The Impact of Mild Cognitive Impairment on Decision Making in Two Gambling Tasks

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Objectives. This study aimed to investigate whether patients with mild cognitive impairment (MCI) present difficulties in making decisions under ambiguity and under risk.

Methods. Performance of MCI patients in the Iowa Gambling Task (IGT) and in the Probability-Associated Gambling Task—Revised (PAG-R) was compared with performance of healthy aging peers.

Results. In the IGT, controls made increasingly frequent advantageous selections over time; MCI patients selected randomly from advantageous and disadvantageous decks, with no significant change in performance over time. In the PAG-R, controls decided advantageously in conditions of both (low, high) winning probabilities; patients made less advantageous decisions than controls in conditions of low winning probability.

Discussion. In the decision under ambiguity task (IGT), MCI patients experienced difficulties in learning from feedback and in maintaining an advantageous strategy over time. In the decision under risk task (PAG-R), patients had problems in integrating information from different sources and in adapting their strategy to changes in the decision situation. In summary, MCI patients present difficulties in advantageous decision making that resemble those reported for patients with mild dementia.

Key Words: Aging—Decision making—Dementia—MCI.

MAINTAINING a high-quality life in advanced age relies on advantageous decisions in several domains including medical care, finances, or housing situations. Although recent studies have suggested that decision-making processes change across the lifespan (for a review, see Mather, 2006), little is known about the neuronal, cognitive, and emotional resources that are needed to make self-determined advantageous decisions in older age. Older persons are often the preferred target of deceptive advertisements (American Association of Retired Person, 1996), and it is not unusual to hear that they have been subject to fraud. Recent investigations have revealed that some healthy older adults present difficulties in making advantageous decisions, in particular when information about the options is ambiguous, missing, or misleading (e.g., Denburg et al., 2005, 2007; Fein, McGillivray, & Finn, 2007; Zamarian, Sinz, Bonatti, Gamboz, & Delazer, 2008), or the decision situation is complex (Brand & Markowitsch, 2010). Denburg and colleagues (2007) have also found that older adults who make poor decisions in laboratory decision-making tasks are more susceptible to misleading advertisements than “good decision makers.” This finding suggests compromise of real-world judgment in some healthy older adults.

Older adults with neurodegenerative conditions seem to have pronounced difficulties in decision making (e.g., Brand et al., 2009; Cools, Barker, Sahakian, & Robbins, 2003; Torralva et al., 2007). For example, studies of patients with mild dementia have found that patients make less advantageous decisions than healthy aging peers both in situations of ambiguity, where rules are implicit and information about the options is missing or conflicting, and in situations of risk, where rules are explicit and the probability of an outcome is known or estimable (Delazer et al., 2009; Delazer, Sinz, Zamarian, & Benke, 2007; Sinz, Zamarian, Benke, Wenning, & Delazer, 2008).

To the best of our knowledge, there has been no study assessing whether older adults with mild cognitive impairment (MCI) present difficulties in making advantageous decisions. MCI patients complain of memory impairment, show slight cognitive deficits in formal neuropsychological assessment, but do not fulfill the criteria for a diagnosis of dementia (e.g., Davie et al., 2004; Morris et al., 2001; Petersen, 2004; Petersen et al., 1999). Although intact daily functioning is one of the defining criteria of MCI, a number of recent investigations have reported poor performance for MCI patients compared with healthy aging peers in some complex activities of daily life. MCI patients perform poorly relative to healthy controls in financial tasks such as bank statement management and bill payment (e.g., Griffith et al., 2003), in arithmetic tasks when there is a high load on executive functions (e.g., Zamarian, Semenza, Domahs, Benke, & Delazer, 2007), and in clinically relevant measures of the capacity to consent to medical treatment (e.g., Okonkwo et al., 2008).

Poor decisions in real-life situations can have devastating consequences such as depletion of finances or damage to
health. It is therefore of importance to detect and characterize decision-making deficits. This is particularly the case for MCI patients, as these may still be employed, and thus involved in work-related decisions, or may still participate in everyday decisions with consequence for themselves or their family. In this study, we investigated whether MCI patients are able to make advantageous decisions under ambiguity and under risk. We compared the performance of MCI patients with that of healthy aging peers in two gambling tasks (the Iowa Gambling Task [IGT] and a modified version of the Probability-Associated Gambling task [PAG]). Both gambling tasks are used in neuropsychological research to assess decision making in normal and clinical populations. Recent studies of older participants have found that impairments in laboratory decision-making tasks, such as the IGT, are associated with poor real-world judgment and decision making (Denburg et al., 2007) and may represent an early indicator of subsequent cognitive decline (Denburg et al., 2005).

In the IGT, participants are initially unaware of the rules regulating gains and losses and are expected to extract these rules through experience (e.g., Bechara, Damasio, Damasio, & Anderson, 1994; Bechara, Tranel, & Damasio, 2000). In the PAG, rules are explicit, and participants have to estimate the probability of the possible outcomes and adapt their strategy to changes in the information presented on a given trial (e.g., Bonatti et al., 2009; Delazer et al., 2009; Sinz et al., 2008; Zamarian et al., 2008). In this study, we modified the original version of the PAG to render it more sensitive to subtle deficits in decision making under risk. In the original version, only the following decisions are considered advantageous: choosing to gamble when the probability of winning is high and taking the fixed sum alternative when the probability of winning is low. In the revised version (Probability-Associated Gambling task—revised [PAG-R]), the fixed sum alternative is manipulated in a way that advantageous decisions may sometimes also include choosing to gamble when the probability of winning is low or taking the fixed sum alternative when the probability of winning is high. That is, in the PAG-R, participants have to take into account both the winning probability and the fixed sum alternative to make advantageous decisions. Therefore, they have to show even more flexibility in their decision making.

Several studies have shown that MCI and Alzheimer’s disease (AD) may have remarkably similar neuropathological findings (for a review, see Burns & Morris, 2008). Neuropathological changes such as neuronal loss, amyloid plaques, and neurofibrillary tangles are found to be less pronounced in MCI than in AD, but exceed those observed in healthy aging (e.g., Chetelat et al., 2005; Markesbery et al., 2006). Typically, MCI patients show atrophy in medial temporal areas and in limbic structures such as hippocampus. Recent studies have also found atrophy in prefrontal and in parietal association areas (e.g., Singh et al., 2006). Although not all individuals with MCI develop AD, MCI patients are at greater risk to develop dementia compared with healthy older adults (e.g., Fischer et al., 2007). As the brain areas involved in advantageous decision making are affected in MCI patients (for a review, see Ernst & Paulus, 2005; Trepel, Fox, & Poldrack, 2005), it might be possible that these individuals show impairment in the IGT and the PAG-R. Recent investigations have shown that not only ventromedial prefrontal cortex lesions (VMPFC; e.g., Bechara et al., 1994, 2000; Tranel, Bechara, & Denburg, 2002) but also various other pathologies—including dysfunction of the medial temporal lobes (e.g., Bar-On, Tranel, Denburg, & Bechara, 2003; Brand, Grabenhorst, Starcke, Vandekerckhove, & Markowitsch, 2007; Delazer et al., 2010)—cause deficits in the IGT.

It may be hypothesized that the effect of MCI on decision-making performance in the IGT and the PAG-R mimics to some extent the effect of mild dementia (Delazer et al., 2007, 2009; Sinz et al., 2008). Performance of MCI patients, similar to that of patients with mild dementia, may be compromised by slight deficits in learning, working memory, and executive functions such as cognitive flexibility. In the IGT, MCI patients may thus show poor learning from contingencies and difficulties in maintaining an advantageous strategy, which are reflected by random decisions and frequent shifts between alternatives. In the PAG-R, MCI patients may present problems in estimating probabilities and in adapting their strategy to changes in the decision situation, which would compromise advantageous performance on this task. In summary, we expected MCI patients to perform randomly on the IGT and show poor flexibility in the PAG-R. We did not assume that MCI patients would favor risky decisions as patients with VMPFC damage do (e.g., Bechara et al., 1994, 2000; Tranel et al., 2002).

**METHODS**

**Participant Selection**

MCI patients and healthy older adults participated in the study (for each group n = 22). Groups were comparable in age and education and did not differ with regard to the proportion of male and female participants (Table 1). Healthy controls were recruited from volunteers and relatives. MCI patients attended the outpatient memory clinic at the Department of Psychiatry. They were evaluated prospectively using standard neurological and neuropsychological test procedures. Additional investigations included an informal family interview, cerebral computed tomography, and/or magnetic resonance imaging, routine blood tests, and, when necessary, positron emission tomography, electroencephalogram, and other diagnostic procedures. Diagnosis of MCI was based on the criteria proposed by Petersen (2004; memory complaint, no functional impairment, slight objective cognitive deficits on a formal neuropsychological testing
with scores within 1.5–2 SD from the average range of standardized norms). Overall, exclusion criteria were history of stroke, head trauma, substance abuse, and major neurological, psychiatric, or metabolic disorders that may compromise cognition. None of the participants had a pathological gambling problem. This study was approved by the local ethics committee. Participants gave written informed consent. Participants did not receive any incentive or honoraria in exchange for their participation.

Neuropsychological Background Assessment

Participants performed tests of global cognitive status (Mini-Mental State Examination [MMSE] from the Consortium to Establish a Registry for Alzheimer’s Disease [CERAD] battery; Berres, Monsch, Bernasconi, Thalmann, & Stahelin, 2000), verbal memory (learning, free recall, recognition tests from CERAD), figural memory (free recall of geometrical figures test from CERAD), recognition of abstract figures test from Nürnberger Altersinventar; Oswald & Fleischmann, 1997), verbal fluency (animals/min test from CERAD, s-words/min test from Regensburger Wortflüssigkeitstest; Aschenbrenner, Tucha, & Lange, 2000), psychomotor speed (Trail-Making Test part A [TMT-A]; Lezak, 1998), set shifting (TMT-B), cognitive flexibility and categorization (Odd Man Out [OMO]; Flowers & Robertson, 1985), planning and conceptualization (CLOX Part 1; Royall, Cordes, & Polk, 1998), visuoconstruction (copying a clock, CLOX Part 2; copying geometrical figures test from CERAD), naming to confrontation (CERAD), mental complex calculation (Jackson & Warrington, 1986), numeracy (Lipkus, Samsa, & Rimer, 2001; adapted from Peters et al. 2006), and depression (Geriatric Depression Scale [GDS]; Yesavage et al., 1983). In the numeracy test, 11 questions on risk are presented; participants are asked to select the correct answer among three alternatives (e.g., “If person A’s risk of getting a disease is 1% in ten years, and person B’s risk is double that of A’s, what is B’s risk? 0.5%, 10% or 2%?”).

Table 1. Medians and Interquartile Ranges for Demographic Information and Scores on Neuropsychological Background Tests as a Function of Group

<table>
<thead>
<tr>
<th>Demographic characteristics</th>
<th>MCI patients</th>
<th>Healthy adults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max score</td>
<td>Mdn</td>
</tr>
<tr>
<td>Age (years)*</td>
<td></td>
<td>77.50</td>
</tr>
<tr>
<td>Education (years)*</td>
<td></td>
<td>9.00</td>
</tr>
<tr>
<td>Sex (men:women)*</td>
<td></td>
<td>14:8</td>
</tr>
<tr>
<td>Neuropsychological measures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMSE (CERAD)*</td>
<td>30</td>
<td>27.00</td>
</tr>
<tr>
<td>Verbal memory (CERAD)</td>
<td>Learning*</td>
<td>17.50</td>
</tr>
<tr>
<td></td>
<td>Free recall*</td>
<td>5.00</td>
</tr>
<tr>
<td></td>
<td>Recognition (% correct)*</td>
<td>95.00</td>
</tr>
<tr>
<td>Figural memory</td>
<td>Free recall (CERAD)*</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>Recognition (NAI)*</td>
<td>9.00</td>
</tr>
<tr>
<td>Executive functions</td>
<td>CLOX Part 1*</td>
<td>12.00</td>
</tr>
<tr>
<td></td>
<td>TMT-A (s)*</td>
<td>57.00</td>
</tr>
<tr>
<td></td>
<td>TMT-B (s)*</td>
<td>214.00</td>
</tr>
<tr>
<td>Animals/min (CERAD)*</td>
<td>16.00</td>
<td>12.00</td>
</tr>
<tr>
<td>S-words/min (RWT)*</td>
<td>9.50</td>
<td>7.50</td>
</tr>
<tr>
<td>OMO (correct)*</td>
<td>36.00</td>
<td>33.00</td>
</tr>
<tr>
<td>Language</td>
<td>Naming to confrontation (CERAD)*</td>
<td>13.50</td>
</tr>
<tr>
<td>Visuoconstructive abilities</td>
<td>Copying geometrical shapes (CERAD)*</td>
<td>10.50</td>
</tr>
<tr>
<td></td>
<td>Complex numerical processing</td>
<td>14.00</td>
</tr>
<tr>
<td></td>
<td>Mental complex calculation (raw score)*</td>
<td>9.00</td>
</tr>
<tr>
<td></td>
<td>Numeracy (correct)*</td>
<td>6.00</td>
</tr>
<tr>
<td>GDS*</td>
<td>30</td>
<td>7.00</td>
</tr>
</tbody>
</table>

Note: Mdn = median; Q. = quartile; MMSE = Mini-Mental State Examination; CERAD = Consortium to Establish a Registry for Alzheimer’s Disease; NAI = Nürnberger Altersinventar; TMT-A = Trail-Making Test part A; TMT-B = Trail-Making Test part B; RWT = Regensburger Wortflüssigkeitstest; OMO = Odd Man Out; and GDS = Geriatric Depression Scale.

*a Mann–Whitney U-test.
*Chisquare test.
*Median <1.5 SD from the average range of standardized norms.
*p < .05; **p < .01; ***p < .001.
Decision-Making Tasks

**IGT.**—In the computerized version, four card decks are presented (for details, see Bechara et al., 2000). Participants are required to select one card at a time, for a total of 100 card selections (the total number of card selections is unknown to the participant). Card selections from decks A and B result in large monetary gains followed by large penalties at certain unpredictable times. As the accumulated penalties are larger than the accumulated gains, decks A and B are “disadvantageous” in the long run. Card selections from decks C and D result in small immediate gains followed by small unpredictable losses. As the accumulated penalties are smaller than the accumulated gains, decks C and D are “advantageous” in the long run. Participants are instructed to win as much money as possible (the starting capital is $2,000). They are also informed that some decks are better than others and that, to win, they have to avoid the disadvantageous decks and keep selecting from the advantageous decks. Participants are informed of how much money they won or lost after each trial; this information can be considered as a feedback. In this study, answers were given verbally and were entered by the examiner through mouse click. All participants understood the instructions. At completion of the task, participants evaluated each card deck by pointing on a scale from zero (very bad) to 10 (very good).

**PAG-R.**—In this computerized task, participants have to decide whether to take a fixed sum alternative (a fixed win or loss of 20€ or of 40€) or to gamble 100€ (gamble alternative). The winning probability associated with the gamble alternative is indicated by the ratio of red cubes to blue cubes (9:15, 15:9) presented within a gray-colored box. Red cubes are winning cubes. If participants decide to gamble, cubes in the box are shaken, and the computer pulls out a cube. Participants win 100€ if the cube being pulled out is red. Otherwise, participants lose 100€. Trials with low winning probability (p = .375 for the ratio 9:15; n = 20) and trials with high winning probability (p = .625 for the ratio 15:9; n = 20) are presented in a pseudorandom order either in combination with a negative fixed sum alternative (−20€ or −40€) or in combination with a positive fixed sum alternative (+20€ or +40€). Trials with low winning probability and a fixed sum alternative of −40€ are “incongruent” because it is advantageous to gamble although the winning probability is low. Trials with high winning probability and a fixed sum alternative of +40€ are also incongruent because it is advantageous not to gamble although the winning probability is high. In summary, for trials with low winning probability, there are three congruent conditions (fixed sum alternatives −20€, +20€, and +40€; each n = 5 trials) and one incongruent condition (fixed sum alternative +40€; n = 5 trials). Participants are instructed to win as much money as possible. The starting capital is zero and is adjusted according to the outcome of each selection. Participants are encouraged to answer as fast as possible (time limit 10 s). In this study, answers were given verbally and were entered by the examiner through mouse click. All participants understood the instructions.

In both the IGT and the PAG-R, monetary gains and penalties are hypothetical, and participants do not receive monetary rewards.

**Procedure**

Participants first performed the neuropsychological background tests (~60 min), then the decision-making tasks (~30 min). Participants made a break of approximately 30 min between the neuropsychological testing and the experimental testing. They were allowed to make pauses or to stop the investigation at any time. None of the participants needed additional pauses or showed signs of tiredness during the testing.

Measures of Decision-Making Performance

**IGT.**—Following convention (Bechara et al., 2000), performance was analyzed by dividing the 100 trials into five blocks of 20 card selections and calculating the difference—net score—between the number of selections from advantageous decks (C + D) and the number of selections from disadvantageous decks (A + B). Scores more than zero indicate that more advantageous cards were selected than disadvantageous cards; scores less than zero indicate that more disadvantageous cards were selected than advantageous cards. For each block, we also calculated the number of shifts made between decks. To examine feedback effects on strategy shifts, we computed (a) the percentage of trials in which a participant continued to select advantageously despite negative feedback, which may be thought of as an index of “strategy stability” and (b) the percentage of trials in which a participant shifted from disadvantageous decks to advantageous decks after negative feedback, which may be considered as an index of “strategy flexibility.” Finally, we computed the average evaluation score of the advantageous decks and the average evaluation score of the disadvantageous decks.

**PAG-R.**—The proportion of gambles, that is, of trials in which participants selected the gamble alternative, was computed for each winning probability (low, high) and each condition (congruent, incongruent) separately. In the computation of proportions, the ratio base for the congruent conditions was 15; the ratio base for the incongruent conditions was 5. This computation was performed for each winning probability separately.
Table 2. Medians and Interquartile Ranges for Scores on Decision-Making Tasks as a Function of Group

<table>
<thead>
<tr>
<th>Variables</th>
<th>MCI patients</th>
<th>Healthy adults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mdn</td>
<td>Q.25</td>
</tr>
<tr>
<td>IGT Total net score ([C + D] − [A + B])</td>
<td>−5.00</td>
<td>−20.00</td>
</tr>
<tr>
<td>IGT Total number of shifts between single decks</td>
<td>77.00</td>
<td>59.25</td>
</tr>
<tr>
<td>IGT Strategy stability (%)</td>
<td>36.36</td>
<td>18.18</td>
</tr>
<tr>
<td>IGT Strategy flexibility (%)</td>
<td>50.00</td>
<td>26.04</td>
</tr>
<tr>
<td>IGT Evaluation of advantageous decks (C + D/2)</td>
<td>5.50</td>
<td>4.00</td>
</tr>
<tr>
<td>IGT Evaluation of disadvantageous decks (A + B/2)</td>
<td>5.00</td>
<td>4.00</td>
</tr>
<tr>
<td>PAG-R Number of gambles with low winning probability</td>
<td>10.00</td>
<td>8.00</td>
</tr>
<tr>
<td>PAG-R Number of gambles with high winning probability</td>
<td>14.00</td>
<td>9.25</td>
</tr>
</tbody>
</table>

Note: Mdn = median; Q. = quartile; IGT = Iowa Gambling Task; and PAG-R = Probability-Associated Gambling Task-Revised.

Statistical Analysis

Data analysis.—Normality of data distribution was examined by means of Shapiro–Wilk tests. This analysis was performed for each group separately. Results were significant for both groups in several neuropsychological measures, for MCI patients in the first three blocks of the IGT, and for healthy controls in the incongruent conditions of the PAG-R. Nonparametric statistics were therefore used to investigate between-subjects effects (Mann–Whitney U-test) and within-subjects effects (Wilcoxon signed-rank test). If not differently specified, significance was set at α = .05.

Correlation analysis.—A Spearman rank-order correlation analysis was carried out between decision-making tasks (IGT: net score in Block 5, total number of shifts between single decks; PAG-R: proportion of gambles in incongruent trials with low winning probability, proportion of gambles in incongruent trials with high winning probability) and neuropsychological measures of verbal memory (learning, free recall, recognition), figural memory (free recall of geometrical shapes, recognition of abstract figures), executive functions (conceptualization, set shifting, categorization, categorical verbal fluency, phonological verbal fluency), and complex numerical processing (mental complex calculation, numeracy). This analysis was performed for each group separately as well as for both groups pooled together. Bonferroni correction for multiple correlations was applied (significance was set at α = .001).

Results

Neuropsychological Background Assessment

Healthy controls scored in the average range of standardized norms. Median scores of MCI patients were slightly less than the average range in the MMSE (CERAD) and in the numeracy test. In other neuropsychological tests (verbal and figural memory, executive functions, visuoconstruction, naming to confrontation, mental complex calculation, and depression), the patients’ median scores were within the average range of standardized norms.

Results of Mann–Whitney U-tests indicated significant group differences in several neuropsychological measures (see Table 1 for median scores, interquartile ranges, and significant contrasts). Healthy controls performed significantly better than MCI patients on tests of global cognitive status, verbal and figural memory, executive functions, and complex numerical processing. MCI patients showed slightly higher depression scores than healthy controls, although scores of both groups were in the normal range. (A Spearman rank-order correlation analysis was carried out for MCI patients between scores on the GDS and measures of decision-making performance [IGT: net scores, shifts between decks, strategy stability index, strategy flexibility index; PAG-R: proportions of gambles in congruent trials and in incongruent trials with low winning probability, proportions of gambles in congruent trials and in incongruent trials with high winning probability]. No correction for multiple correlations was applied. Results indicated that performance of MCI patients in both decision-making tasks did not significantly correlate with the GDS scores. Therefore, it seems unlikely that the group differences in the decision-making tasks [see below] were related to the relatively greater depression symptoms reported by the MCI patients as compared with the healthy controls.). Applying Bonferroni correction (significance at α = .003), group differences remained significant in the MMSE, in the numerical processing tests (mental complex calculation, numeracy) as well as in some measures of verbal memory (learning, free recall), figural memory (free recall of geometrical shapes), and executive functions (categorical verbal fluency, cognitive flexibility).

Iowa Gambling Task

Net score.—Results of a Mann–Whitney U-test conducted to investigate group differences in the total net score failed to reach significance (Table 2). Changes in performance over
time were analyzed by comparing Block 1 to Block 5. This contrast was not significant for MCI patients, but it was significant for healthy controls (Figure 1a), $z = -2.90$, $p = .004$.

Groups performed comparably in Block 1. A significant group difference was found in Block 5, $z = -2.04$, $p = .041$. Overall, these results suggest that MCI patients selected randomly from advantageous and disadvantageous decks; healthy controls made increasingly frequent advantageous selections over time.

**Shifts.**—Groups differed with regard to the total number of shifts between decks (Table 2), $z = -2.35$, $p = .019$. The difference between Block 1 and Block 5 was significant for healthy controls (Figure 1b), $z = -2.68$, $p = .007$, as well as for MCI patients (Figure 1b), $z = -2.05$, $p = .041$. In summary, both healthy controls and MCI patients made less shifts between decks over time. MCI patients shifted between decks more frequently than healthy controls.

**Feedback effects on strategy shifts.**—Healthy controls and MCI patients did not differ with regard to the index of strategy flexibility. Significant group differences were found in the index of strategy stability (Table 2), $z = -2.69$, $p = .007$. In summary, MCI patients demonstrated poorer strategy stability than healthy controls (performance in the first trials of the IGT is regulated by random decisions. Block 1 was therefore excluded from this analysis).

**Evaluation scores.**—The difference between advantageous and disadvantageous decks was significant for healthy controls (Table 2), $z = -2.98$, $p = .003$, but it was not significant for MCI patients. In summary, at completion of the task, healthy controls evaluated the advantageous decks more favorably than the disadvantageous decks; MCI patients evaluated advantageous and disadvantageous decks equally favorably.

**PAG-R**

Participants performed advantageously on this task, if they decided to gamble proportionally more often in incongruent trials than in congruent trials with low winning probability and proportionally less often in incongruent trials than in congruent trials with high winning probability (overall, participants selected the gamble alternative more frequently in trials with high winning probability than in trials with low winning probability [Table 2], $z = -2.83$, $p = .005$).

**Low winning probability.**—The difference between the proportion of gambles in congruent trials and the proportion of gambles in incongruent trials was significant for healthy controls (Figure 2), $z = -3.55$, $p < .001$, but it was not significant for MCI patients. Groups differed significantly with regard to the proportion of gambles in incongruent trials, $z = -2.43$, $p = .015$. No significant group difference was found with regard to the proportion of gambles in congruent trials.

**High winning probability.**—The difference between congruent and incongruent trials was significant for healthy controls (Figure 2), $z = -3.64$, $p < .001$, as well as for MCI patients, $z = -2.89$, $p = .004$. Groups did not significantly differ from each other.

In summary, healthy controls decided advantageously in all conditions of the PAG-R. MCI patients decided advantageously in trials with high winning probability. However, they made less advantageous decisions than healthy controls in trials with low winning probability.

**Correlation Analysis**

Results of the analysis performed for each group separately did not survive correction for multiple correlations.
Results for the groups pooled together indicated significant correlations between the IGT and neuropsychological measures of figural memory, categorization, and numeracy. Specifically, the overall number of shifts between single decks inversely correlated with the number of correct answers in the numeracy test, \( r = -.475, p = .001 \); the number of correct answers in the categorization test (OMO), \( r = -.498, p = .001 \); and the score in a measure of figural memory (free recall of geometrical shapes, CERAD), \( r = -.584, p < .001 \). No other significant correlation was found for the IGT. Performance on the PAG-R did not correlate with either performance on the IGT or performance on neuropsychological tests.

**Discussion**

In this study, we aimed to assess whether older individuals with MCI without dementia present difficulties in making advantageous decisions under ambiguity and under risk. Decision making represents an important ability for leading an independent life and has been found to be poor in a subgroup of healthy older adults (e.g., Delazer et al., 2005, 2007) and relevantly impaired in patients with mild dementia (e.g., Delazer et al., 2007, 2009; Sinz et al., 2008; Torralva et al., 2007). However, no study so far has investigated decision making in patients with MCI. Here, we compared performance of MCI patients with performance of healthy aging peers in two gambling tasks. The IGT is thought to assess decision making under ambiguity (at least in the initial trials of the task; for a discussion, e.g., Brand, Labuda, & Markowitsch, 2006). The PAG-R assesses the ability to make decisions under risk. Results of a formal neuropsychological assessment indicated that, although both groups scored within the average range of standardized norms, MCI patients performed poorly relative to healthy controls on measures of episodic memory, executive functions, and complex numerical processing. Groups also differed in several measures of decision making.

In the IGT, healthy controls made increasingly frequent advantageous selections and less frequent shifts between decks over time. At completion of the task, healthy controls evaluated the advantageous decks more favorably than the disadvantageous decks. Overall, these findings suggest that healthy older adults learned to decide advantageously by using feedback and consolidated their strategy over time (see also Zamarian et al., 2008). In contrast to healthy controls, MCI patients made random decisions and showed poor strategy stability. Also, MCI patients evaluated advantageous and disadvantageous decks equally favorably. In summary, MCI patients showed difficulties in learning from feedback and in maintaining an advantageous decision strategy over time. These difficulties resembled those presented by patients with mild dementia (Delazer et al., 2009; Sinz et al., 2008). Performance of MCI patients on the IGT clearly differed from performance of VMPFC patients who show an evident preference for risky alternatives (e.g., Bechara et al., 1994, 2000; Tranel et al., 2002).

MCI patients significantly differed from healthy controls in the decision under risk task as well. Healthy controls decided advantageously in the congruent conditions as well as in the incongruent conditions of the PAG-R. They demonstrated a capacity to adapt their choices to changes in the information presented on a given trial and to take into account multiple sources of information (i.e., winning probability and fixed sum alternative) to make advantageous decisions under risk. MCI patients decided less advantageously than healthy controls. Their response pattern suggests that they based their decisions on the winning probability and ignored the changing fixed sum alternative. In summary, MCI patients, in contrast to healthy older adults, showed difficulties in integrating information from different sources and in adapting their choices to changes in the decision situation. In previous investigations (e.g., Bonatti et al., 2009; Delazer et al., 2009; Sinz et al., 2008; Zamarin et al., 2008), we used a version of the PAG where participants could make advantageous decisions by taking into account only the winning probability. We found that healthy older adults and patients with Parkinson’s disease without cognitive impairment perform flawlessly on this task, but that patients with mild dementia perform very poorly (Delazer et al., 2009; Sinz et al., 2008). This study demonstrates that MCI patients may also present difficulties in decision making under risk when the task demands are high.

In this study, we carried out a correlation analysis to explore the possible contribution of episodic memory, executive functions, and complex numerical processing to decision-making performance. Results indicated that capacity to maintain a strategy over time in the IGT was associated with good figural memory, good categorization ability, and a high level of numeracy (understanding of basic probability and mathematical concepts; Lipkus et al., 2001). We can only cautiously interpret this analysis, as significance was reached only when the groups were pooled together. However, its results are in line with previous investigations suggesting that executive functions contribute to both decision making under ambiguity and decision making under risk (e.g., Brand et al., 2006; Sinz et al., 2008; Zamarin et al., 2008) and that intact episodic memory is important for making good decisions (e.g., Gupta et al., 2009; but see Turnbull & Evans, 2006). Our results also suggest that understanding of basic probability and mathematical concepts might play a role in the decision under ambiguity task.

This study adds to previous investigations on decision making in older age (e.g., Denburg et al., 2007; Fein et al., 2007; Zamarin et al., 2008) and to studies on impairments of MCI patients in complex activities of daily living (e.g., Griffith et al., 2003; Okonkwo et al., 2008; Zamarin et al., 2007). In summary, it shows that healthy older adults decide advantageously under ambiguity and under risk even when the task demands are high. In a previous investigation
(Zamarian et al., 2008), we compared performance of healthy older adults with performance of younger adults and found no significant age effects in the original version of the PAG. It has been proposed that the original version of the PAG is not sufficiently demanding for healthy aging persons and that significant age effects are found in more complex decision under risk tasks (Brand & Markowitsch, 2010). Further research is needed to determine whether the revised version of the PAG is an adequate tool for detecting an age-related decline in decision making under risk. This study also shows for the first time that older adults with MCI without dementia present difficulties in making advantageous decisions. MCI patients make poorer decisions than healthy older adults when the decision situation is not well defined, information about risk is missing or conflicting, and learning from contingencies is needed. They also have problems when full information about a complex and changing decision situation is given, and learning from experience is not required. To some extent, impairments of MCI patients in both decision-making tasks mimic those of patients with mild dementia (Delazer et al., 2007, 2009; Sinz et al., 2008).

In conclusion, this study indicates that patients with MCI without dementia have problems in making advantageous decisions under ambiguity and under risk. Decision-making deficits may have a strong impact on everyday functioning. Real-life decision situations are typically more complex and less structured than those presented in the IGT and the PAG-R. Also, real-life decisions are frequently made under time pressure (e.g., during car driving). Although we cannot exclude the possibility that MCI patients are able to compensate for their deficits in some situations, showing apparently intact daily functioning, we suggest that they may experience pronounced difficulties when complex decisions are required. Future research might investigate whether our findings can be generalized to real-life decision situations. Also, as this study assessed MCI patients who were attending an outpatient memory clinic, future research might address whether there are individual differences between persons with MCI who seek for treatment and persons with MCI who do not.

**References**


