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**ECOLOGICAL RELEVANCE OF THE IOWA GAMBLING TASK IN
ALZHEIMER'S DISEASE AND MILD COGNITIVE IMPAIRMENT**

**Jean-Pierre Jacus (Ph.D)^{1,2}, Marie-Christine Gély-Nargeot (Pr)², and Sophie Bayard
(Ph.D)²**

¹ Consultations mémoire, Centre hospitalier du val d'Ariège, Foix, France.

² Laboratoire Epsilon, EA 4556, Université Paul-Valéry, Montpellier, France.

Corresponding author: Jean-Pierre Jacus, Consultations mémoire, Centre hospitalier du val d'Ariège, Foix, France. Tel: + 33 (0) 6 85 07 64 72 – Fax: + 33 (0) 5 61 03 31 75

jeanpierrej@chi-val-ariege.fr

Coauthor: Marie Christine Gély-Nargeot marie-christine.gely-nargeot@univ-monpt3.fr

Coauthor: Sophie Bayard bayardsophie@yahoo.fr

Abstract: *Background* – In spite of their extensive use, the ecological relevance of tasks dedicated to assessing real-world decision-making in a laboratory setting remains unclear. *Objectives* – Our study aims to evaluate the relationships between on the one hand decision-making, and on the other behavioral competencies and awareness of limitations. *Methods* – We recruited 20 patients with Alzheimer’s disease (AD), 20 patients with amnesic Mild Cognitive Impairment (aMCI), and 20 healthy controls. Decision-making was assessed using the *Iowa Gambling Task* (IGT). Behavioral competencies and awareness of limitations were evaluated using the *Patient Competency Rating Scale* (PCRS), requiring each participant and a relative to complete the same 30 questions on the participant’s competencies. Behavioral competencies were measured using Self- and Relative-ratings and awareness was evaluated by subtracting the Self-rating score from the Relative-rating score. *Results* – Using the median-split approach, the percentage of disadvantageous decision-makers was higher in both MCI and AD groups than among healthy controls (respectively; $p=0.02$, $p=0.03$), without any difference between clinical groups. The percentage of participants with poorer behavioral competencies was higher in both MCI and AD groups than among healthy controls (respectively, Self-rating: $p=0.025$, $p=0.01$; Relative-rating: $p=0.08$, $p=0.08$), without any differences between clinical groups. All groups were comparable on awareness. In the whole sample, disadvantageous decision-making performances were associated with both reduced behavioral competencies and poor awareness of limitations (respectively: $OR=3.47$, $p=0.03$; $OR=5.4$, $p=0.004$). *Conclusion* – Our findings contribute to demonstrating the ecological relevance of the IGT. Behavioral competency integrity and awareness of limitations are both associated with advantageous decision-making performances.

Key words: Alzheimer’s disease; Awareness; Decision-making; Mild cognitive impairment; Personal autonomy.

1 Introduction

Decision-making is a broad and complex construct used in several domains, such as economy or management. In the neurobehavioral sciences, decision-making has been defined as the ability to make choices that are advantageous for survival in the long term ^[1]. Data from the literature indicates that this concept covers a complex set of cognitive and emotional processes related to the ability to modulate the perception of reward and punishment in order to operate choices that are advantageous in the long term ^[2-4]. In an experimental setting, decision-making can be assessed using gambling tasks which are considered to simulate real-world decision-making. These tasks require the participants to make the most advantageous decisions by choosing the options that provide the best reinforcement from among several alternatives. Decision-making tasks are either based on reinforced learning, where premises, outcomes, rewards, or punishments are initially unknown (decision under ambiguity) ^[1], or on situations where the potential consequences of different options and their subsequent probabilities require explicit information (decision under risk) ^[2-3]. In both types of task, the best option is that which provides the lowest but the safest reward.

Thus decision-making tasks depending on reinforced learning set risk-taking against benefits in order to operationalize the concept of decision-making as “*making choices that are advantageous for survival in the long term*”. The expected behavior mediated by the reinforcement schedule is choosing the safest options, and hence the lowest benefits (see below 2.3 Iowa Gambling Task).

Decision-making was modelled according to the following processes involving three main systems ^[5-6]:

- The first step concerns the stimulus-encoding system, involving the ventromedial prefrontal cortex (VMPFC), the striatum and the orbitofrontal cortex (OFC). In this step,

there is an identification of the different options and the attribution of an expected value for each of them.

- The second step concerns the action-selection system, involved in learning and subjective value-encoding. In this step, the subject gives preference to an option and selects an action. The action that follows a decision seems to be processed mainly in the anterior cingulate cortex (ACC), the lateral prefrontal cortex and the lateral and medial intra-parietal cortices.
- The last step concerns the expected reward system, involving in particular the amygdala and the basal ganglia. This system is thought to be modulated by the dopaminergic system. In this step, there is comparison between the expected value and that obtained, and the appearance of feelings such regret or disappointment.

It can be noted that other conceptualizations in experimental setting using reinforced learning and the benefits/costs ratio have recently been suggested. These studies, which require participants to perform a physical task (effort) in return for real benefits, reported very interesting results about the brain areas involved in the costs (dorsal ACC), the benefits and the subjective values (VMPFC), and their relationships ^[7-8]. In a similar way, other studies have reported very interesting results on the neural areas and the mechanisms involved in reinforced learning and influencing choices ^[9].

In spite of their relevance, these experimental designs appear more appropriate to approach motivation, willingness, representation of reward value and preference for an option, which mainly relate to the first step in decision-making (i.e. to explain how the brain learns implicitly to choose the option that minimizes the cost of action ^[8]). Nevertheless, decision-making in terms of adaptation for survival ^[4] involves the ability to modulate the perception of reward and punishment in order to distinguish the highest reward from the safest, and then to operate the best choice in the long term. Our paper concerns only this second process.

Using laboratory decision-making tasks, neuropsychological research has significantly improved our knowledge of the fundamental mechanisms of decision-making, as well as of the factors that may diminish the ability to make advantageous decisions ^[10-11]. Nevertheless, despite the extensive use of laboratory decision-making tasks in research, and more recently in clinical practice, evidence for their ecological validity is lacking. Yet arguments in favor of the ecological validity of tasks dedicated to assessing real-world decision-making in a laboratory setting are required for interpretation ^[12]. Ecological validity refers to similarity between a behavior observed in an experimental setting and that observed in natural conditions. This suggests that decision-making processes are involved in complex activities of daily-living, which requires awareness of limitations in these complex activities (for instance ability to be efficient and careful).

Alzheimer's disease (AD) and mild cognitive impairments (MCI) are both characterized by functional impairments in complex activities that imply decision-making processes (e.g. financial management, appointment scheduling, taking complex drug treatments) ^[13-15]. In addition, among patients with these two clinical conditions, various studies have also documented impairments in awareness of limitations ^[16-17].

Furthermore, patients with AD, as well as those with MCI, typically perform less well than do healthy controls on decision-making tasks ^[17-22]. These patients made random decisions and showed poor strategic stability because of their difficulties in learning from feedback ^[18-22]. A recent study suggested that they were unable to memorize previously learned responses or to establish new stimulus-reward relationships. This profile has been shown to be congruent with the temporal and parietal atrophy reported in this pathology ^[22]. In addition we have recently found the decision-making profile for MCI patients to mimic that of AD patients ^[23]. To the best of our knowledge, no study has investigated the association between decision-making

and daily living behavioral competencies in MCI and AD compared to healthy control subjects.

Using the same three groups of participants, the aims of the present study were to suggest an ecological relevance of decision-making task, by: (1) comparing MCI and AD patients' abilities to perform a variety of daily living tasks; (2) exploring the contribution of behavioral competencies to decision-making performances; (3) exploring the contribution of awareness of limitations in behavioral competencies to decision-making performances. This constitute an original contribution to the literature because these associations were not explored in our previous study nor in any other.

We hypothesized that both AD and MCI would negatively impact daily living behavioral competencies. We also hypothesized that disadvantageous decision-making would be associated with both reduced behavioral competencies and poor awareness of limitations

2 Methods

2.1 Participants

Sixty participants took part in the study: 20 healthy controls, 20 patients with AD, and 20 participants with MCI of amnesic type (aMCI). AD and aMCI patients were recruited from a memory clinic (Centre Hospitalier du Val d'Ariège, France). The diagnosis of aMCI was made by a senior neurologist and a clinical neuropsychologist (J-P J) using specific operational criteria defined by Petersen ^[24], which included: (1) memory complaint corroborated by an informant; (2) impaired episodic memory between -1.5 and -2 standard deviations from the population norm; (3) normal general cognitive function as determined by a normative *Mini Mental State Examination* – MMSE score ^[25-26]; (4) intact activities of daily living as determined by clinician judgment, and a structured interview with the patient and an informant; (5) and not meeting criteria for AD of the National Institute of Neurological and

Communicative Disorders and Stroke/AD and Related Disorders Association – NINCDS-ADRDA. None of the participants had a pathological gambling problem. The patients with AD were diagnosed according to the NINCDS-ADRDA criteria and the *Clinical Dementia Rating Scale*. The patients underwent extensive medical and neurological examinations to ensure the absence of any other major neurological conditions. They also underwent a neuro-radiological examination, including nuclear magnetic resonance imaging. The control group included 20 healthy community-dwelling adults. They were recruited from a pool of adult participants and senior-citizen associations. They had no history of neurological disease or psychiatric disorder. All controls had a MMSE score above the 10th percentile taking into account their level of education ^[26]. None of the participants were using medication known to affect memory or other cognitive functions. All healthy control participants, patients and caregivers gave informed consent for participation in the study.

2.2 Background neuropsychological assessment

All participants underwent a neuropsychological assessment including (a) the MMSE ^[25]; (b) the *Hayling test* ^[27-28] assessing inhibition control; (c) the *Trail-Making-test* ^[29] measuring mental flexibility and (d) the *Updating test* with 6, 8, 10 and 12 items evaluating working memory ^[30-31]. These executive measures (inhibitory control, cognitive flexibility and working memory) are in reference to the model developed by Miyake et al. for executive functions ^[32]. In addition, AD and aMCI patients were examined using the *free-cued recall test* ^[33] evaluating episodic memory, and the *Delayed Match to Sample (DMS-48)* relevant for the diagnosis of pre-hippocampus lesions ^[34]. aMCI patients presented pathological scores on the DMS-48, suggesting AD in the pre-clinical stage, and/or scores on the free-cued recall test corresponding to the criteria for aMCI for high risk of progression towards AD proposed by Berr et al ^[35]. These criteria were a free recall score ranging from 15 to 17/48 and/or a cued recall score ranging from 35 to 40/48.

2.3 Iowa Gambling Task

Decision-making was assessed using the *Iowa Gambling Task* – IGT ^[1]. In this task, participants are told that the aim of the game is to win as much (fictitious) money as possible. The task entails a series of selections of 100 cards from four decks (A, B, C and D), but participants are not informed of the number of trials. Although they are told that some card decks might be better than others, they do not know which are advantageous or disadvantageous. Decks A and B are classified as disadvantageous because the final balance is negative, with large immediate gains of money but greater losses later on. In contrast, selecting a card from decks C and D produces small gains, but unpredictable losses are smaller, so that these decks yield more money in the long run and are thus considered to be advantageous.

We calculated an overall net score (advantageous minus disadvantageous card selections) to analyze IGT performance (IGT total net score). Following a proposal by Brand et al ^[2-3], we also made a distinction between the initial phase (trials 1-40; blocks 1 and 2), and the second part of the IGT (trials 41-100; blocks 3, 4 and 5). In this respect, the IGT blocks 3-5 (trials 41-100) net score is also considered as an outcome. Positive IGT net scores indicate an advantageous decision-making profile.

2.4 Patient Competency Rating Scale

Behavioral competencies and awareness of limitations were assessed using the *Patient Competency Rating Scale* – PCRS ^[36] requiring each participant and a relative to complete the same 30 questions on the participant's ability to perform a variety of simple and complex behavioral tasks. These 30 questions are divided into four domains of competence: *Activities of daily-living*, *Cognition*, *Interpersonal relations* and *Emotion*. The participant and his/her relative completing the questionnaire is asked to judge how easy or how difficult a certain behavioral activity is. Items in the scale were scored from 1 to 5, with 1= "can't do", 2= "very

difficult to do", 3= "*can do, but with difficulty*", 4= "*fairly easy to do*", and 5= "*can do with ease*", with higher scores indicating greater competency.

Behavioral competencies were assessed using two dependent variables: (a) the Relative-PCRS score which corresponds to the relative's rating and (b) the Participant-PCRS score which corresponds to the participant's rating (self-report). Behavioral competency dependent variables were expressed using the median-split approach. Cut-offs were computed on the whole sample median scores. In this way, scores below the median on both Relative- and Participant-PCRS reflect poorer competencies.

Awareness of limitations was assessed by subtracting the Participant-PCRS from the Relative-PCRS scores which correspond to Awareness-PCRS. Positive Awareness-PCRS scores indicate better awareness of behavioral competency limitations. These behavioral measures, completed by participants and their relatives, used the same 30 questions concerning the cognitive abilities and emotional control involved in decision-making processes.

2.5 Statistical analyses

The statistical analyses were carried out using the *Statistical Package for Social Sciences* (SPSS .20). Data were examined for normal distribution (tested with the Kolmogorov-Smirnov test). As the majority of variables were not normally distributed ($p < 0.05$), we used non-parametric statistics. Comparisons between groups concerning the background neuropsychological assessment and the demographic data were performed using the Kruskal & Wallis non parametric test. As healthy controls and clinical groups were not comparable for some demographic variables, and to take covariates into account, we used cut-offs for clinical data, which were expressed as percentages of subjects for the categorical variables. Pearson's Khi square test (χ^2), odds ratios (OR) and their confidence intervals (CI) were estimated using a conditional logistic regression model. The level of significance was set at $p < 0.05$.

3 Results

3.1 Demographic data and background neuropsychological assessment (Table 1)

Table 1 summarizes demographic data and neuropsychological performances for each group. There was a significant group effect on both age and years of education (respectively $\chi^2=15.82$, $p=0.0001$; $\chi^2=9.74$, $p=0.008$). The AD and aMCI patients were older (respectively $p<0.0001$ and $p=0.01$) and less educated (respectively $p=0.01$ and $p=0.005$) than the healthy controls, without any significant difference between clinical groups (all p -values >0.05). The groups were matched for gender [$\chi^2=0.95$, $p=0.62$].

There was a significant group effect on the MMSE ($\chi^2=24$, $p<0.0001$), healthy controls performed better than both aMCI patients ($p<0.0001$) and AD patients ($p<0.0001$). aMCI patients performed better than AD patients ($p=0.01$). Regarding flexibility, inhibition and working memory, healthy controls always performed better than AD and aMCI patients, (all p -values <0.05), without any significant differences between the clinical groups (all p -values >0.05), except for the number of errors in flexibility and 8-item *Updating test* which did not reach significance (p -values >0.05). Concerning episodic memory, AD patients performed significantly less well on the *free-cued recall test* than aMCI patients (all p -values <0.05).

Insert Table 1 about here

3.2 Clinical data: (Table 2)

3.2.1 Patient Competency Rating Scale:

3.2.1.1 Relative-PCRS

As the Relative-PCRS total score was associated with age in the whole sample (OR=1.08, $p=0.04$), the results were analyzed with age as a covariate variable. There was a significant group effect on behavioral competencies assessed by the relative (Relative-PCRS: OR=3.21,

$p=0.006$). The percentage of participants with lower Relative-PCRS score (median=105.5 [58–130]) was significantly higher in AD and aMCI groups than among control subjects ($p=0.008$ for each comparison) There was no significant difference between the clinical groups ($p=0.74$).

A comprehensive analysis of Relative-PCRS results indicated a significant group effect for the *Cognition* (OR=2.57, $p=0.02$), *Interpersonal relations* (OR=2.81, $p=0.03$) and *Emotion* (OR=2.28, $p=0.04$) subscales. No significant effect was noted for *Activities of daily-living* (OR=1.53, $p=0.28$). Post-hoc analysis showed that on the *Cognition* dimension, the percentage of participants with lower Relative-PCRS scores (median=4 [1.75–5]) was significantly higher in the AD and aMCI groups than among healthy controls (respectively: $p=0.02$ and $p=0.006$). No significant difference was observed between the clinical groups ($p=0.74$). Regarding the *Interpersonal relations* subscale, the percentage of participants with lower Relative-PCRS score (median=4.29 [2–5]) was significantly higher in the aMCI group than among healthy controls ($p=0.002$) and a statistically non-significant trend was noted for AD compared to healthy controls ($p=0.058$). No significant difference was reported between the clinical groups on this dimension ($p=0.26$). Finally, the *Emotion* subscale showed that the percentage of participants with lower Relative-PCRS score (median=3.57 [1.71–5]) was significantly higher in AD group than among healthy controls ($p=0.02$). On this dimension, no significant difference was noted between either AD and aMCI Relative-PCRS scores ($p=0.40$) or the aMCI and healthy control Relative-PCRS scores ($p=0.25$).

3.2.1.2 Patient Competency Rating Scale: Participant-PCRS

There was a significant group effect on behavioral competencies assessed by the participants (self-rating) (Participant-PCRS: $\chi^2=7.6$, $p=0.02$). The percentage of participants scoring low for Participant-PCRS (median=107 [63–130]) was significantly higher in the AD and aMCI

groups than among healthy controls (respectively: $p=0.025$; $p=0.01$), without any significant difference between the clinical groups ($p=0.74$).

A comprehensive analysis of Participant-PCRS indicated a significant group effect for the *Activities of daily-living* (median=4.5 [1.88–5]; $\chi^2=9.16$, $p=0.01$) and *Cognition* (median=4.065 [1.63–5]; $\chi^2=12.4$, $p=0.002$) subscales. Post-hoc analysis showed that for these two dimensions, the percentage of participants having a lower Participant-PCRS score was significantly higher in the AD and aMCI groups than among healthy controls (*Activities of daily-living*: respectively, $p=0.047$, $p=0.003$; *Cognition*: respectively, $p<0.0001$, $p=0.02$). There was no significant difference between the clinical groups (*Activities of daily-living*: $p=0.29$, *Cognition*: $p=0.18$). Finally, no significant group effect was noted for either the *Interpersonal relations* subscale ($\chi^2=4.8$, $p=0.09$) or the *Emotion* subscale ($\chi^2=0.4$, $p=0.81$).

3.2.1.3 Patient Competency Rating Scale: Awareness-PCRS

No significant group effect was reported for any of the Awareness-PCRS dimensions (total score, $p=0.62$; *Activities of daily-living*, $p=0.18$; *Cognition*, $p=0.27$; *Interpersonal relations*, $p=0.18$; *Emotion*, $p=0.41$).

3.2.2 Iowa Gambling Task

In the groups and in the whole sample, neither age nor education was associated with IGT net scores (all p -values >0.05). A statistically non-significant trend was observed for the IGT total net score ($\chi^2=5.51$, $p=0.064$). However a significant group effect was observed for the IGT blocks 3-5 (trials 41-100) net score ($\chi^2=6.46$, $p=0.04$) The proportion of participants with a disadvantageous decision-making profile on the IGT blocks 3-5 net score was significantly higher in the AD and MCI groups than in the healthy control group (respectively, $p=0.02$ and $p=0.03$), without any difference between the clinical groups ($p=0.89$).

Insert Table 2 about here

3.3 Association between Iowa Gambling Task performances and the Patient Competency Rating Scale

3.3.1 Behavioral competencies

A logistic regression analysis between behavioral competencies (Relative PCRS) and decision-making showed that the percentage of participants scoring low for the Relative-PCRS (total score) was significantly higher among individuals with a disadvantageous decision-making profile on the IGT (blocks 3 – 5 net score<0) (67.9% versus 32.1%, OR=3.47, IC95%=1.08–11.13, $p=0.03$, covariate: age). The same pattern of association was found only for the Relative-PCRS *Emotion* subscale: the percentage of participants scoring low for Relative-PCRS *Emotion* was significantly higher among individuals with a disadvantageous decision-making profile compared to those with an advantageous profile (72% versus 28%, OR=4.2, IC95%=1.24–14.17, $p=0.02$, covariate: age).

Insert Figure 1 about here

3.3.2 Awareness of behavioral competency limitations

A logistic regression analysis between awareness of behavioral competency limitations (Awareness PCRS) and decision-making showed that the percentage of participants with poor awareness of their behavioral competency limitations (Awareness-PCRS) was significantly higher among individuals with a disadvantageous decision-making profile compared to those with an advantageous profile (75% versus 25%, OR=5.4, IC95%=1.70–17.10, $p=0.004$). Similarly, the same pattern of association was found only for the Awareness-PCRS *cognition* subscale: the percentage of participants with a low score on Awareness-PCRS *cognition* was significantly higher among individuals with a disadvantageous decision-making profile compared to those with an advantageous profile (60.7% versus 39.3%, OR=3.26, IC95%=1.08–9.77, $p=0.035$).

Insert Figure 2 about here

4 Discussion

The percentage of participants having a disadvantageous decision-making profile was significantly higher in the AD and aMCI groups than among healthy controls and the two clinical groups were comparable on this variable. These results were fully expected since we have reported with the same sample of participants that decision-making among aMCI patients mimicked that of AD patients and was impaired compared to that of healthy controls [22].

These expected results are congruent with the hypothesis of impaired reinforced learning in decision-making impairment in AD and MCI patients [18-22]. Because the clinical groups differed mainly on episodic memory performances and not on executive performances, these results can also appear congruent with the main role of the prefrontal cortex (supporting executive functions) and in particular the VMPFC, in reinforced learning [7-9] and in stimulus encoding [5-6].

In fact, the main results of this study confirm our hypothesis. Firstly, behavioral competencies are reduced in both AD and aMCI subjects compared to healthy controls. Secondly, disadvantageous decision-making is associated with both reduced behavioral competencies and poor awareness of limitations.

4.1 Reduced behavioral competencies and awareness of limitations in AD and aMCI:

Despite the recommendations of the National Institute on Aging - Alzheimer's Associations workgroups on diagnostic guidelines for Alzheimer's disease, clearly highlighting the "*preservation of independence in functional abilities*" and "*no evidence of a significant impairment in social or occupational functioning*", for the diagnosis of aMCI leading on to

Alzheimer's disease ^[37], a functional impairment in the most complex behavioral tasks is known to be a sign ^[14-15].

Surprisingly, our results reported that the percentage of participants with lower competencies was significantly higher in clinical groups than among healthy controls, and the clinical groups were comparable on this variable. So our results are partially congruent with results such those of Marshall et al ^[15] reporting that AD patients had more functional impairment than aMCI patients, who were also impaired, compared to healthy controls. First of all, this functional comparability between AD and aMCI patients can be explained by the evaluation tool used. In fact, no general agreement or guidelines exist for clinicians and researchers on how to evaluate aspects of functional autonomy in MCI. In both clinical and research contexts, evaluation is mainly based on qualitative judgment ^[38-39]. Here, we opted for evaluations based on the perceived degree of competencies in a wide variety of daily tasks including basic self-care and more complex social, interpersonal, and emotional activities. Basic self-care is preserved in mild AD as in aMCI and most complex activities can be impaired in these both clinical entities that can explain our results reporting a functional heterogeneity within clinical groups.

Secondly, these results can be also explained by the comparability of the two clinical groups of our sample in terms of executive functions. The clinical groups were demographically comparable and mainly differed on episodic memory performances. Various studies have reported the involvement of executive functions in functional impairment ^[13, 15, 40-41] and at group level, we observed that patients with AD and aMCI had lower global scores than the controls for Participant-PCRS (self-report) and Relative-PCRS, without significant differences between the clinical groups.

Concerning the awareness of competency limitations in the groups, interestingly, participant ratings were in accordance with those of their close relatives. This probably explains why we

failed to observe a significant group effect for Awareness-PCRS. Here we used an assessment methodology based on the discrepancy between caregiver and subject ratings known to be the most reliable in the assessment of awareness ^[42]. Nevertheless, there are as many studies reporting awareness disorders in AD and MCI, as studies not reporting these disturbances ^[42-44]. In a similar manner, the incidence of awareness disorders in AD is reported to range from 20% to 80% by Starkstein ^[42], suggesting a wide heterogeneity, which could explain our results. Finally it appears possible that participants in this study, whatever their cognitive status, were concerned by their difficulties, and that participation in the study in itself entails a recruitment of subjects with better awareness.

4.2 Association between both reduced behavioral competencies and poor awareness of limitations and decision making:

Very few studies have been carried out on the ecological relevance of lab-based measures of decision-making ^[11]. Clinical studies suggest a link between IGT scores and real-world, clinically relevant, risky behaviors ^[10, 45-46].

A very interesting study, carried out by Denburg et al ^[47] compared older normal subjects, clinically impaired (total net score < 22/100) and unimpaired (total net score > 22/100) on the IGT. The authors reported that impaired decision-makers were more likely to fall prey to fictitious, deceptive advertising in an experimental design, suggesting compromised real-world judgment and decision-making abilities. Nevertheless, associations between functional impairment in activities of daily living and disadvantageous decision-making has never been investigated. Because decision-making involves executive processes ^[2-3, 5-6, 20] which can also be involved in activities of daily living ^[13, 15, 40-41], we expected disadvantageous decision-making to be associated with poorer daily living behavioral competencies. Our hypothesis was fully confirmed, since the percentage of participants (in the whole sample) with low competencies was significantly higher (67.9%) among participants with a disadvantageous

decision-making profile (IGT blocks 3 – 5 net score < 0) than among participants with high competencies (32.1%). The subscale analyses showed that this association between disadvantageous decision-making and reduced behavioral competencies was observable only for the *Emotion* subscale. This association is congruent with the impact of emotional control on decision-making processes, such as the expected reward system, involving limbic and emotional substrates enabling advantageous choices in the long run ^[6].

Even though there was no group effect for Awareness-PCRS, this variable was associated with disadvantageous decision-making. The percentage of participants (in the whole sample) with poor awareness of behavioral competency limitations (75%) was significantly higher among patients with a disadvantageous decision-making profile (IGT net score 3 – 5 < 0) than among participants with better awareness (25%). It is known that awareness disorders in AD or MCI, as in other pathologies, are associated with executive disorders, and inability to accept help and care and to avoid dangers which increases dependency ^[50-52]. Thus impairment of the awareness of behavioral competency limitation leads to overestimating behavioral competencies, which can lead to disadvantageous decision-making in daily living. The association between poor awareness of behavioral competency limitations and disadvantageous decision-making on the IGT underlines the ecological relevance of this task. In addition, subscale analyses showed that this association was observable only with the *Cognition* subscale, highlighting the cognitive correlates of decision-making as measured by the IGT ^[20-21].

4.3 Limitations

Several limitations in our study need to be addressed.

4.3.1 Participants

Sample size – Because of the small sample size, we used a binary statistical methodology known to decrease the variability of data, which leads to a loss of information. Also, the median split approach tends to confound group status (healthy versus clinical). However, the two clinical groups were necessary to include subjects with functional impairments for comparison with healthy subjects without functional impairment, as well as to include subjects with liable to present awareness impairments. In these conditions, using the groups as covariates in a logistic regression model would have led to erasing the differences between groups (here, differences concerning functional impairment), which would have been inappropriate.

MCI patients – In order to focus on the main role of episodic memory and to envisage a possible continuum from normality to AD, we considered the criteria proposed by Barbeau et al, ^[34] requiring pre-hippocampal impairments, and/or the criteria proposed by Berr et al, ^[35] requiring scores for high risk of progression towards AD, disregarding mild executive impairment. Consequently, the MCI' group was probably heterogeneous because it comprised patients who were aMCI for single and multiple domains. Finally, the MCI' group was globally comparable to AD patients on executive functions, which highlights the difficulties in defining the boundaries between MCI and very mild AD using Petersen's criteria ^[53]. This could explain why the clinical groups were comparable on behavioural competencies (Relative PCRS) and decision-making, since both measures involve executive processes ^[2-3, 13, 15]. Figures 1 and 2 show that the MCI' group was probably more heterogeneous for decision-making profile / PCRS profile ratio, compared to the AD patients.

4.3.2 Evaluation tools:

PCRS – The PCRS is not an evaluation tool specifically dedicated to assessing awareness in AD and MCI patients. Using an awareness scale developed for Alzheimer's patients (such the

AQ-D)^[50] could be more appropriate than using the PCRS, developed for brain injury. This could explain why we failed to reach significant results concerning awareness in the AD group. Nevertheless, there is no awareness tool validated in French in AD or MCI and using the discrepancy approach. Therefore, the PCRS, which distinguishes different domains involved in decision-making processes, appeared more relevant for our hypothesis than other scales, such the AQ-D, which furthermore does not have a valid French language version.

4.3.3 Experimental methodology:

Our results were based on a cross-sectional approach, which does not integrate causality. In fact, a logistic regression analysis with age as a covariate suggested that poorer competencies in daily living could contribute to disadvantageous decision-making. Nevertheless the link between competencies in daily living and decision-making as assessed by the IGT is presumably bi-directional, as is the link between awareness of competency limitations and decision-making.

In the context of the present study, the question remains as to whether a propensity towards disadvantageous choices on the IGT constitutes a potential risk factor for a decline of competencies, or a decrease in awareness of competency limitations which could reduce autonomy in daily living. Longitudinal studies on elderly subjects could demonstrate whether reduced IGT performance predisposes to a decline in autonomy of this sort. Finally, we are aware that our sample was too small. This statistical limitation could explain some similarities between the clinical groups.

5 Conclusion

The aim of our study was to explore associations between decision-making, behavioral competencies and awareness of limitations, which could suggest an ecological relevance of the IGT. It was not to prove the ecological validity of this task. Consequently our results

should be considered exploratory, and this study contributes to documenting the ecological relevance of the IGT. Behavioral competency integrity and awareness of limitations are both associated with advantageous decision-making in AD and aMCI.

Nevertheless, the replication of these results on larger samples could help confirm whether our findings can be generalized, and evaluate the clinical implications for future interventions. Finally, further prospective studies are needed to clarify whether reduced IGT performances in the elderly at baseline predispose to further decline in behavioral competencies in daily living activities. In reference to Denburg's considerations about financial abuse and impaired decision-making in ageing ^[47], these results could have implications for preventive care, enabling an early diagnosis of vulnerability in old age and the detection of subjects at risk for abuse, in particular because of an overestimation of their abilities.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Table 1: Demographic data and background neuropsychological assessment.

	Median [range]	HC (n=20)	MCI (n=20)	AD (n=20)	Statistics	P value
Demographic	Age	71 (64 – 85)	75.5 [61 – 83]	80.5 [71 – 90]	$\chi^2=15.82$	0.0001^a
	Gender, % females	65	55	50	$\chi^2=0.95$ *	0.62
	Years of education	11.5 [6 – 14]	8 [6 – 16]	8.5 [6 – 17]	$\chi^2=9.74$	0.008^a
Cog	Mini Mental State Ex.	28.5 [26 – 30]	25.5 [24 – 29]	24 [21 – 29]	$\chi^2=24$	0.0001^b
Flexibility	TMT 4 time	95.5 (53 – 240)	234.5 (72 – 240)	209 (95 – 240)	$\chi^2=19.96$	<0.0001^a
	TMT 4 errors	1 (0 – 2)	1 (0 – 4)	1 (0 – 2)	$\chi^2=2.52$	0.28
Inhibition	Hayling time	3.86 (2.7 – 11.2)	7.84 (3.4 – 18.4)	7.82 (3.1 – 15.3)	$\chi^2=15.88$	<0.0001^a
	Hayling errors	2 (0 – 7)	5.5 (0 – 26)	9 (0 – 21)	$\chi^2=17.21$	<0.0001^a
Working memory	Updating 6	3.75 (2.6 – 5.7)	2.93 (1.8 – 5.7)	2.68 (1.1 – 4.7)	$\chi^2=12.17$	0.002^a
	Updating 8	2.7 (1.5 – 4.6)	2.62 (1.5 – 3.7)	2.56 (1.1 – 3.7)	$\chi^2=5.45$	0.065
	Updating 10	2.87 (2 – 5)	2.56 (1.7 – 3.6)	2.31 (1.1 – 3.2)	$\chi^2=12.07$	0.002^a
	Updating 12	3.06 (2 – 5)	2.43 (1.2 – 4.6)	2.43 (1.1 – 4.1)	$\chi^2=10.49$	0.005^a
Free cued recall test	3 first free recall/48	---	20 (9 – 32)	10 (1 – 18)	Z=-4.28	<0.0001^c
	3 first cued recall/48	---	41 (34 – 48)	29.5 (17 – 38)	Z=-4.97	<0.0001^c
	Delayed free recall/16	---	7.5 (1 – 16)	2 (0 – 8)	Z=-4.24	<0.0001^c
	Delayed cued recall/16	---	14 (12 – 16)	9 (3 – 14)	Z=-4.76	<0.0001^c

AD: Alzheimer’s disease; HC: healthy controls; MCI: mild cognitive impairment; χ^2 : Kruskal & Wallis test excepted for **Gender, % females** where Pearson’s χ^2 * was used; Z: Mann & Whitney test. ^aHC ≠ (MCI = AD); ^bHC ≠ MCI ≠ AD; ^cMCI ≠ AD

Table 2. Performances on the *Iowa Gambling Task* and the *Patient Competency Rating Scale*.

	HC (n=20)	MCI (n=20)	AD (n=20)	Statistics	P value
<i>Decision-making profile, % of participants with a net score < 0</i>					
IGT total net score	33.3	72.2	55.6	$\chi^2=5.51$	0.06
IGT blocks 3 – 5 net score	26.3	63.2	61.1	$\chi^2=6.46$	0.04^a
<i>Relative-PCRS, % of participants with a score < median (105.5)</i>					
Total score	15	65	70	OR=3.21^d	0.006^a
- Activities of daily-living	23.5	63.2	57.9	OR=1.53 ^d	0.28
- Cognition	15.8	68.4	65	OR=2.57^d	0.02^a
- Interpersonal relations	15	76.5	69.2	OR=2.81^d	0.03^b
- Emotion	30	55.6	70.6	OR=2.28^d	0.04^c
<i>Participant-PCRS, % of participants with a score < median (107)</i>					
Total score	25	60	65	$\chi^2=7.6$	0.02^a
- Activities of daily-living	21.1	70.6	52.9	$\chi^2=9.16$	0.01^a
- Cognition	20	55	75	$\chi^2=12.4$	0.002^a
- Interpersonal relations	70	40	40	$\chi^2=4.8$	0.09
- Emotion	45	55	50	$\chi^2=0.4$	0.81
<i>Awareness-PCRS, % of participants with a score < 0</i>					
Total score	45	60	50	$\chi^2=0.93$	0.62
- Activities of daily living	35	60	35	$\chi^2=3.39$	0.18
- Cognition	30	55	45	$\chi^2=2.57$	0.27
- Interpersonal relations	30	55	55	$\chi^2=3.34$	0.18
- Emotion	35	55	50	$\chi^2=1.74$	0.41

AD: Alzheimer's disease; HC: healthy Controls; MCI: mild cognitive impairment; IGT: Iowa Gambling Task; PCRS: Patient Competency Rating Scale; ^a HC ≠ (MCI = AD); ^b HC = AD, AD = MCI, HC ≠ MCI; ^c HC = MCI, MCI = AD, HC ≠ AD; ^d adjustment for age.

Figure 1: Percentage of participants with poor behavioral competencies on the PCRS- total score depending on the decision-making profile (IGT blocks 3-5 net score).

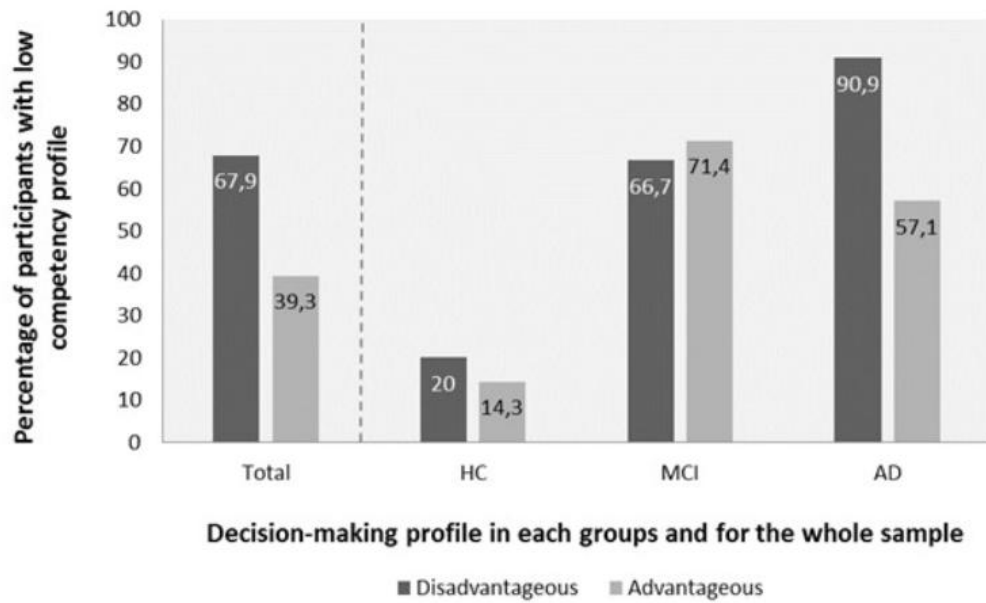


Figure 2: Percentage of participants with poor awareness in behavioral competency limitations according to decision-making profile (IGT blocks 3-5 net score).

