.07</td>
</tr>
<tr>
<td></td>
<td>Block design</td>
<td>-.39</td>
<td>.08</td>
<td>-.27</td>
</tr>
<tr>
<td></td>
<td>Speed</td>
<td>-7.54</td>
<td>.87</td>
<td>-.46</td>
</tr>
<tr>
<td></td>
<td>Factor 1 (Analytic)</td>
<td>-1.38</td>
<td>.68</td>
<td>-.09</td>
</tr>
<tr>
<td></td>
<td>Factor 2 (Heuristic)</td>
<td>2.30</td>
<td>.58</td>
<td>.16</td>
</tr>
</tbody>
</table>

Note. The dependent variable is age

Finally, separate regression analyses with gender, education, MMSE score, perceptual speed and fluid intelligence were included as covariates (in a separate block) followed by the Factor 1 and Factor 2 scores as predictors. This confirmed the outcome of the simple correlation analysis even when individual and age-related differences in several background and cognitive variables were taken into account. Specifically, the regression analysis showed that Factor 1 (analytic) was significant predictor of age ($t = -2.0, p < .05$). Furthermore, Factor 2 (heuristic) was highly significant predictor of age in this analysis, $t = 3.94, p < .01$.

Discussion

The aim of the present study was to investigate the structure of the DMC construct as measured by the Swedish version of the A-DMC (Hansson et al., 2010; Marklund, 2008), and the results confirm that the decision-making skills reflect a positive manifold (as proposed by Stanovich & West, 2000), rather than random performance error.

The data used was from the fifth round of Betula Project. Although the Betula project is a cohort study, huge amounts of data is collected covering different aspects of the individuals’ life (physiological, psychological and socio-economic variables). The present study had good participant rate and low dropouts, and the collected data was from 364 participants from age 25 to 80 years old. This may explain the better performance achievements found, compared to earlier studies.
At step one of the analyses we were aiming at to clarify whether DMC should be considered as a multidimensional measure comprising the six subcomponents (tasks) of the A-DMC battery or whether these tasks should be considered as a related measure of more general components of DMC. From the factor analysis (table 1) a two-component solution was obtained, with the DMC-tasks applying decision rules, resistance to framing and consistency in risk perception constituting factor 1 scores. While factor 2 comprised the DMC tasks under/overconfidence, resistance to sunk costs and recognizing social norms, the two factors together explained 80% of the total variance. Descriptive statistics for the six components in table 2 are in line with those by Bruine de Bruin et al., (2007), except that in the present study somewhat better performance was achieved in the Recognizing Social Norms and Applying Decision Rules tasks. In table 3, positive correlations were found between the tasks Applying Decision Rules, Consistency in Risk and Resistance to Framing, which also is in line with earlier results (e.g., Bruine de Bruin, et al., 2007; Del Missier et al., 2012). In other words, older participants who performed poorer than the younger ones in Applying Decision Rules, also tended to perform poorly in framing tasks and in risk perception.

The second aim of the study was to examine age-related differences in decision-making by relating each participant’s factor scores to age. As seen in table 4, it was observed that the correlation between age and analytic scores was highly significant, suggesting that the analytic aspects of decision-making that require fluid cognitive ability decline with age. Meanwhile, heuristic aspects of decision-making were not negatively affected by increasing age. The difference between age groups can also be seen in tables 1 and 2, where the actual scores are presented. The younger participants received higher scores on analytic-factor tests, while their performance in heuristic tasks were poorer than the older participants.

Although the analytical aspects of decision making competence may deteriorate with old age, this may be compensated for by a greater store of accumulated experience, perhaps explaining the better performance in heuristic tasks. Also, there may be some generational differences in knowledge (focus). Perhaps today’s schools focus on fast learning and computerized information processing and learning, while schools 40-50 years ago were simpler in not teaching as many subjects within so many different fields? Also, not everyone had the same opportunity to get an education. For example, elderly females haven’t had the same educational possibility as their male counterparts, and therefore they may perform worse on numerical and probabilistic information compared, not only to their younger counterparts, (as shown by Peters et al., 2006), but also compared to males of their own age? This could also mean that they would be more vulnerable to framing errors.

The framing error issues are also of interest in the field of numeracy, health choices and health decisions. For example Peters et al. (2006) present that less numerate individuals are more susceptible to framing errors, and that decisions were instead influenced by emotions. In three studies (Black et al., 1995: Schwartz et al., 1997: Fagerlin et al., 2005) women’s judgments concerning breast cancer risks and the advantages of mammography and clinical breast exams were studied. When information was presented numerically, less numerate women overestimated their risk of getting, and dying as a result of breast cancer and the absolute risk reduction from screening.
Conversely, more numerate women made more accurate judgments of the benefits of mammography and clinical breast exams. Fagerlin et al. (2005) showed that more numerate individuals estimated their risks significantly more accurately than less numerate individuals. Further, these studies and other decision and health studies (e.g., Estrada et al., 2004; Peters et al., 2006; Reyann and Brainerd, 2007) show that numerate individual in general choose better hospitals and therefore had better hospital outcomes.

Our present knowledge concerning framing/numeracy and their importance in decision-making concerning medication and health decisions could be used to great advantage. However, it is naturally also necessary that hospital staff know about this and take it into consideration when giving advice concerning medication and life style, both when presenting information numerically, and linguistically. This information could be equally taken advantage of in other contexts, such as by insurance companies aiming to sell their product. For this reason it is important to inform senior citizens and their kin about this possibility, in order to prevent unwise investments or decisions.

Being aware of both sides of the coin concerning decision-making and cognitive changes, it is important to provide elderly individuals with this information. This could prevent unnecessary anxiety, as some may mistake cognitive declines for signs of other diseases (Alzheimer’s disease, depression). By presenting both the positive and the less positive changes it would be easier to inform elderly people without angering or insulting them. Most importantly, it should be in the society’s interest to inform and invest in young people’s education, especially math, as it can be considered a lifelong insurance.
References


Mäntylä, T., Still, J., Gullberg, S., & Del Missier F. (2010). Decision-making in adults with ADHD. *Journal of Attention Disorders* 16(2) 164-173.


