Decision-making and ageing: everyday life situations under risk and under ambiguity

Fanny Gaubert (✉ f.gaubert@univ-lyon2.fr)
Laboratoire d'Etude des Mécanismes Cognitifs, Lumière University Lyon 2

Céline Borg
University Hospital of Saint-Etienne, Hôpital Nord

Jean-Christophe Roux
Laboratoire de Tribologie et Dynamique des Systèmes, Ecole Nationale d'Ingénieurs Saint-Etienne

Hanna Chainay
Laboratoire d'Etude des Mécanismes Cognitifs, Lumière University Lyon 2

Research Article

Keywords: ageing, decision making, under risk, under ambiguity; IGT, daily-life, executive function, working memory

Posted Date: July 22nd, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1870043/v1

License: ☒ This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License
Abstract

Cognitive modifications over ageing can affect decision making competence (DMC). As it is a core ability in autonomy preservation, our study aims to investigate its changes in old adults and to determine if they are linked to the deterioration of executive functions and working memory. For this purpose, 50 young adults and 50 old adults were assessed with executive, working memory and DMC tasks. The latter comprised the Iowa Gambling task (IGT) and a scenarii task based on daily life-inspired situations, under risk and under ambiguity conditions. Results revealed lower performances in old adults compared to young adults for updating, inhibition and working memory tasks. The IGT failed to distinguish the two groups of age, but the scenarii task did it, as young adults were more risk and ambiguity seekers than old adults. Moreover, updating and inhibition capacities appeared to influence DMC.

Highlights

- Young and old adults decision making differs in daily life decisions tasks
- Old adults are more risk and ambiguity averse than young adults
- Under risk, the context of gain or loss influences more old than young adults
- Under ambiguity, percentage of certainty influences more old than young adults
- Inhibition and updating capacities influence decision making under ambiguity and under risk

1 Introduction

1.1 Decision-making through the ageing process: impairing ability

The presence, or not, of Decision Making Competence (DMC) impairment in healthy elderly subjects is still debated. DMC can come into play in two kinds of situations: under ambiguity or under risk. Where the possible outcomes and the probability of their occurrence are uncertain, the decision-making context is considered to be ambiguous. However, the decision is deemed to be at-risk when the decision-maker is able to estimate the probability of all the possible outcomes occurring (Brand et al., 2007; Levy et al., 2009). In normal ageing, DMC under risk appears to divide the scientific community, sometimes described as similar to young adults [3, 4], and sometimes described as modified [5]. On the other hand, in situations under ambiguity, researchers agree on the presence of changes in DMC in late adulthood [4, 6]. To our knowledge, only one study has compared the ability to make decisions in both situations with the same elderly participants [4]. The authors reported no difference in performance between old and young adults on the Probability-Associated Gambling (PAG) task (i.e. decisions under risk), but found that the elderly group made more disadvantageous choices in the Iowa Gambling Task (IGT) (i.e. decisions under ambiguity).
1.2 Decision-making impairment through the ageing process: factors involved

The decisional strategies may vary across the life span (Johnson, 1990; Mata et al., 2007; Mata et al., 2015; Zamarian et al., 2008). Healthy elderly participants appear to rely on simpler strategies than young adults do, reducing cognitive load [7–9] and to struggle more in keeping to the same stable plan [4]. Where there is no other choice than to use complex strategies, the elderly make more errors in their execution [9]. This point is one of particular interest in the present study, which aims to systematically investigate 1) DMC deficit in ageing, and 2) the links between this deficit and the one in executive functions and working memory.

Executive functions and feedback processing seem to play an important role in the ability to take advantageous decisions in aging (Brand and Markowitsch, 2010). Under ambiguity, the decision would rely more on feedback, a factor dependent on both emotional processes and cognitive aptitudes. Under risk, cognitive functions would be involved in a more general way, starting with executive functions and working memory [11]. The difficulty in adapting decisions to the context has also been reported by Deakin et al. (2004), with the elderly always betting similar amounts of money regardless of the probability of winning. The authors also described a longer deliberation time in older adults compared to young adults. Based on the Socioemotional Selectivity Theory (SST), McCarrey et al. (2010) suggested their main goal is well-being, so elderly participants might avoid soliciting functions with a high cognitive load, which could put them in a difficult position, and favour functions with a low cognitive load. As the deployment of these functions degraded with age can lead to failure and frustration, older adults might change their decision-making strategy, even if this modification gives rise to other choices. In this context, they might rely more on their personal experience than on environmental information, that is to say, more on a heuristic strategy (i.e. effortless, fast, emotional etc.) than on an analytical strategy (i.e. slow, deliberative, controlled etc.). Deakin et al. (2004) used the Cambridge Gambling Task (CGT), which is a laboratory gambling task assessing decision-making under risk. We can assume that the heuristic strategy might not be appropriate for this situation, leaving the participants with the only alternative of using the analytical mode. As older adults appear not to be familiar with this second kind of strategy, their difficulties might be visible through the lengthened deliberation time.

Finally, modifications in the use of executive functions occur with age, and these changes are very likely to impact DMC in late adulthood. Finucane et al. (2002) supported the idea that memorising the relevant information would be one of the cornerstones of DMC. They showed that elderly participants were more inconsistent, and made more errors than younger adults due to an incorrect understanding of the situation. The findings of Fein et al. (2007) have corroborated this idea by revealing that disadvantageous choices were correlated with immediate memory capacity in older adults, and working memory capacity in younger adults (Finucane et al., 2007). There are numerous studies demonstrating modifications in memory function (i.e. working memory, episodic encoding and retrieval) in older adults at behavioural and neuronal level. They especially suggest, that to maintain the same level of
performance as younger adults, older adults need to recruit more areas of the brain, notably in contralateral regions and in the prefrontal cortex (Cabeza et al., 2004; Gutchess et al., 2005). Lee et al. (2008), studying DMC under risk, also revealed that compared to younger adults, older adults activated contralateral prefrontal areas and overactivated the right insula. These different findings support the idea that memory and DMC impairment are closely linked.

In sum, ageing engenders modifications in cognition affecting DMC. However, these findings should be moderated by studies exposing heterogeneous results among groups of elderly participants (Brand & Schiebener, 2013; Denburg et al., 2007; Hess et al., 2012). Indeed, greater age might not be responsible for decision-making impairment per se, but could be a part of a combination of accountable factors. In this sense, individual characteristics would appear to play a major role.

1.3 Decision-making impairment through the ageing process: factor interaction results

The second question concerning DMC through the ageing process should address the presence of a general decision-making deficit in late adulthood, that is to say, affecting all elderly participants. Brand and Schiebener (2013) refined their initial model [20] by showing that the correlation between age and performances in the GDT was moderated, in addition to executive functions, by logical thinking. Other authors have shown that low DMC was correlated with the combination of advanced age, poor cognitive abilities, and low level of education (Hess et al., 2012). Thus, it seems that ageing does not systematically involve DMC impairment, but rather that decision-making deficits emerge when greater age is combined with other factors. These findings in the decision-making field seem to be consistent with the scaffolding theory of aging and cognition (STAC) [21]. The latter posits that secondary circuits are recruited to compensate the structural modifications affecting the brain with ageing, and to preserve cognitive performances at the highest level for as long as possible. These secondary neural networks would mainly involve the contralateral hemisphere and the prefrontal cortex (PFC), which appears to be the most versatile brain area. For instance, Rogalsky et al. (2012) found that older adults with bilateral activations in vm-PFC experienced significantly better performances in the IGT than older adults with only right vm-PFC activations. While cerebral changes appear to be dependent on the individual (i.e. genetic factors, chronic illnesses, etc.), so does the deployment of the scaffolding framework [21]. Some characteristics would appear to enhance its efficiency, such as physical fitness or being accustomed to cognitive tasks, especially when they are challenging (i.e. new or with a high level of difficulty). In other words, cognitive performances in late adulthood would be the result of a combination of structural degradation and the ability to build compensatory networks. Because the DMC seems to be dependent on different cognitive functions, it would hence be impacted by the combination of these two processes.

In sum, changes in DMC occur frequently in late adulthood and appear to have multiple causes. It seems that several cognitive functions, such as working memory or executive functions, would be involved in the ability to make decisions in older people. However, to our knowledge, no study has examined purposefully and precisely the links between DMC under risk and under ambiguity and cognitive competences in
ageing. In addition, the most studies have investigated the DMC with IGT or other laboratory tasks that are quite far away from everyday life situations. Thus, the present study aims to investigate, in a systematic way, DMC under risk and under ambiguity in older adults, with tasks based on everyday life situations compared to the traditional IGT, and in relation with the efficiency of other cognitive functions. Though we cannot consider our experimental tasks to be ecological, we hope that participants’ responses will be closer to real-life than responses collected with a gambling task. Some behavioural differences may emerge between the two kinds of tasks, but for now, we cannot say how they could manifest. We first predict that, with ageing, DMC under ambiguity will be more impaired than DMC under risk. Our study will also examine how executive functions (updating, mental set shifting, and inhibition process) and working memory are correlated with DMC in older adults, compared to younger adults. We predict that, in line with the STAC, the regressions will be stronger for the elderly than for their younger peers, and that the correlations will be proportional to the extent of cognitive impairment. Among the executive functions, the inhibitory process should be especially involved as it is used to mask non-pertinent information, and is known to degrade with ageing. Concerning working memory, to our knowledge, no findings are available providing us with a possible basis for making precise predictions about the involvement of maintenance or manipulation process impairment in DMC. However, as the hippocampus appears to be frequently atrophied in late adulthood, we can assume that maintenance will be impaired in old adults. While prefrontal activations compensate for the deficit, we might at least observe manipulation impairments in older adults sooner than in younger adults, probably due to overactivation in prefrontal regions.

2 Method

2.1 Participants

Two groups of participants were included in the study, a group of 50 older adults (29 women and 21 men) and a group of 50 younger adults (34 women and 16 men). The old adults were aged between 62 and 87 years old (M = 71.8, SD = 5.7), and the young adults between 18 and 32 years old (M = 26.3, SD = 3.5). The proportion of men and women were comparable in the two groups, χ² (df = 1, N = 100) = 1.07, p = .30. Education level was assessed with a 5 points scale (i.e. 1: no education, 2: primary school, 3: first half of secondary school, 4: baccalaureate degree or equivalent, 5: tertiary education). The young adults (M = 4.98, SD = 0.14) had a higher educational level than the old adults (M = 4.16, SD = 0.96) χ² (df = 1, N = 100) = 31.84, p < .001 (there was no participant having level 1 of education).

2.1.1 Neuropsychological examination

The elderly participants underwent a brief neuropsychological assessment composed of the Mini Mental State Examination (MMSE), which indicated a preserved mental global status (M = 29.2, SD = 0.97)) (Folstein et al., 1975; French version: Hugonot et al., 2008), and the brief frontal efficiency battery (Batterie Rapide d’Efficience Frontale, BREF) (M = 17.4, SD = 0.73) (Dubois & Pillon, 2000). They also underwent,
for the purposes of another study, the Revised Observed Tasks of Daily Living (OTDL-R) (M = 41.1, SD = 2.2) (Diehl et al., 2005) and Quality of Life in Alzheimer’s Disease (QoL-AD) (M = 38, SD = 5.69) (Logsdon et al., 1999) assessments. The OTDL-R assesses the level of autonomy using everyday life objects (e.g. telephone, medicines, etc.). Due to time constraints, we had to reduce this test, and we retained to three in the healthcare field, one in the communication field, and two in the finance field. The QoL-AD assesses the quality of life.

All the participants completed the South Oaks Gambling Screen (SOGS) (Lesieur & Blume, 1987), an instrument to identify pathological gamblers, in order to be able to exclude these participants from the study. None of them had a pathological gambling profile. The older adults completed the Hospital Anxiety and Depression scale (HAD) and the younger adults, the Spielberg State-Trait Anxiety Inventory. In addition, the participants’ mood was assessed with the Brief Mood Introspection Scale (BMIS) (Mayer & Gaschke, 1988).

### 2.2 Experimental tasks

All the tasks, apart from Stroop tests, were programmed and run with E-Prime 2.0 software (Psychology Software Tools Inc.) on a Dell laptop with azerty keyboard.

Each task began with instructions, an example to illustrate them, and practice trials. The instructions were written on the screen and were also always given verbally by the experimenter. Before starting the experiment, the participants were asked to explain what they had understood in their own words.

This study used many tasks to assess executive functions, working memory and decision making. As their detailed description would be very long, we propose here only quick explanations, but all details are provided in the appendix section.

#### 2.2.1 Executive function assessment

To assess executive functions (EF), we used the classification of Miyake, Friedman, Emerson, Witzki, Howarter and Wager (2000) as a basis. According to these authors, the executive system is not unitary: its several components would not be completely independent. The authors focus the EF evaluation on updating, mental set shifting and inhibition functions, and suggest assessing each function with three different tasks. In the present study, to simplify our protocol which takes several hours of testing, we chose to reduce the number of tasks from 3 to 2 for each function.

#### 2.2.1.1 Updating process

**Letter memory (Lettre à jour)**

updating span task during which participants had to remember the two last letters of consonants sets containing between 2 and 5 items.
N-back

3 levels N-back (N = 1, 2 and 3) task were proposed during which participants had to compare the consonant displayed on the screen to the consonant that had appeared N times earlier, depending on the level.

2.2.1.2 Mental set shifting

The two following tasks were created based on the study of Friedman et al. (2008).

Number-Letter

in this task, the participants had to alternate between a parity decision and a vowel/consonant decision depending on the location on the screen (i.e. at the top or at the bottom) of a number/letter pairing (e.g. 7G).

Category Switch

the participants had to classify words according to one category between two (i.e. “does the target word fit into a shoebox?” vs “does the target word is made by humans ?“) depending on a visual cue (i.e. the drawing of a shoebox vs of a hand).

2.2.1.3 Inhibition

Stop Signal

during a learning phase, the participants had to indicate the location of pink triangle (i.e. left or right) as quickly as possible. During the test phase, the same instruction was given with the difference that participants had to hold their answer when they heard a beep sound. Following the horse-race model, the Stop Signal Reaction Time was calculated.

Stroop test was used to assess interference suppression. For the old control adults, the Victoria Stroop version [23] and for young adults the standard test [24] were employed.

2.2.2 Working memory tasks

To assess working memory, we used the Time-Based Resource Sharing (TBRS) model (Camos & Barrouillet, 2014). This functional model assumes that the maintenance and processing components of working memory are both dependent on the same limited resource: attention, which moves from one to the other quickly and continuously. When the attentional focus is on the processing component, the memory trace of the information to be maintained would appear to degrade. However, to avoid decay, it is necessary to refresh the information by refocusing attention on this information (Barrouillet et al., 2004).
In order to study these two components of working memory, we programmed three complex span tasks, drawn from the protocol of Barrouillet et al. (2004). Whatever the task was, the participants had to remember consonant sets. The three tasks shared the same design, except for the processing phase. The latter was an interferent subtask displayed between each letter to remember. For the first complex span task the participants had to repeat “baba” syllables sets, for the second they had to perform a reading operation task (e.g., 8/+1/9/-2/7 …) and for the last one, they had to do a continuous operation task (e.g., 8/+1/response/-2/response...).

Before performing the three complex span tasks, forward and backward digit span were proposed. Both were composed of 16 spans, the forward spans from 2 to 9 digit long and the backward spans from 2 to 8 digit long. After two failures within the same span length, the task was stopped.

2.2.3 Decision-making tasks

2.2.3.1 Iowa Gambling Task (Bechara et al., 2000)

The participants performed the traditional IGT (Bechara et al., 2000), which requires to maximize an initial amount of money by selecting decks of cards. Each selection engenders loss or gain of money. Two decks are considered as advantageous and two as disadvantageous (for more details see the appendix).

2.2.3.2 Experimental task based on everyday life situations

The experimental task is composed of two subtasks, one assessing decisions under ambiguity, and the other assessing decisions under risk. It is drawn from two protocols, in two different studies: Lauriola and Levin (2001), and Lauriola et al. (2007).

Each subtask is composed of 36 short scenarios based on everyday life situations (see Fig. 1 for examples). For each trial, the context is described, in two or three sentences, in the top part of the screen. Below, two boxes labelled with the number 1 (i.e. on the left-hand side) or 2 (i.e. on the right-hand side) propose two possible options. The participants are instructed to read all the information, and to select their preferred option by pressing the 1 key or the 2 key. The context, as well as the options, remain continuously visible. The next trial appears once the participants have pressed the keys mentioned (i.e. 1 or 2). In the under-risk condition, the participants are required to choose between one safe option (100% probability of occurrence) and a risky one (x% likelihood of occurrence). Half the scenarios involve a loss vs a smaller loss, or a gain vs a bigger gain. In the under-ambiguity condition, the 36 scenarios are in fact the same 4 stories repeated under 9 different probabilities. The participants are required to choose between an unambiguous option (x% likelihood of occurrence) and an ambiguous one (unknown % likelihood of occurrence). In both subtasks, x can take the value of 2, 10, 20, 40, 50, 60, 80, 90 and 98% likelihood. In one half of the scenarios, the numerical information is given as a percentage (e.g. 2% likelihood of catching up one's delay), and in the other half, it is given as a frequency (2 chances out of 100 of catching up one's delay). The numerical information format as well as the location of the two options are counterbalanced. For the under-risk condition, the order of the scenarios is randomised. For the under-ambiguity condition, the order of the scenarios is semi-randomised.
2.3 Procedure

The participants were first contacted by e-mail, attaching the information letter and the experimenter’s contact details (i.e. e-mail and phone number). If they were interested in the study, a phone call was scheduled with the experimenter in order to explain the procedure better, answer any questions, and schedule the meetings.

The study was composed of three sessions. The first was dedicated to assessing executive functions, the second to assessing working memory, and the third to assessing the decision-making competence. The first two lasted approximately one and a half hours, while the duration of the last was approximately one hour. The sessions were separated by one-week intervals, and took place at the laboratory.

The first session commenced with a reminder of the purpose and of the organisation of the study, and the signature of the informed consent form. After having completed neuropsychological tests and questionnaires, the 6 executive tasks were proposed in random order. Participants were allowed a 5-minute break after each task.

The second session commenced with the anxiety scales (i.e. HAD for the older adults and Spielberger State-Trait Anxiety Inventory for the younger adults). The three working memory tasks were then performed, always in the same order: the baba span, the reading operation task, followed by the counting operation span. For the last two tasks, a cut-off criterion was applied: from the fourth consecutive error, the participants could choose to stop the task. The main reason for this cut-off was to avoid unnecessary effort that could impact the performances in the last task. If the participants made more than 4 errors in a row, but enjoyed challenging situations, the experimenter let them finish.

The last session commenced, once again, with the anxiety scales, to which the BMIS (i.e. a mood scale) was added. The three decision-making tasks (i.e. IGT and the two experimental subtasks), and the OTDL-R, were performed. Their order was counterbalanced, but the two experimental tasks (i.e. with everyday life scenarios) were never presented one immediately after another to avoid a potential reduction in the participants’ interest as the two task were quite similar. Because of the COVID-19 pandemic, the scenario task has been adapted for the young adults in a remote mode, and thus, not programmed on E-Prime but on Psytoolkit [25, 26].

The experimental manipulation was mainly delivered by one experimenter (i.e. the PhD student who had programmed the tasks). Three others experimenters (i.e. Master 2 students in Neuropsychology) also participated to the delivery. They were trained by the main experimenter to do it properly.

2.4 Transparency and openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study, and we follow JARS (Kazak, 2018). Materials, data and analysis code for this study are available under request to the first author. Data were analyzed using JASP (version 0.14.0.0, JASP Team, 2022) and SPSS (version 21.0). This study’s design and its analysis were not pre-registered.
3 Results

3.1 Group comparisons

3.1.1 Executive functions and working memory tasks

To compare the elderly participants’ performances in executive functions and working memory tasks to those of young adults because these two groups significantly differed in level of education the ANCOVA were conducted.

The Table 1 presents participants results in the tasks assessing executive functions and working memory. Only the significant results will be described here below. Globally, the older adults obtained significant lower performances than the young adults for the tasks assessing up-dating ability (composite score $p < .001$). For the N-back test, a stopping criteria allowed the participants to start a 3-back level only if they had achieved a minimum of 75% of hits. The Chi Squared Test showed a significant difference between the two groups, $\chi^2 (df = 1, N = 100) = 25, p < .001$. The older adults accessed significantly less to the third level compared to the young adults. For working memory tasks, the older adults performed significantly less well than young adults only in digit span backward ($p = .027$). The difference was also observed in inhibition capacity, with a lower score at the Stroop test, suggesting lower interference suppression skills. Concerning the flexibility, the mixed results were observed as the switching cost was more substantial for the young than for the older adults in one task (FlexiPaire, $p < .005$) but not the other (FlexiCat, $p = .587$). However, once the errors in switch and non-switch trials analyzed independently in FlexiPaire, it appeared that the two groups of participants accounted for as many errors in switch trials ($F(1,97) = .059, p = .809$), but that older adults committed significantly more errors than young adults in non-switch trials ($F(1,97) = 7.71, p = .007$). Besides, they were in a significantly more pleasant mood than the younger adults did ($p < .001$) before executing the two decision making tasks but they arousal did not differ.
Table 1
Results for executive functions and working memory tasks and t-test comparisons for old adults and young adults

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD) OA</th>
<th>Mean (SD) YA</th>
<th>Statistic</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Up-dating ability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letter memory score</td>
<td>11.22 (1.23)</td>
<td>11.86 (0.35)</td>
<td>F(1,96) = 3.16</td>
<td>.078</td>
</tr>
<tr>
<td>1-back score</td>
<td>10.84 (3.39)</td>
<td>13.84 (1.39)</td>
<td>F(1,97) = 25.7</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>2-back score</td>
<td>6.20 (3.94)</td>
<td>9.74 (3.59)</td>
<td>F(1,97) = 20.4</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>MRT 1-back</td>
<td>645.52 (92.38)</td>
<td>528.67 (78.05)</td>
<td>F(1,97) = 29.9</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>MRT 2-back</td>
<td>630.41 (192.45)</td>
<td>617.54 (96.22)</td>
<td>F(1,97) = .051</td>
<td>.822</td>
</tr>
<tr>
<td><strong>Up-dating composite score</strong></td>
<td>0.93 (0.43)</td>
<td>0.44 (0.28)</td>
<td>F(1,97) = 33.9</td>
<td>&lt; .001</td>
</tr>
<tr>
<td><strong>Switching ability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Switch on errors (FlexiCat)</td>
<td>0.34 (0.80)</td>
<td>0.28 (0.93)</td>
<td>F(1,97) = .297</td>
<td>.587</td>
</tr>
<tr>
<td>Cost Switch on errors (FlexiPaire)</td>
<td>-0.34 (0.96)</td>
<td>0.08 (0.63)</td>
<td>F(1,97) = 8.38</td>
<td>.005</td>
</tr>
<tr>
<td><strong>Switching composite score</strong></td>
<td>-0.00 (0.03)</td>
<td>0.01 (0.04)</td>
<td>F(1,97) = 5.72</td>
<td>.019</td>
</tr>
<tr>
<td><strong>Inhibition ability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSRT Stop-Signal</td>
<td>225.41 (96.93)</td>
<td>209.34 (80.27)</td>
<td>F(1,97) = 1.57</td>
<td>.212</td>
</tr>
<tr>
<td>Stroop score (interference board)</td>
<td>0.86 (0.23)</td>
<td>1.37 (0.27)</td>
<td>F(1,97) = 66.6</td>
<td>&lt; .001</td>
</tr>
<tr>
<td><strong>Working Memory ability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit span forward</td>
<td>6.34 (1.38)</td>
<td>6.84 (0.27)</td>
<td>F(1,97) = .18</td>
<td>.672</td>
</tr>
<tr>
<td>Digit span backward</td>
<td>5.06 (1.19)</td>
<td>5.98 (1.35)</td>
<td>F(1,97) = 5.03</td>
<td>.027</td>
</tr>
<tr>
<td>Complexe span - baba</td>
<td>4.86 (1.13)</td>
<td>5.52 (0.61)</td>
<td>F(1,97) = 2.32</td>
<td>.13</td>
</tr>
<tr>
<td>Complexe span – reading operation</td>
<td>3.90 (1.33)</td>
<td>4.76 (1.92)</td>
<td>F(1,97) = 1.32</td>
<td>.25</td>
</tr>
<tr>
<td></td>
<td>Mean (SD) OA</td>
<td>Mean (SD) YA</td>
<td>Statistic</td>
<td>p</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------</td>
<td>------------------</td>
<td>-----------------</td>
<td>---------</td>
</tr>
<tr>
<td>Complexe span – continuous operation</td>
<td>3.42 (1.21)</td>
<td>4.30 (1.83)</td>
<td>F(1,97) = 3.02</td>
<td>.085</td>
</tr>
<tr>
<td>Working memory composite score</td>
<td>0.67 (0.14)</td>
<td>0.79 (0.15)</td>
<td>F(1,97) = 3.72</td>
<td>.056</td>
</tr>
</tbody>
</table>

Mood before IGT

| BMIS: Plaisant/unplaisant   | 55.32 (4.52)     | 51.27 (5.06)     | F(1,95) = 11.1  | < .001  |
| BMIS: Arousal/Calm          | 27.58 (3.76)     | 27.63 (3.19)     | F(1,95) = .199  | .656    |

Mood before scenarii

| BMIS: Plaisant/unplaisant   | 55.32 (4.52)     | 49.51 (5.82)     | F(1,94) = 19.8  | < .001  |
| BMIS: Arousal/Calm          | 27.58 (3.76)     | 27.26 (3.58)     | F(1,97) = .001  | .988    |

For switching scores, the highest are the scores the less flexible were the participants. For the updating scores, the highest are the scores the most efficient were the updating skills. For inhibition ability, the highest is the SSRT, the most impulsive were the participants and the highest is Stroop z-score, the most efficient were the interference suppression skills. For working memory, the highest are the scores, the most efficient were the working memory skills. For the pleasant/unpleasant scale and the arousal/calm scale, the highest the scores were, the most pleasant and aroused was the participants’ mood.

### 3.1.2 Iowa Gambling Task

The number of advantageous choices (i.e. selection of decks C and D), as well as the number of strategy switching (i.e. from advantageous choices to disadvantageous, and vice versa) were used for the statistical analysis: in total (i.e. 100 trials), per half (i.e. two halves of 50 trials) and per block (i.e. 5 blocks of 20 trials). In addition, the analysis was performed on a net score which was calculated by subtracting the number of disadvantageous deck selections (A + B) from the number of advantageous deck selections (C + D). Preliminary analyses were performed to check for sphericity (Mauchly’s test) or normality of the distribution (Shapiro-Wilk), and homogeneity of variance (Levene’s test). Independent samples t-tests were performed on the total number of advantageous choices and on the total number of strategy switching, with Group (young vs old adults) as grouping variable. Repeated-measures ANCOVA were also performed on the number of advantageous choices and on the number of strategy switching with Half (first vs. second) and Blocks (first vs. second vs. third vs. fourth vs. fifth) as within-subject factor and Group (young adults vs. old adults) as between-subject factor, and including education as covariate. These analyses were followed by post-hoc comparisons. A violation of the sphericity was
observed for the number of advantageous choices per block, for the net score and for the number of strategy switching.

Advantageous choices

The repeated-measure ANCOVA did not bring out a significant effect of blocks on the number of advantageous choices, F(3.5, 341.8) = .97, p = .417 (see Fig. 2), neither simple group effect F(1, 97) = 2.21, p = .14 nor interference group*block effect F(3.5, 341.8) = .80, p = .512. As the absence of effect may be due to the introduction of education as a covariate, to check whether the effect of block exists in each group taken independently, the ANOVA was performed for young and older adults separately. A significant effect was observed for young adults F(3.5, 341.8) = 9.13, p < .001, \( \eta^2_p = .157 \) with less advantageous choices in the 1st bloc than the 3rd, 4th and 5th blocs and less in the 2nd bloc than the 4th bloc (all p < .05). The effect of bloc did not reach significance for older adults F(4, 196) = 2.35, p = .055, \( \eta^2_p = .046 \).

There was not a significant effect of halves (1–50 trials vs 51–100 trials), F(1, 97) = .48, p = .48 (see Fig. 3.a.), neither a significant group effect F(1, 97) = 2.21, p = .14 nor an interference group*halves effect F(1, 97) = 2.54, p = .11. As previously the ANOVA was performed for young and older adults separately. A significant effect was observed for young adults, F(1, 49) = 791, p < .001, \( \eta^2_p = .94 \), but also older adults, F(1, 49) = 579.0, p < .001, \( \eta^2_p = .922 \), with less advantageous choices in 1st halve than in 2nd halve in both groups.

Strategy switching

A repeated-measure ANCOVA showed a significant effect of the blocks, F(3.45, 335.1) = 9.04, p < .001, \( \eta^2_p = .08 \), on the number of switches (see Fig. 4). The post hoc analyses showed significant differences in the number of switches between the 1\textsuperscript{st} block, the 2nd, the 3rd, the 4th and the 5th ; between the 2nd and the 3rd, the 4th and the 5th ; and between the 3rd and the 4th and the 5th (all p < .05). The participants switched less often between the two kind of decks as the task progressed. Neither simple effect of group, F(1, 97) = .002, p = .96, nor interaction group*block effect, F(3.45, 335.1) = 0.28, p = .86, were observed on the number of switches.

Net score

Concerning the net score, there was not significant effect of blocks, F(3.52, 341.8) = .97, p = .42, neither simple group effect, F(1, 97) = 2.21, p = .14, nor interference group*block effect, F(3.52, 341.8) = .80, p = .52, (see Fig. 3.b).

3.1.3 Scenarii task

The number of risky and ambiguous decisions (i.e. respectively under risk and under ambiguous conditions) were used for the statistical analysis. Preliminary analyses were performed to check for normality of the distribution (Shapiro-Wilk), and homogeneity of variance (Levene’s test). Repeated-
measures ANCOVAs were performed first on the total risky decision and the total ambiguous decision independently, to globally compare young and older adults decisions making, with Group (young adults vs. old adults) as between-subject factor and Condition (under risk, under ambiguity) as within-subject factor, then on the number of risky decisions and separately on the number of ambiguous decisions with Group as between-subject factor and first Context (gain vs. loss) as within-subject factors (for the under risk condition only) and then Numerical presentation (percentage vs. frequency), including in each analysis education as covariate. These analyses were followed by post-hoc comparisons.

Under risk task

In the risk condition, the ANCOVA showed significant group effect $F(1, 97) = 11.14, p < .001, \eta_p^2 = .103$ but no context effect, $F(1, 97) = .37, p = .542$, with globally more risks taken by the young adults (mean = 18.86, SE = 0.52) compared to the old adults (mean = 15.86, SE = 0.44) (see Fig. 5.a). More importantly a significant interaction effect group*context, $F(1, 97) = 17.74, p < .001, \eta_p^2 = .109$, was observed. Both groups took more risk in context of loss compared to context of gain. In context of gain, young adults took significantly more risks than old adults (respectively, mean = 8.10, SE = 2.40; mean = 4.32 SE = 2.42 ($p < .001$), but in context of loss, both group took similar risks (respectively, mean = 10.76, SE = 4.55; mean = 11.54, SE = 2.35 ; t (98) = 1.27, p = 0.21) (see Fig. 5.b.).

A second ANCOVA with percentages of certainty as within-subject factor, did not show neither percentages of certainty effect $F(6.82, 661.82) = .595, p = .765$, nor effect of interaction group*certainty $F(6.82, 661.82) = 1.28, p = .255$ (see Fig. 6). Supplementary ANCOVAs were performed for the two contexts (i.e. gain and loss) independently. In context of gain, no significant effect of the percentage of certainty $F(8, 776) = 1.44, p = .177$ was observed. However a significant simple effect of the group $F(1,97) = 68.81, p < .001, \eta^2 = .098$ and a significant interaction effect group*certainty $F(8, 776) = 7.84, p < .001, \eta^2 = .056$ were revealed. The post hoc analyses showed that both groups made comparable risks for all the percentages of certainty (all $p_{bonf} > .151$), except for 2% ($t(98) = -10, p_{bonf} < .001$) and 60% ($t(98) = -5, p_{bonf} < .001$). In both cases, young adults took more risks than old adults (see Fig. 6.a). In context of loss, significant effects of the percentage of certainty $F(8, 776) = 2.35, p = .017, \eta^2 = .016$, of the group $F(1,97) = 7.45, p = .008, \eta^2 = .018$, as well as an interaction effect group*certainty $F(8, 776) = 11.78, p < .001, \eta^2 = .078$ were observed. The post hoc analyses revealed that the number of risks only differed between the two groups for 2% of certainty $t(98) = 8.78, p_{bonf} < .001$, with more risks taken by the old adults (see Fig. 6.b).

The correlation analysis showed no relation in gain context between the percentage of certainty and the number of risky options selected ($r = -.09, p = .064$) in young adults, but in loss context, the higher the percentage of certainty was, the more young adults selected the risky option ($r = .26, p < .001$). In old adults, more risks were taken in context of gain when the percentage of certainty was high ($r = 0.19, p < .001$), but less risks were taken in context of loss when the percentage of certainty was high ($r = -0.11, p = .023$).
In both conditions, under risk and under ambiguity, half of the trials expressed the numerical information in frequencies and the other half in percentages. Under risk condition, neither simple effect of the numerical presentation, $F(1, 97) = .12, p = .73$ appeared significant, nor interaction effect group*numerical presentation $F(1, 97) = .18, p = .66$.

Under ambiguity task

Under ambiguity condition, the ANCOVA with factors group and percentage of certainty showed a significant effect of the group $F(1,97) = 33.18, p < .001, \eta^2_p = .255$ with older adults selecting significantly less ambiguous options (mean = 10.36, SE = 0.93) than young adults (mean = 17.72, SE = 0.48). The interaction group*certainty was also significant $F(5.62, 545.44) = 14.92, p < .001, \eta^2_p = .133$ (see Fig. 7). The post-hoc analysis, after Bonferroni correction, showed the significant differences between young and old adults for 0 %, 60%, 80%, 90%, 98% of certainty conditions (all $p < .001$) with older adults choosing less ambiguous options than young adults. There was no significant differences between different percentages of certainty in young adults. In old adults, after Bonferroni correction, significantly less number of ambiguous options chosen was observed in 2% condition than all other condition except 0 %, in 0 % condition than 80%, 90% and 98%, in 0 % condition than 50%, 60%, 80%, 90%, and 98%, and in 40% condition than 0 % condition. The correlation analyses showed reverse decisional strategies between young and old adults. In young adults, the higher was the percentage of certitude, the more they selected ambiguous options ($r = .105, p < .001$). On the contrary, in old adults, the higher was the percentage of certitude, the less they selected ambiguous options ($r = -.444, p < .001$).

Under ambiguity condition, neither simple effect of the numerical presentation, $F(1, 97) = .016, p = .90$ appeared significant, nor interaction effect group*numerical presentation $F(1, 97) = .002, p = .96$.

### 3.2 Correlation et regression analyses with EF and WM tasks

#### 3.2.1 Correlations

The correlation analyses between the results of the executive functions tasks (i.e. the up-dating composite score, the switching composite score, the Stroop score and the SSRT) and the working memory composite score, and the results of the decision making tasks for the two groups all together were performed first. Then the participants were split into two groups, high and low performers, for each score and the correlation analysis were performed again on each group separately. To separate the high from the low performers, the median was calculated independently for the young and the old adults. The 25 young adults and the 25 old adults with the best scores were gathered into the high performers group, and the 50 others participants (i.e. 25 young and 25 old adults) were gathered into the low performers group.

Preliminary analyses were done to check for normality of the distribution (Shapiro-Wilk). Pearson’s $r$ coefficient was used, except in case of normality’s deviation, the Spearman’s rho was used instead.
3.2.1.1 Global correlations

No correlation was found between the cognitive tasks scores and the number of advantageous choices in the IGT. However, the strategy changes during the IGT (i.e. number of switches between advantageous et disadvantageous decks) correlated with the Stroop score (rho = -0.22, p = .033, see Fig. 8).

For the scenarii tasks, the up-dating composite score ($r = -0.428$, $p < .001$), the working memory composite score ($r = 0.245$, $p = 0.014$) and the Stroop score ($r = 0.435$, $p < 0.001$) correlated with the total number of ambiguous options chosen in the under ambiguity condition (see Fig. 9). The up-dating composite score ($r = -0.315$, $p < .001$) and the Stroop ($r = 0.382$, $p < .001$) correlated with the total number of risky options chosen in the under risk condition (see Fig. 10).

For the scenarii under risk, the up-dating composite score ($r = -0.423$, $p < .001$) and the Stroop ($r = 0.480$, $p < .001$) correlated with the number of risky options chosen in the gain context (see Fig. 10). No other correlation was significant neither in gain nor in loss context.

3.2.1.2 Correlations for high and low performers
Table 2
Correlations between the results in the decision making tasks and the results in executive and working memory tasks for high and low performers independently

<table>
<thead>
<tr>
<th></th>
<th>Advantageous decisions IGT</th>
<th>Strategy switching IGT</th>
<th>Total risky decisions</th>
<th>Total ambiguous decisions</th>
<th>Risky decisions in gain context</th>
<th>Risky decisions in loss context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switching composite score</td>
<td>rho = -0.03, p = 0.847</td>
<td>rho = 0.00, p = 0.98</td>
<td>rho = 0.19, p = 0.20</td>
<td>rho = 0.03, p = 0.85</td>
<td>rho = -0.02, p = 0.90</td>
<td>rho = 0.21, p = 0.14</td>
</tr>
<tr>
<td>High performers</td>
<td>rho = 0.18, p = 0.20</td>
<td>rho = -0.04, p = 0.81</td>
<td>rho = 0.13, p = 0.36</td>
<td>rho = -0.04, p = 0.81</td>
<td>rho = -0.00, p = 0.35</td>
<td>rho = -0.00, p = 1.00</td>
</tr>
<tr>
<td>Low performers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Up-dating composite score</td>
<td>rho = -0.17, p = 0.24</td>
<td>rho = -0.04, p = 0.77</td>
<td>rho = -0.35, p &lt; .001***</td>
<td>rho = -0.55, p &lt; .001***</td>
<td>rho = -0.41, p = 0.00**</td>
<td>rho = -0.11, p = 0.45</td>
</tr>
<tr>
<td>High performers</td>
<td>r = -0.19, p = 0.19</td>
<td>r = 0.20, p = 0.18</td>
<td>r = -0.37, p &lt; .001***</td>
<td>r = -0.56, p &lt; .001***</td>
<td>r = -0.63, p = 0.09</td>
<td>rho = 0.09, p = 0.56</td>
</tr>
<tr>
<td>Low performers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroop score</td>
<td>r = 0.30, p = 0.03</td>
<td>r = -0.03, p = 0.82</td>
<td>r = 0.38, p = 0.00**</td>
<td>r = 0.41, p = 0.56</td>
<td>r = -0.10, p = 0.47</td>
<td></td>
</tr>
<tr>
<td>High performers</td>
<td>r = 0.16, p = 0.27</td>
<td>r = -0.07, p = 0.61</td>
<td>r = 0.43, p &lt; .001***</td>
<td>r = 0.54, p &lt; .001***</td>
<td>r = 0.51, rho = 0.15</td>
<td></td>
</tr>
<tr>
<td>Low performers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSRT</td>
<td>r = 0.15, p = 0.32</td>
<td>r = -0.02, p = 0.89</td>
<td>rho = 0.22, p = 0.13</td>
<td>r = 0.18, p = 0.04</td>
<td>r = 0.18, p = 0.18</td>
<td>r = 0.18, p = 0.23</td>
</tr>
<tr>
<td>High performers</td>
<td>rho = -0.24, p = 0.10</td>
<td>rho = 0.05, p = 0.75</td>
<td>rho = -0.31, p = 0.03*</td>
<td>rho = -0.31, rho = -0.43</td>
<td>rho = -0.43, rho = -0.03</td>
<td></td>
</tr>
<tr>
<td>Low performers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working memory composite score</td>
<td>r = 0.21, p = 0.09</td>
<td>r = 0.19, p = 0.19</td>
<td>r = 0.31, p = 0.17</td>
<td>r = 0.31, p = 0.17</td>
<td>rho = 0.01, p = 0.96</td>
<td></td>
</tr>
<tr>
<td>High performers</td>
<td>rho = -0.11, p = 0.47</td>
<td>rho = 0.10, p = 0.50</td>
<td>r = -0.04, p = 0.78</td>
<td>rho = -0.02, p = 0.02**</td>
<td>r = 0.25, p = 0.02*</td>
<td></td>
</tr>
<tr>
<td>Low performers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Significant correlations (Table 2) appeared for low and high performers between the up-dating score on one hand and the Stroop score on the other hand and the total number of risky decisions, the total number of ambiguous decisions and the number of risky decisions in the context of gain. Significant correlations also appeared between the SSRT and the total number of risky and ambiguous decisions, but only for the low performers. Finally, the working memory composite score correlated with the total number of ambiguous decisions, for high and low performers, and with the number of risky decisions in context of gain, for the low performers only.

### 3.2.2 Regressions

In order to analyze the implication of the executive function and the working memory on the decision making competency, multiple regression analysis were performed by entering for each analysis one of the decision making ratings (i.e. advantageous decisions at the IGT, number of switches during the IGT, total risky choices in the scenarii task under risk condition, total ambiguous choices in the scenarii task under ambiguity condition) as dependent variable and the up-dating composite score, the working memory composite score, the switching composite score, the Stroop score and the SSRT of the Stop Signal task as predictors. The analysis was performed on all results together without distinguishing young and old adults. Only the significant models are reported in the Table 3.
Table 3
Multiple regressions with the decision making tasks as criterion and the executive and working memory tasks as factor scores

<table>
<thead>
<tr>
<th>Task</th>
<th>β</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>« Strategy switching (IGT) »</td>
<td>-.21</td>
<td>-2.16</td>
<td>.033</td>
</tr>
<tr>
<td>Stroop score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2_{adj} = .036$, $F(1,98) = 4.65$, $p = .033$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>« Ambiguous choices (scenarii task) »</td>
<td>.28</td>
<td>2.40</td>
<td>.018</td>
</tr>
<tr>
<td>Stroop score</td>
<td>-.26</td>
<td>-2.24</td>
<td>.028</td>
</tr>
<tr>
<td>Up-dating composite score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2_{adj} = .213$, $F(2,97) = 14.39$, $p &lt; .001$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>« Risky choices (scenarii task) »</td>
<td>.38</td>
<td>4.09</td>
<td>.000</td>
</tr>
<tr>
<td>Stroop score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2_{adj} = .14$, $F(1,98) = 16.72$, $p &lt; .001$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>« Risky choices in context of gain »</td>
<td>.48</td>
<td>5.42</td>
<td>.000</td>
</tr>
<tr>
<td>Stroop score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2_{adj} = .22$, $F(1,98) = 29.35$, $p &lt; .001$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Regarding the number of shifts between the advantageous and the disadvantageous decks during the IGT, one model came out with the Stroop score that explained for 3.6% of the variance. For the total number of ambiguous choices in the scenarii task under ambiguity condition, two models came out. The most robust including the Stroop score and the up-dating composite score explained for 21.3% of the variance. For the total number of risky choices in the scenarii task under risk condition one model came out with the Stroop score that explained for 14% of the variance. The analysis performed for each context (i.e. gain vs loss) separately, sorted out that the Stroop score explained for 22% of the variance in the context of gain, but no significant model came out for the context of loss.

4 Discussion

This study aimed to investigate the differences in DMC under risk and under ambiguity between young and old adults. To this purpose, tasks based on everyday life situations and the traditional IGT were used. This study also examined how executive functions (updating, mental set shifting, and inhibition process) and working memory impact DMC in older adults, compared to younger adults.
The results of the cognitive functions tasks and of the decisional tasks will first be discussed, comparing young and old adults performances and then the correlations and regressions analyses, between cognitive functions and DMC for all participants together.

4.1 Executive functions and working memory through ageing

The present results brought out significant differences between the performances of young and old adults in cognitive tasks. Indeed, the elderly showed weaker scores in the tasks assessing up-dating, inhibition and working memory abilities compared to their younger peers.

4.1.1 The up-dating skills in ageing

The deficit in up-dating in older adults, measured by n-back task, was reported previously [27–29], with an increased response time and a diminution in the number of hits with ageing. The present study brings similar observations, except for the 2-back response time that did not differ between the two groups. In fact, the old adults answered as quickly for both difficulty levels, whereas the young adults underwent a slowdown in their response time between the 1 and 2-back levels. The speed of stimuli presentation during the 1-back level may already have been very cognitively demanding for old adults, and the fact that this restrained response time was maintained during the 2-back phase did not give them time to respond properly. Consequently, they made much more errors during the 2-back task. Furthermore, a stopping criteria allowed the participants to start a 3-back level if they had achieved a minimum of 75% of hits in 2-back level. While 30 of the 50 young adults accessed to this last phase, only 6 of the 50 old adults did it. These data seem compatible with the suggestion that the strategy privileged to achieve the task evolves through age, the young adults relying more on executive functions and the old adults on attentional process, this change being closely linked to the decrease of prefrontal cortex activation [30, 31].

4.1.2 The inhibition skills in ageing

Concerning the inhibition ability: the two groups had comparable performances for the Stop Signal task, but young adults performed better on the Stroop test than the old adults. In the literature, the conclusions remain quite contradictory. Bherer et al. (2004) and Troyer et al. (2006) claimed that the interference suppression component is particularly vulnerable to ageing, but according to Rey-Mermet and Gade (2018) it is intact, unlike the performances at tasks appealing for motor inhibition (e.g. the Stop Signal). Interestingly, the absence of age effect on the Stroop score does not mean that the inhibition process is identical for young and old adults. Indeed, from a neurophysiological perspective, Tam et al. (2015) showed that long response time was not associated with the same cerebral activations in young and old adults. For the latter, frontoparietal areas were mainly involved, probably being the results of compensatory or dedifferenciation phenomena. Gajewski et al. (2020) showed that on a behavioral level Stroop performance was lower for old adults than middle-age and young adults and for middle-age
adults than young adults, but high Stroop old adults performers had larger contingent negative variation (CNV) (i.e. linked to pro-active task control) and larger P2/N2 complex (i.e. linked to reactive task control) compared to old adults with low Stroop performance, but comparable CNV and P2/N2 complex to middle-age and young adults. As far as we know, less studies have investigated motor inhibition in old adults by the means of Stop Signal tasks. One of them showed lengthened SSRT (i.e. Stop Signal Response Time) in old adults compared to young adults, meaning that ageing is associated with an increase of impulsiveness (Hu et al., 2018). However, this study used visual modality for the go and the stop signals. Interestingly, it has been proven in young adults that the modality of the task affects the inhibitory process, with faster detection in auditory modality and thus, shorter SSRT (Ramautar et al., 2006). Lee and Hsieh (2017), who compared old adults and middle-age adults with an auditory stop signal paradigm, did not find any significative difference in the SSRT between the two groups either. Old adults may experience difficulties to inhibit a motor response in visual modality only. This modality already being less efficient in young adults, it might be more fragile and vulnerable to aging. The decline of the performances in Go-No go tasks observed with ageing corroborate this hypothesis [29, 33]. A second interpretation could also be that the task used in the present study did not contain enough items to show the age effect. Indeed, there were three blocks of 30 trials including 8 stop signals.

### 4.1.3 The mental flexibility skills in ageing

Concerning mental flexibility, the composite score calculated from the cost of switch trials on errors in the two switching tasks came out comparable for both groups. The tasks taken apart, it appeared that young adults were more sensible to the switch cost than old adults on FlexiPaire only. In fact, the mean number of switch errors was higher in the old adults group, but their number of non-switch errors was even bigger, so their cost switch was negative. In the literature, a consensus emerges concerning a deficit in switching ability with ageing (Bherer et al., 2004; Erb et al., 2020; Huff et al., 2015). However, all of them based their analyses on the switch cost on the mean response time (MRT). Huff et al. (2015) linked the performances’ difference to the attentional process, arguing that participants with stronger attentional skills were “tuned” to the task, and thus slowed down by the switch trials. On the contrary, participants with weaker attentional skills, like the old adults, were less “tuned”, and consequently, less influenced by the instruction change. In the present study, 4 keys were used to record the participants’ answer. Participants who were not familiar with computer’s material could not use one finger per key, but two, or even sometimes only one, for the four keys. For this reason, the response time in our two switching tasks cannot be taken into account. Anyhow, in addition to compare the switching cost on MRT, Huff et al. (2015) also compared the switching cost on errors, which was not affected by ageing.

### 4.1.4 The working memory skills in ageing

Finally, working memory integrity has also been compared between young and old adults. According to the composite score, the old and young adults showed comparable performances, even if the p was very close to the significance threshold. However, the old adults performed significantly less well in the digit span backward task compared to young adults. This latter result is in line with the meta-analysis of Bopp and Verhaeghen (2005), revealing an effect of age on several spans tasks (i.e., short-term memory,
reordering and working memory spans) with the young adults always performing the best. However, this effect would modulate with the spans’ category, the working memory spans being the most sensitive and the short-term memory spans being the least sensitive. To our knowledge, no study investigated working memory in ageing through the time based resources sharing (TBRS) perspective. In this context, it is hard to confront our results to the literature. Nevertheless, researches using reading or computation spans tasks reached another conclusion: performances in working memory spans are affected by ageing [41, 42].

To sum-up this section, old adults expressed difficulties compared to young adults in the tasks assessing up-dating, inhibition and working memory. These results are consistent with previous researches. The absence of deficit in mental flexibility in the old adults could result from the assessing task construction, which did not allow the analyses of the MRT.

4.2 Decision making competence and ageing

As a reminder, decision making competency (DMC) was assessed with two tasks: the IGT and a scenario task, composed of two conditions: under risk and under ambiguity decisional situations.

4.2.1 The Iowa Gambling Task

For the IGT, there was no measurement that showed a difference between the two groups. First of all, both groups improved as the task progressed, with more advantageous selections and higher net scores at the end of the game. Group-separated analyses however pointed out a significant increase in the number of advantageous choices over the task for the young adults, which was not observed in old adults. In the literature, contrasted results are found with studies observing no age effect on the net score over the five blocks (Wood et al., 2005; Zamarian et al., 2008), studies highlighting lower net score over the task in old adults compared to young adults [45], and studies describing heterogeneous results, with only a subset of participants among the older group showing impaired performances [43, 44, 46]. However, we considered necessary to keep in mind while discussing the results that the definition of young and old adults age intervals was very heterogeneous among the studies, possibly impacting the results.

In our study, the number of shifts between advantageous and disadvantageous decks was also analyzed. Both groups switched more often between the decks at the beginning of the exercise (i.e. blocks 1 and 2) than at the end (i.e. blocks 4 and 5). According to Zamarian's et al. (2008) results, old adults produced significantly more strategy changes, and adapted significantly less their behavior over the task than young adults. Wood et al. (2005), as for them, brought out that decisions made by old adults relied as much on the gains as on the losses, whereas young adults decision making was more sensible to the losses. The selection of the decks in older adults was also highly dependent on the recent outcomes, contrary to the young adults that selected the decks independently of this characteristic.
Several causes can be envisaged to explain data divergence. First of all, the participants’ age in the groups, and especially in the young adults group, were not equivalent in the studies. In the present study, the average age of the young group was at least 10 years younger than in Zamarian et al. (2008), Denburg et al. (2007) or Fein et al. (2007). The brain undergoes modifications over the time, and thus, performances in cognitive tasks can modulate even among a population of young adults. Indeed, the increase of white matter reach for example its peak around 37 years old, and then decrease, but more slowly than it has grown (Lebel et al., 2012). Recent studies precisely described links between white matter integrity and fluid intelligence (Chen et al. 2020; Li et al., 2020). The IGT, at least its first part, should require fluid intelligence (Li et al., 2017). A first hypothesis could be that fluid intelligence, were less mature in the 26 average years old group compared to the groups with an average age above 36 years old. Finally, the lack of maturity in the young group could have had the same consequences on the IGT performances as the deterioration impacting the old adults. This could explain why we did not find any difference between our two groups of age whereas other studies did. A second hypothesis rely on studies describing the old adults’ DMC as heterogeneous, with other factors that, only when coupled with age, can influence the decision. For instance, different patterns of activations among old adults can lead either to better or to poorer performances. Indeed, bilateral activations in vm-PFC or greatest amplitude in anticipatory skin conductance responses before picking a card from advantageous decks were related to better performances in the old adults [46, 51]. Without objective measures, some characteristics of the decisional process in old adults may stay invisible. It could be possible that for some random reasons, the old adults included in the present study were better to compensate, resulting in a behavior similar to the young adults group.

4.2.2 The scenarii task and its under risk condition

In the under risk condition, young adults selected more risky options (i.e. options with a percentage of certainty inferior to 100) than old adults. These results corroborate those of Deakin et al. (2004) and Lee et al. (2008). Deakin et al. (2004) showed with the Game of Dice Task (GDT) that old adults took also more time to deliberate than young adults. In the present study, the deliberation time could not be analyzed as the response time depended on the reading speed too.

Interestingly, the context of decision making (i.e., of gain or loss) may influence the decision depending of age. In the present study, both groups took similar risks in loss context, but young adults took more risks than old adults in gain context. This tendency to avoid risk in a context of gain and, on the contrary, to prefer it in a context of loss has been described by Kahnemann and Tversky (1979) through their Prospect Theory. It posits that two problems mathematically equivalent can be influenced by irrelevant information, from a rational perspective, and thus, lead to different decisions (Gollier et al., 2003). So in overall, young and old adults in the present study were sensible to the context (i.e., to the frame effect), but to a lesser extent the youngest group than the eldest, especially in gain context. These results corroborate those of Kim et al. (2005) who, relying on the resource allocation hypothesis (Hess et al.,2001), suggested that the old adults were more inclined to rely on the heuristic mode for the realization of tasks with high level of complexity, which is less appropriated to make decisions under risk condition.
In accordance with STT [58–61], because old adults are more interested in their well-being, they would rather prefer to avoid risk in a context of gain (i.e. in order to obtain a smaller but sure gain), and seek it in a context of loss (i.e. to try to avoid a sure loss). On the contrary, the young adults’ actions are directed by the pursuit of new knowledge, thus they shall dare more risks than old adults in context of gain because it is more conductive to the acquisition of new knowledge. Despite their thirst for knowledge, they are still influenced by the context, and tend to avoid more often the risky options to obtain a gain than to prevent a loss. Their choices would then be directed by their seek of knowledge and the estimation of their survival chances. Interestingly, when comparing with healthcare scenarii two groups of old adults, one being younger than the other (i.e. young old adults vs old old adults), the opposite effect appears: the eldest chose more disadvantageous options than the youngest old adults (Pertl et al., 2017). According to the authors, impaired executive functions would this time be the cause.

The number of risks taken depending on the percentage of certainty and the context (i.e. gain or loss) showed a major difference between the two groups for 2% of certainty: old and young adults expressed a reverse response pattern. Indeed, in context of gain, young adults chose almost always the risky options whereas the old adults almost never. In context of loss, young adults never selected the risky options, while old adults mainly chose them. Response pattern in old adults seems quite logical regarding the global answering strategy. However, the explanation concerning young adults behavior is less clear. For the gain context, maybe the very low percentage of certainty exerts an over-effect on their novelty seeking, making them privileging the risky option. Concerning the context of loss, we do not know how to interpret their risk avoidance. It might be due to a random effect, and thus, need to be challenged by future studies. In addition, the correlation analyses showed results that seem to be in line with the SST. Indeed, the old adults adopted a strategy favoring their well-being, by taking higher risks with higher percentage of certainty in context of gain, but lower risks with higher percentage of certainty in context of loss. The young adults, on the contrary, adopted a strategy satisfying their curiosity, at least in context of loss during which they took more and more risks as the percentage of certainty increased.

Another factor that may influence the decision making is the type of numerical presentation (i.e. frequency vs percentage). In the present study, no effect of the numerical presentation appeared. Pertl et al. (2017), had nevertheless showed that frequency format was the hardest one to process in the eldest compared to younger participants, after having demonstrated in another study that ratio processing predicted decision making under risk (Brand et al., 2014). These two information in mind, we could have expected less advantageous decisions when the relevant information is given in frequencies.

4.2.3 The scenarii task and its under ambiguity condition

Concerning the condition of the scenarii task that was under ambiguity, the young adults selected significantly more ambiguous options (i.e. with unknown percentage of certainty) than the old adults. It is possible that, as for the decision making under risk, young adults selected more ambiguous options than old adults because it coincided more with their goals, the quest of knowledge. Tannou et al. (2020) found out that ageing is associated with reduced speed processing in decision making under ambiguity.
condition in a more pronounced way. However, decisions based on personal experience and with small temporal constraints appeared to be little impacted by the senescence. Our task, based on daily life situations and without time restriction seems then highly suitable for the old adults to succeed.

Whereas young adults selected ambiguous options in the same proportion for all the certainty percentages of the unambiguous options, old adults globally reduced their number of ambiguous options’ selection as the percentages of certainty in the unambiguous options increased. At our knowledge, no other study assessed decision making under ambiguity with daily life-inspired scenarios in old adults population. Lauriola et al. (2007) proposed however a similar exercise, which focused on healthcare situations and was addressed to young adults only. Their results showed a general trend to ambiguity avoidance, even among the participants considered as “ambiguity seeking”. Using the Ellsberg’s task, they also showed that the higher the probability of the unambiguous urn was, the most the participants selected it instead of the ambiguous urn. This is precisely what we observed in the present study with the old adults, but not with their younger peer. However, some studies using equivalent tasks to that of the Ellsberg’s with young and older adults did not find effect of age, at least when no feedback was given (Leuker et al., 2020; Sproten et al., 2018). The emotional state of the young adults included in the present study could be at the origin of these differences. The data with young adults were collected during pandemic COVID-19 period and in a remote mode. This pandemic context might have triggered some stress, in young adults which could have impacted their decisions. It seems indeed that decision making under ambiguity would be more vulnerable to stressing situations than decision making under risk (Cano-López et al., 2016).

4.3 Cognitive implications in decision making competence

Another purpose of our study was to investigate the links between executive function (i.e. up-dating, inhibition and mental flexibility processes), working memory and decision making in ageing.

Little of correlations appeared significant and only when the data of all the participants were included in the analysis. The strategy changes (i.e. the number of switches between advantageous and disadvantageous decks) correlated with the Stroop score. In fact, the better the Stroop score was, the less participants shifted between the decks. According to the regression analysis, the Stroop explained for 3.6% of the strategy changes’ variance. At our knowledge, very few studies investigated the links between IGT performances and executive function or working memory in old adults. Using the Iowa Scale of Personality Change (ISPC), Nguyen et al. (2013) showed an impact of the executive personality on the IGT performances, especially the impulsivity component. Wood et al. (2005) showed that the young adults owed their good IGT performances to their ability to learn and memorize, whereas the old adults relied on their affective reactions. Both groups probably resorted to inhibitory abilities, but not in the same way. The young adults might have deployed a long-term inhibitory strategy (i.e. they first tried to understand the task, and then, inhibited the disadvantageous decks), while the old adults might have deployed a short-term inhibitory strategy (i.e. they adapted their selections more or less trial after trial). An argument in favor of the hypothesis of inhibitory ability implication for accurate IGT performances comes from Schmicker et al. (2019) study. They showed that old adults trained with a selective attention task...
(involving some inhibitory processing), but not with a short memory task, improved their IGT performances. To sum up, inhibition ability seems especially useful to perform at the IGT.

In the scenarii task, up-dating and inhibition (i.e. the Stroop score only) were especially involved. Under ambiguity, both of that functions explained (i.e. 21%) in part the decisional performances. Under risk, only the Stroop score explained (i.e. 14%) in part the decisional performances. Working memory was also linked to the decision under ambiguity, but no causal relation was found. The present study showed a special implication of the up-dating (i.e. the up-dating in working memory) in the scenarii task. These results go along with the previous study using the N-back task [71]. In front of a situation that brings a decision up, memories of similar decisional circumstances are activated to guide the new decision and have to be maintained in working memory [72]. To grow in efficiency, the decision-maker will have to focus on the relevant information, and thus, to suppress the distracting information: the inhibitory process comes into play.

As some previous researches had pointed out the fact that ageing alone would not be enough to deteriorate DMC, we split the participants into two performing level groups (i.e. high and low performers), and conducted correlations analyses. Interestingly, new correlations were highlighted between DMC and cognitive functions, but only for the low performers’ group. Indeed, the SSRT (i.e. impulsivity indicator) and the total number of risky and ambiguous decisions were correlated: the more low performers were impulsive (i.e. had a short SSRT), the more they were ambiguity and risk seekers, notably in context of gain. The scenarii task was not designed to be processed as fast as possible. Multiple information was given and no time limit was programmed, so the participants could detect what was relevant, process it, and make the decision they felt was best. Impulsive participants probably did not take the time to understand what they read, and so, could not process it properly, leading to a larger selections of risky and ambiguous options. Indeed, as these options promised a chance to obtain bigger gains, they maximized the attentional capture potential, in particular in impulsive participants, whatever the chance to win was. A parallel could be done with the results of Brand and Schiebener (2013) who had showed that the combination of poor logical thinking and old age influenced negatively decision making under risk. Impulsive people tend to hurry answering, and does not leave space for reasoning or logical thinking. Even if no data are available to assure that the low performers of the present study had poor logical thinking, they were at least more impulsive than the high performers, and this characteristic may have impacted logical thinking. Other abilities, not tested in the present study, once combined with age factor, could also affect DMC. This is for instance the case of feedback processing: age adults with difficulties in managing feedback would struggle more to make advantageous decisions [20].

4.4 Limitations

Our study presents some limitations. First of all, the tasks were programmed to be doable by patients with Alzheimer’s disease, for the purpose of another study. Therefore, some of them (i.e. the two tasks assessing mental flexibility and the Stop Signal task) were maybe too easy to let appear significant differences between the two groups of age. Second, although we have included 50 participants in each group, which is a high number of participants for inferential analyses, it is rather small for conduct robust
correlations and regressions analyses for each group separately. Unfortunately giving the pandemic context we were not able to include more old participants. This is why we privileged conducting these analyses on all participants together. For the future studies it would be interesting to test the hypothesis according to which cognitive functions would be implicated differently in DMC depending on the age. Finally, whereas the old adults performed the scenario task in the laboratory, the pandemic situation made us change the task for the young adults, who performed it at home during the lockdown. The mode of administration may have interacted with the performances.

5 Conclusion

Compared to young adults, old adults showed impaired performances in the majority of the cognitive tasks. The IGT failed to distinguish the two age groups, but the scenarii task highlighted more risk and ambiguity seeking in young adults than in the eldest. Surprisingly, this observation was especially remarkable in context of gains, under risk condition. The SST could provide a satisfactory explanation: the old adults avoid risk and ambiguity to maximize their well-being, and the young adults seek risk and ambiguity in their quest of knowledge. Inhibition and up-dating would be particularly implicated in the DMC, whatever the condition (i.e. under risk or under ambiguity) is.

Declarations

Ethics approval and consent to participate

All methods were performed in accordance with the relevant guidelines and regulations in Ethics Approval and Consent to participate in Declarations. Indeed, the study was approved by the ethical committee of Comité de Protection des Personnes Ile de France XI and received the n°19031-57438. All the participants received and signed an inform consent form, which was also explained orally.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by the University Lyon 2, for the purpose of a PhD thesis.
Author's Contributions

FG, CB and HC have made substantial contributions to the design of the work. FG has made the conception of the tasks, the acquisition, most of the analyses and the interpretation of the data, and was a major contributor in writing the manuscript. HC and JCR contributed to the data analyses. CB and HC also contributed to substantively revised the work. All authors read and approved the final manuscript.

Acknowledgments

We thank Pr. Marco Lauriola and Pr. Gijsbert Stoet for their quick and precious answers concerning the tasks conception. We thank Chloé Gadille, Marie Guinand and Mathilde Hammani for their help in the delivery. We thank Hippolyte Fournier and Théo Héritier for their help in some statistical questions.

References


Figures
Figure 1

Example of scenario under risk on the left (a.), and under ambiguity on the right (b.)

![Figure 1](image)

Figure 2

Mean of advantageous selections in IGT blocks (max = 20) in old and young adults (bars represent standard errors).

![Figure 2](image)
Figure 3

(a) Mean of advantageous selections in IGT halves in old and young adults; (b) IGT net score, corresponding to (C+D)-(A+B) decks selections. Bars represent standard errors.

Figure 4

Mean frequency of switches between advantageous (C+D) and disadvantageous decks in IGT (bars represent standard errors)
Figure 5

(a) Mean selections of less advantageous choices: ambiguous in under ambiguity scenarios and risky under risk scenarios; (b) Mean selections of risky options in under risk scenario depending on the context of gain or loss. Bars correspond to standard errors.

Figure 6

Mean number of risky options selected depending on the percentage of certainty in the risky options, in gain context (a) and in loss context (b). Bars correspond to standard errors, maximum choice of ambiguous options per percentage = 2.
Figure 7

Mean number of ambiguous options selected depending on the percentage of certainty in the unambiguous options. Bars correspond to standard errors, maximum choice of ambiguous options per percentage = 4.
Figure 8

Correlations between the number of switches during the IGT and the Stroop score, the number of switches maximal being 99
Figure 9

Correlations between the total number of ambiguous options (max = 36) chosen in the under ambiguity condition and the up-dating composite score (a), the working memory composite score (b), and the Stroop score (c).
Figure 10

Correlations between the total number of risky options (max = 36) chosen in the under risk condition; and the up-dating composite score (a), and the Stroop score (b); and between the number of risky options in the context of gain (max = 18) chosen, the up-dating composite score (c), and the Stroop score.

Supplementary Files
This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1.docx