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# Impact of ambiguity and risk on decision making in mild Alzheimer's disease

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**Abstract**

Decisions under ambiguity and decisions under risk are crucial types of decision making in daily living at any age. This is the first study assessing these two types of decisions in patients with mild dementia of Alzheimer's type (DAT) by means of the Iowa Gambling Task (IGT) and a newly developed, Probability-Associated Gambling (PAG) task. While rules for gains and losses are implicit in the IGT, in the PAG task rules are explicit and winning probabilities, which change from trial to trial, can be estimated. Results of the IGT indicated that DAT patients made more disadvantageous decisions than healthy controls. Patients also shifted more frequently among decks, i.e. under ambiguity decisions were taken randomly and no advantageous strategy was established over time by DAT patients. Thus, not only actual choices but also development of advantageous strategies may be revealing about decision making in the IGT. Compared to controls, patients demonstrated less advantageous choices in the PAG task as well. They gambled more often in the low winning probabilities and less frequently in the high probabilities than healthy participants. Patients' performance on both tasks correlated with measures of executive functions. Findings of the present investigation are consistent with the early pathological cerebral changes and related (cognitive, emotional) deficits reported for DAT. As suggested by our study, decisions under ambiguity as well as decisions under risk are impaired in mild DAT. It may thus be expected that patients with mild DAT have difficulties in taking decisions in every-day life situations, both in cases of ambiguity (information on probability is missing or conflicting, and the expected utility of the different options is incalculable) and in cases of risk (outcomes can be predicted by well-defined or estimable probabilities).


*Keywords:* Decision; Risk; Ambiguity; DAT

## 1. Introduction

Decision making is a fundamental and complex skill which is crucial at any age. Old persons have to face decisions regarding their health care, medical treatment, retirement, housing situation and financial issues, just to name a few. They not only have to consider the benefit of a decision for their current living situation, but also to anticipate the consequences of decisions in the nearer and farer future. Some characteristics seem to specify older adults' decision making as compared to younger adults'. Older adults often try to evade taking decisions; they rely more on emotional processing than on analytical processing and avoid negative affects when making decisions (for a review Mather, 2006). Despite their cognitive impairment, patients affected by mild dementia of Alzheimer's type (DAT) also have to take important decisions. These decisions are sometimes particularly difficult, given that the progress of the disease and its impact on the living situation is an incalculable variable. Decision-making impairments have been found in patients with neurodegenerative conditions such as Huntington's disease (Stout, Rodawalt, & Siemers, 2001), Parkinson's disease (Brand et al., 2004; Busemeyer & Stout, 2002; Cools, Barker, Sahakian, & Robbins, 2003; Czernecki et al., 2002; Perretta, Pari, & Beninger, 2005; Thiel et al., 2003), fronto-temporal dementia (Torralva et al., 2007) or Korsakoff syndrome (Brand, Fujiwara, et al., 2005), but there has been very little research on decision making in DAT. A recent study (Delazer, Sinz, Zamarian, & Benke, 2007) suggests that patients with mild DAT differ from healthy controls in decision making with explicit and stable rules. No studies so far investigated two further types of decision making in mild DAT, decision making under ambiguity with implicit rules for gains and losses and decision making under risk with explicit rules and changing probabilities from trial to trial. As suggested by the available evidence (for a detailed review and analysis see

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Brand, Labudda, & Markowitsch, 2006; Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005), decision making under ambiguity and decision making under risk rely on partially different neuronal structures and require different cognitive abilities. We will first summarize the neuropsychological evidence related to decisions under ambiguity, then the evidence for decisions under risk.

### 1.1. Decision making under ambiguity

In a series of studies Damasio, Bechara and coworkers demonstrated that ventromedial prefrontal cortex (VMPFC) lesions impair the ability to make advantageous choices and to learn from positive and negative feedback in the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994; Bechara, Tranel, & Damasio, 2000; Damasio, 1996; Damasio, Tranel, & Damasio, 1991). In the IGT, participants are presented with four decks of cards and have to select cards without knowing the consequences of their choices (for a comprehensive review see Dunn, Dalgleish, & Lawrence, 2006). Unknown to participants, two decks of cards offer large wins but long-term punishments ("bad decks"), while two decks offer small wins but smaller punishment, thus leading to a net win ("good decks"). Healthy participants gradually develop a tendency towards advantageous choices over the task. As suggested by Damasio et al. (1991) and Damasio (1994), healthy individuals are biased by somatic markers to choose alternatives which proved successful in similar decision situations and to avoid choices which proved disadvantageous in previous experiences. Importantly, individuals develop anticipatory skin conductance responses and start to choose advantageously before they consciously recognize the good decks of the IGT (Bechara et al., 1994; Bechara, Tranel, Damasio, & Damasio, 1996). In contrast to healthy participants, patients with VMPFC lesions choose more cards from the disadvantageous decks even when they experience large penalties. They do not show any anticipatory skin conductance response when selecting from the disadvantageous decks. Overall, results of the IGT studies indicate that patients with VMPFC lesions show insensitivity to future consequences of their choices. The IGT has been used to examine decision making in several patient groups with psychiatric or neurological diseases, such as Parkinson's and Huntington's disease (Stout et al., 2001; Thiel et al., 2003), fronto-temporal dementia (Torralva et al., 2007), schizophrenia (e.g., Whitney, Fastenau, Evans, & Lysaker, 2004) or obsessive–compulsive disorder (Cavedini, Riboldi, D'Annucci, et al., 2002; for a review Dunn et al., 2006).

Though emotions are thought to be critical in the IGT (Damasio, 1994; Loewenstein & Lerner, 2003), several studies show that other processes as well are essential in successfully performing the task. Busemeyer and coworkers (Busemeyer & Stout, 2002; Stout et al., 2001; Stout, Busemeyer, Lin, Grant, & Bonson, 2004) proposed a cognitive model with three parameters which are essential in successful decision making: motivation, learning-rate and choice-consistency. Learning and memory processes, rather than motivational processes, were crucial for decision-making difficulties in patients affected by Huntington's disease (Busemeyer & Stout, 2002; Campbell, Stout, & Finn, 2004; Stout et al., 2001). Huntington's disease patients demonstrated to answer more randomly as the task progressed (Busemeyer & Stout, 2002). The role of memory and explicit recall in the IGT has been controversially discussed. While a case study on a severely amnesic patient suggested that explicit memory is not relevant in answering the IGT (Turnbull & Evans, 2006), a recent study reported severe deficits in the IGT in a small group of amnesic subjects (Gutbrod et al., 2006). The role of executive functions in the IGT is also under debate. The seminal studies by Bechara and Damasio (e.g., Bechara et al., 2001; Bechara, Damasio, Tranel, & Anderson, 1998; Bechara et al., 2000) emphasize the role of the limbic loop, the VMPFC and the emotional responses mediated by related neurotransmitter systems. On the other side, recent studies also attribute a critical role to the dorsolateral prefrontal loop and to executive functions such as flexibility, reversal learning and set-shifting. In contrast to earlier studies (Bechara et al., 2001; Cavedini, Riboldi, D'Annucci, et al., 2002; Cavedini, Riboldi, Keller, D'Anucci, & Bellodi, 2002), Brand, Grabenhorst, Starcke, Vandekerckhove, and Markowitsch (2007) and Brand, Recknor, Grabenhorst, and Bechara (2007) report significant correlations between the IGT and a task of categorization and set-shifting (Wisconsin Card Sorting Test, WCST; Brand, Recknor, et al., 2007; Hinson, Jameson, & Whitney, 2002). These different studies' outcomes may be due to the different measures used. Correlations between IGT and WCST may emerge stronger when the last block of the IGT is assessed but may be more moderate when the overall sum of advantageous decks is taken into consideration (e.g., Brand, Recknor, et al., 2007). Brand and coworkers suggest that the IGT can be separated into different stages: decision making under ambiguity in the first trials (rules are unknown to the subject) and decisions making under risk in the latter trials (rules are gradually discovered). As the task proceeds and subjects gain insight into the underlying rules, cognitive demands change and put more load on executive functions. The shift from decision making under ambiguity to decision making under risk is gradual and individually different.

### 1.2. Decisions under risk

There are gambling tasks providing explicit rules in every trial and allowing the estimation of the chance to win and the risk to loose. In the Cambridge Gambling Task (CGT; Rogers et al., 1999), participants have to assess the probability of an event (whether a yellow token is hidden under a red or blue box) and to bet a certain proportion of their capital on their decision. The probabilities are changing in each trial and participants have to decide explicitly. Another task where outcome probabilities are displayed in a direct and simple manner is the Cups task (Levin & Hart, 2003). In a similar way, in the Game of Dice Task (GDT; Brand et al., 2004; Brand, Fujiwara, et al., 2005; Brand, Kalbe, et al., 2005) participants have to explicitly evaluate the chance to win and the risk to loose. Before each throw, subjects have to choose a single number or a combination of numbers (2, 3 or 4 numbers together). Each choice is related to a high or low gain and to a high or low loss. Subjects are asked to maximize their capital (1000 €) within 18 dice tosses. In contrast to the CGT, probabilities in the GDT are stable from trial to trial and participants have the chance to develop advantageous long-term strategies (Brand et al., 2006). The GDT has been used to assess decision making in various patient groups. Patients with Korsakoff syndrome (Brand, Fujiwara, et al., 2005), Parkinson's disease (Brand et al., 2004) and pathological gambling (Brand, Kalbe, et al., 2005) show severe deficits and select risky alternatives more frequently than healthy controls. Importantly, significant correlations between the GDT and categorization and set-shifting in the WCST were found in patients with Korsakoff syndrome (Brand, Fujiwara, et al., 2005) and Parkinson's disease (Brand et al., 2004), suggesting a crucial role of the dorsolateral prefrontal loop in decision making under risk. In patients with pathological gambling, the frequency of advantageous decisions in the GDT was correlated with performance in the WCST but not with personality traits (Brand, Fujiwara, et al., 2005). In the present study we use a new task of decision making under risk (Probability-Associated Gambling task (PAG) described in Section 2). In variance to the GDT, the most advantageous alternative in this gambling task is not always the most conservative one. Advantageous choices in the GDT may be either related to accurate estimation of risk and probability or to conservative behaviour and risk aversion. In the PAG task, advantageous choices require the assessment of probability and risk. Extreme conservative behaviour in this task does not lead to an advantageous response pattern as in the GDT. Furthermore, probabilities in the PAG task change from trial to trial, whereas choice alternatives in the GDT are stable over the task.

### *1.3. Decision making in healthy aging*

Lifespan developmental changes in performance on the IGT have been observed in several studies. Performance on this paradigm improves with increasing age until adulthood (Crone & van der Molen, 2004; Hooper, Luciana, Conklin, & Yarger, 2004; Kerr & Zelazo, 2004; Overman et al., 2004), while it appears to decrease in older age (Denburg, Tranel, & Bechara, 2005; Denburg, Tranel, Bechara, & Damasio, 2001; Lamar & Resnick, 2004). Denburg et al. (2005) described decision-making impairments in old persons in the absence of other neuropsychological deficits. Deficits in decision making were attributed to age-related alterations of the neural structure in prefrontal regions and to decline in the associated cognitive functions (frontal-lobe hypothesis of aging; West, 1996, 2000). Wood, Busemeyer, Koling, Cox, and Davis (2005) analysed performance in the IGT in younger (18–34 years) and older adults (65–88 years), and found that both groups were successful in solving the task. However, groups differed in their strategies. Younger adults profited from good learning and memory; older adults were helped by accurately representing the valence of wins and losses.

Importantly, age differences also appear in dealing with the emotional aspects of a decision (Bechara, Damasio, Damasio, & Lee, 1999). As people get older, emotional goals, such as emotional satisfaction at the current moment, become more important than non-emotional goals (e.g., achievement of new information; Carstensen, Isaacowitz, & Charles, 1999). These changes in goals seem to have an effect on older adults' decision making. Compared to younger adults, older adults more likely attend to and remember information with a positive connotation than negative information (Carstensen & Mikels, 2005; Mather, 2004; Mather & Carstensen, 2005). Older adults also remember their past decisions in a more positive light and typically neglect negative aspects of their experiences (Mather & Johnson, 2000). Changes in emotional processing possibly lead older adults, relative to younger adults, to focus on different aspects of the available information during decision making (Mather, Knight, & McCaffrey, 2005). Older adults tend to avoid taking decisions (if possible) and show aversion towards risky situations (for a review Mather, 2006).

### *1.4. Decision making in mild DAT*

DAT is characterized by typical structural, neurochemical and cognitive changes as the disease progresses. Pathological changes in mild DAT affect primarily the medial temporal lobes and limbic structures (e.g., entorhinal cortex, hippocampus), and then extend to the association cortices of the frontal, temporal and parietal lobes (Braak & Braak, 1991). Degeneration in the basal forebrain (e.g., the nucleus basalis of Meynert) leads to a prominent decrement in neocortical and hippocampal levels of the neurotransmitter acetylcholine (Beach et al., 2000; Whitehouse et al., 1982). Although DAT pathology mainly affects cortical grey matter, a study by Naggara et al. (2006) using diffusion tensor imaging revealed abnormalities in the frontal and temporal white matter in mild DAT patients. These changes are compatible with early temporal-to-frontal disconnections. Associated with the distribution of these pathological changes, the disorder is primarily characterized by a gradual, but progressive decline in memory (Welsh, Butters, Hughes, Mohs, & Heymann, 1992). Early deficits also occur in tasks relying on executive and attentional functions when simultaneous and rapid integration of multiple types of information is required (for a review Perry & Hodges, 1999). Further impairments can also be found in language and semantic knowledge, abstract reasoning, constructional and visuo-spatial abilities (Salmon & Bondi, 1999). Apart from cognitive functions, emotional processing may show changes as the disease progresses. Chu, Tranel, Damasio, and Van Hoesen (1997) suggested that the degeneration of the VMPFC contributes to the autonomic dysregulation and emotional disturbances in DAT. A specific role in the emotional processing disorders as the disease progresses has been attributed to amygdala degeneration (Hamann, Monarch, & Goldstein, 2002; Mori et al., 1999). Some studies report emotional processing difficulties in DAT which seem, however, to be less pronounced than the cognitive deficits (Boller et al., 2002). Bucks and Radford (2004) describe relatively spared non-verbal emotional processing skills as compared to the general cognitive decline in patients with DAT.

Up to now little attention has been paid to decision-making processes in dementia. In a recent study, Delazer et al. (2007) investigated decision making in mild DAT using the GDT. Overall, no significant group differences between patients and healthy controls were found in the number of safe choices. However, differences between mild DAT patients and healthy participants emerged from a more detailed analysis of participants' performance. Mild DAT patients shifted more frequently between safe and risky alternatives than healthy controls and showed no tendency towards safe and advantageous responses as the task proceeded. Frequent changes between strategies indicate that decisions were taken randomly, that no advantageous strategy was established and that no consistent response pattern was developed over time. While healthy controls showed learning as the task proceeded, DAT patients did not adapt their strategies. The proportion of "consistently safe responders" was significantly higher in the control group than in the DAT group. Finally, analysis of reaction times indicated that differences in response behaviour were not due to fast and impulsive decision taking in the DAT group. Though the study by Delazer et al. (2007) highlighted some difficulties in decision making in individuals suffering from mild DAT, several questions remain to be answered.

To the best of our knowledge, it has not been yet investigated how mild DAT patients decide in situations of ambiguity and how they decide in situations of changing probabilities. In the present study, these types of decision making are assessed through the IGT and the PAG task. In the decision under risk task (PAG), changing probabilities are presented in every trial. It is assessed whether participants are able to choose advantageous alternatives. In variance to the GDT, extreme conservative behaviour is not advantageous. Thus, DAT patients may show difficulties in the PAG task which are more evident than the ones described for the GDT by Delazer et al. (2007). Moreover, the PAG task requires to flexibly assess probabilities of the possible gains and losses in every trial. It is likely that DAT patients show some difficulties in a task which requires flexible adaptation to changes in decision situations.

In the decision under ambiguity task (IGT), different hypotheses may be forwarded. Major importance has been attributed to emotional processing in the IGT. Since emotional processing is relatively preserved in the early stages of the disease, it is possible that mild DAT patients successfully perform an implicit task of decision making. Alternatively, it may be assumed that slight deficits in emotional processing (e.g., Chu et al., 1997; Hamann et al., 2002; Mori et al., 1999) or decline in cognitive functions such as inhibition, flexibility and set-shifting (e.g., Zamarian, Semenza, Domahs, Benke, & Delazer, 2007), or working memory (e.g., Morris, 1994) lead to disadvantageous performance. In both tasks (IGT, PAG) the number of advantageous choices and the number of disadvantageous choices will be analysed. Disadvantageous choices in the IGT are risky; disadvantageous choices in the PAG task are either too risky or too conservative. Further to the analysis of overall choices, we will assess the time course of decisions. It will be assessed whether mild DAT patients and healthy controls learn over the blocks of the IGT and whether they establish a consistent and advantageous response pattern. It may be hypothesized that failure in the IGT may be either due to impulsive and perseverate selection of disadvantageous decks associated with high immediate wins and losses or, alternatively, to the inability to recognize rules and to establish advantageous strategies. While the first pattern would be reflected by perseveration of risky decisions, the latter would be indicated by frequent shifts between choice alternatives.

## 2. Methods

### 2.1. Participants

Patients were outpatients consecutively recruited from the Memory Clinic of Neurology (Innsbruck, Austria), which they were referred to because of memory problems. They were examined in detail using standard neurological and neuropsychological test procedures. Additional investigations consisted of an informal interview, CT or MRI of the brain, routine blood samples and, when required, SPECT, EEG and other diagnostic procedures. Twenty-two patients (18 females) were diagnosed as having probable DAT according to NINCDS-ADRDA criteria (McKhann et al., 1984). The presence of significant vascular ischemic disorder was screened out according to the Hachinski ischemia scale (Hachinski et al., 1975). DAT patients showed problems with memory combined with variable other cognitive impairments, including executive functions, constructive abilities or language. Patients mean age was 76.6 years/S.D. 2.2, mean educational level was 9.5 years/S.D. 1.6, mean Mini Mental State Examination score (MMSE; Folstein, Folstein, & McHugh, 1975) was 23.4/S.D. 2.4. Thus, we classified the group as mild DAT. All but three patients received cholinergic substitution therapy according to international standards. The control group included 22 healthy elderly participants (17 females, mean age 75.2 years/S.D. 5.4; mean educational level 10.0 years/S.D. 1.6). All patients and controls had normal or corrected-to-normal sight and sufficient hearing ability. Comparing demographic variables (age, education), anxiety scores (HADS-D; Herrmann, Buss, & Snaith, 1995; patients 5.5/S.D. 2.5; controls 6.6/S.D. 2.7) and depression scores (HADS-D; patients 3.6/S.D. 2.6; controls 4.7/S.D. 2.8), no significant group differences were found. Moreover, all participants were classified as non-problem gamblers (they took part to gamble or lottery activities less than five times a year) using the CPGI questionnaire measuring problematic gambling behaviour (Wynne & Smith, 2002). The study was approved by the local ethical committee and informed consent was obtained from all participants.

### 2.2. Neuropsychological background tests

DAT patients and healthy old adults performed the MMSE (Folstein et al., 1975). They were all tested on verbal short-term memory and working memory (digit span forward and backward of the Nürnberger Altersinventar, NAI; Oswald & Fleischmann, 1997), psychomotor speed (Trail Making Test-part A, TMT-A; Lezak, 1998), and complex mental calculation (Jackson & Warrington, 1986). The OMO test (Odd-Man-Out; Flowers & Robertson, 1985) was used as a measure of the ability to maintain mental sets and to shift between sets. In this test, 40 cards in four separate blocks (with 10 cards each block) are presented and participants are required to indicate which letter or geometrical figure is different from the others. Two different rules (size or shape) can be used. Subjects are allowed to freely choose the first rule which has to be maintained along the first block. In the second block, the alternate rule has to be found out and maintained for the block. Rules should be alternated in the remaining two blocks as well. As part of the diagnostic process, DAT patients were also assessed on verbal memory (learning, recall and recognition subtests of the CERAD battery; Berres, Monsch, Bernasconi, Thalmann, & Stahelin, 2000), figural memory (free recall of geometrical shapes, CERAD), object naming (Boston Naming Test, short version, CERAD), categorical verbal fluency (animals/min, CERAD), planning abilities (CLOX-1; Royall, Cordes, & Polk, 1998), and constructive abilities (copying geometrical shapes, CERAD). Furthermore, they were screened for ideomotor apraxia (IAHB[1]) and underwent an assessment of executive functions including subtests of conceptualization, mental flexibility, motor programming, sensitivity

[1] Kuen E. Motorik und Altern vor einem neuropsychologischen Hintergrund [unpublished graduate thesis]. Innsbruck: Leopold Franzens University; 2002.

to interference, inhibitory control, and environmental flexibility (subtests of the Frontal Assessment Battery, FAB; Dubois, Slachevsky, Litvan, & Pillon, 2000).

## 2.3. Decision tasks

### 2.3.1. Iowa Gambling Task

Participants completed the computerized version of the IGT consisting of four decks of cards labelled A, B, C and D (Bechara et al., 2000; for a comprehensive review see Dunn et al., 2006). The participants make 100 card selections one at a time (the total number of card selections is unknown to the participants). In our study, the answer was given verbally by the participant and was entered by the examiner by mouse click. Selecting a card from decks A and B results in large gains of money. However, at certain unpredictable times this gain is followed by a large penalty, so that these decks are considered to be the disadvantageous (or "bad") decks in the long run. On the other side, selecting a card from decks C and D produces small immediate gains in money. The unpredictable losses are also small, so that these decks will reward more money in the long run and are thus considered to be the advantageous (or "good") decks. Every time after selection of a card, the computer generates a distinct sound indicating gain or loss and a message is displayed on the screen indicating the amount of money the participant has won or lost. On the top of the computer screen, a green bar changes according to the amount of money won or lost after each selection. According to the win/loss, the length of the green bar increases/decreases. Before starting the task, participants are told that the aim of the game is to win as much money as possible (the starting capital is 2000 dollars). They are instructed that they can choose cards from any deck and are allowed to switch decks at any time. It is also explained that some decks are better than others and that for winning participants have to avoid the bad decks and cling to the good decks (for exact and detailed instructions see Bechara et al., 2000).

### 2.3.2. Probability-Associated Gambling task (PAG task)

In this computerized task subjects are instructed to imagine they are participating in a lottery game with the goal to win as much money as possible. In every trial they are presented with a display and asked to decide whether they take either a safe but small amount of a loss/win of 20 € ("fixed sum") or the risk to gamble for 100 € ("gamble"). The chance of winning in every trial is indicated through a grey-coloured box where a changing ratio of red and blue cubes (total 24 cubes) is presented. If the participant decides to gamble, the cubes are shaken in the box and one cube is drawn. Every time a red cube is drawn, the subject gains 100 €. Alternatively, if a blue cube is drawn, the subject loses 100 €. The ratio of red to blue cubes (3:21, 9:15, 15:9, 21:3) varies from trial to trial in a pseudo-randomized manner. Each winning probability occurs five times (either in combination with a negative or a positive fixed sum) in the entire 40 trials. In the trials with the low winning probabilities (3:21 or $p = 0.125$, and 9:15 or $p = 0.375$), it is advantageous to take the fixed sum (regardless of whether the fixed sum consists of ±20 €). In contrast, in the trials with the high winning probabilities (15:9 or $p = 0.625$, and 21:3 or $p = 0.875$) it is advantageous to gamble. Each trial is displayed for a period of 10 s. If there is no response within these 10 s, the fixed sum is automatically selected, accompanied by a short confirmative noise. If the participant decides to gamble, the gain (a red cube has been drawn) or the loss (a blue cube has been drawn) are presented visually and pointed out by two different acoustic signals (gain = jingle of a cash desk; loss = dull noise). Dependent on the outcome, the capital (starting capital = 0 €) is adjusted and presented on the screen. The answer is given verbally by the participant and entered by the examiner by mouse click.

## 2.4. Statistical analysis

In general, group comparisons were performed by means of independent-sample *t*-tests. Paired-sample *t*-tests were applied to contrast conditions within

Table 1
Results of the neuropsychological background tests

| | *M* (S.D.) | | *t*-Test (*p*-value) | No. of patients scoring below cut-off |
|---|---|---|---|---|
| | DAT patients (*N* = 22) | Controls (*N* = 22) | | |
| MMSE | 23.4 (2.4)** | 29.5 (0.8) | 0.0001 | 20/22[a] |
| Digit span forward (NAI) | 5.4 (1.3) | 5.6 (1.0) | n.s. | 5/22[b] |
| Digit span backward (NAI) | 3.2 (1.0) | 4.1 (0.8) | 0.002 | 13/22[c] |
| TMT_A (s) | 95.7 (34.7)** | 49.6 (13.0) | 0.0001 | 15/22[d] |
| Cognitive flexibility (OMO) | 8.3 (6.5)** | 1.2 (1.0) | 0.0001 | 16/22[e] |
| Complex mental calculation | 5.8 (3.7) | 12.5 (4.2) | 0.0001 | 10/22[f] |
| Verbal memory—recall (CERAD) | 2.0 (1.6)** | – | – | 18/22[a] |
| Figural memory—recall (CERAD) | 2.3 (2.2)** | – | – | 18/22[a] |
| Object naming (CERAD) | 11.6 (1.6)* | – | – | 12/22[a] |
| Categorical verbal fluency (CERAD) | 11.1 (5.2)* | – | – | 12/22[a] |
| Copying geometrical shapes (CERAD) | 8.9 (1.9)* | – | – | 12/22[a] |
| CLOX-1 | 8.0 (3.4)** | – | – | 15/22[g] |
| Ideomotor apraxia (IAHB) | 11.9 (1.5) | – | – | 4/22[h] |
| FAB total score | 12.0 (2.9)** | – | – | 17/22[i] |
| FAB conceptualization | 1.6 (0.8) | – | – | – |
| FAB mental flexibility | 1.9 (0.9) | – | – | – |
| FAB motor programming | 1.8 (1.0) | – | – | – |
| FAB sensitivity to interference | 2.3 (1.0) | – | – | – |
| FAB inhibitory control | 1.6 (1.1) | – | – | – |
| FAB environmental flexibility | 2.9 (0.2) | – | – | – |

Legend: *M*, mean; S.D., standard deviation; n.s., not significant; *group mean below 1 S.D. from standardised norms; **group mean below 2 S.D. from standardised norms.

[a] Cut-off 1.64 S.D.
[b] Cut-off 5.
[c] Cut-off 4.
[d] Cut-off 10th percentile.
[e] Cut-off 3.
[f] Cut-off 5.
[g] Cut-off 11.
[h] Cut-off 10.5.
[i] Cut-off 15.

a group. Performance on the IGT and the PAG task separately was analysed by means of an analysis of variance (ANOVA) with a mixed design (see below for a detailed description of the factors in each analysis). Scores on both tasks were arcsine-transformed to achieve a better approach to the normal distribution. To quantify performance on the IGT and analyse a possible trend across task performance, trials were divided into five separate blocks of 20 trials each. A performance score for each block was then calculated by summing up the number of advantageous choices (i.e., good decks C + D). Finally, relationships between neuropsychological tests of executive functions (TMT-A, TMT-B, CLOX-1, NAI, verbal fluency, OMO, FAB) and performance on the gambling tasks (IGT and PAG) were calculated using Pearson product-moment correlations. Overall, test significance was set at $p \leq 0.05$. There were one control and four DAT patients who were not assessed on the IGT and one DAT patient who did not receive the PAG task.

## 3. Results

### 3.1. Neuropsychological background tests

Patients showed cognitive deficits typical for mild DAT and scored significantly lower than controls in all examined neuropsychological functions except for verbal short-term memory (see Table 1).

### 3.2. Iowa Gambling Task

#### 3.2.1. Choices in the IGT

A repeated-measures ANOVA with blocks (1–5) as within-subjects factor and group (DAT patients, controls) as between-subjects factor was carried out on the frequency of advantageous choices (C + D). Results revealed a highly significant main effect of group ($F[1,38] = 15.03$, MSE = 2.40, $p < 0.0001$). Overall, DAT patients selected the advantageous decks (C + D) less frequently than healthy controls. The main effect of block was also highly significant ($F[4,152] = 11.39$, MSE = 1.02, $p < 0.0001$) and entered into a highly significant interaction with group ($F[4,152] = 8.83$, MSE = 0.79, $p < 0.0001$). The two groups significantly differed in all but one condition (i.e., block 2; Fig. 1). DAT patients chose the advantageous decks more frequently than healthy controls in the first block ($t[38] = -3.07$, $p < 0.01$), whereas the reverse pattern was found for block 3, 4 and 5 ($t$-tests, all $p < 0.05$). Within-group contrasts indicated that the frequency of advantageous choices significantly increased over the task for healthy participants (block 1 vs. 5: $t[21] = -4.73$, $p < 0.001$), while no relevant difference between blocks was detected for DAT patients (Table 2).

#### 3.2.2. Strategy changes

Performance on the IGT was further analysed by means of a repeated-measures ANOVA with block (5) as within-subjects variable and group (2) as between-subjects variable carried out on the frequency of shifts between advantageous and disadvantageous decks. Both the main effect of group ($F[1,37] = 24.29$, MSE = 15.80, $p < 0.0001$) and the main effect of block ($F[4,148] = 5.55$, MSE = 0.504, $p < 0.0001$) were highly significant, whereas the block × group interaction did not reach significance. Overall, DAT patients shifted between advantageous and disadvantageous decks more often than controls (Fig. 2). Contrasts between block conditions demonstrated that

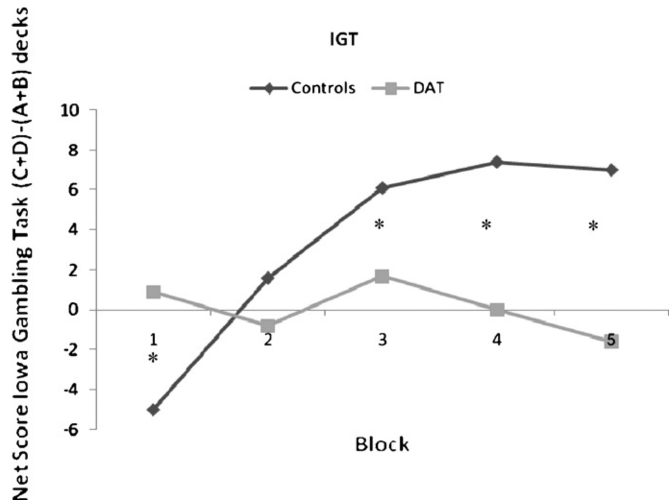


Fig. 1. Performance on the Iowa Gambling Task (IGT) as a function of group (DAT patients, healthy controls) and blocks (1–5). Each block (1–5) represents 20 sequential card selections. Net score is calculated by subtracting the number of disadvantageous deck selections (A + B) from the number of advantageous card selections (C + D). A negative net score indicates poor decision making. Significant group differences are depicted by an asterisk (*).

Table 2
Overall results of performance on the Iowa Gambling Task (IGT) and the Probability-Associated Gambling (PAG) task

| | *M* (S.D.) | | *t*-Test (*p*-value) |
|---|---|---|---|
| | DAT patients | Controls | |
| IGT | | | |
| Advantageous choices (C + D) (frequency) | | | |
| Total sum | 49.4 (4.4) | 58.5 (8.6) | 0.0001 |
| Block 1 | 9.5 (1.7) | 7.5 (2.4) | 0.005 |
| Block 2 | 9.6 (1.6) | 10.8 (2.3) | n.s. |
| Block 3 | 10.8 (1.9) | 13.0 (3.0) | 0.01 |
| Block 4 | 10.0 (1.9) | 13.7 (3.6) | 0.0001 |
| Block 5 | 9.2 (1.6) | 13.5 (4.3) | 0.0001 |
| Shifts between single decks (frequency) | | | |
| Total sum | 92.0 (10.6) | 59.0 (24.6) | 0.0001 |
| Block 1 | 19.6 (0.5) | 13.9 (5.0) | 0.0001 |
| Block 2 | 19.3 (1.2) | 12.9 (5.3) | 0.0001 |
| Block 3 | 17.8 (4.2) | 11.4 (6.0) | 0.001 |
| Block 4 | 18.5 (2.0) | 11.0 (5.6) | 0.0001 |
| Block 5 | 16.7 (4.0) | 9.8 (5.5) | 0.0001 |
| Shifts between good (C + D) and bad (A + B) decks (frequency) | | | |
| Total sum | 61.2 (9.4) | 35.7 (19.1) | 0.0001 |
| Block 1 | 13.4 (2.6) | 8.0 (4.4) | 0.0001 |
| Block 2 | 13.1 (1.9) | 8.6 (4.1) | 0.0001 |
| Block 3 | 11.5 (3.4) | 7.0 (5.0) | 0.003 |
| Block 4 | 12.4 (2.6) | 6.8 (4.8) | 0.0001 |
| Block 5 | 10.9 (3.8) | 5.3 (3.9) | 0.0001 |
| Net win (€) | 1834 (731) | 1967 (902) | n.s. |
| Final borrow (€) | 3059 (1029) | 2455 (858) | 0.053 |
| PAG | | | |
| Gambles (frequency)[a] | | | |
| $p = 0.125$ | 1.2 (1.0) | 0.3 (0.6) | 0.0001 |
| $p = 0.375$ | 1.6 (1.4) | 0.5 (0.8) | 0.004 |
| $p = 0.625$ | 3.2 (1.1) | 3.8 (1.1) | n.s. |
| $p = 0.875$ | 3.7 (1.3) | 4.7 (0.6) | 0.002 |

Legend: *M*, mean; S.D., standard deviation; n.s., not significant.
[a] Trials corresponding to different fix sums (+20, −20) are collapsed.

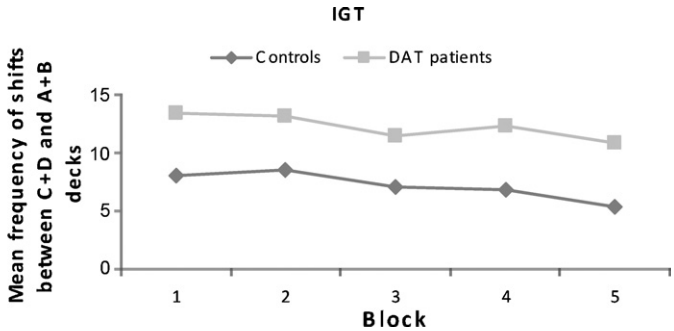


Fig. 2. Mean frequency of shifts between advantageous (C + D) and disadvantageous decks (A + B) in the Iowa Gambling Task (IGT) as a factor of group (DAT patients, healthy controls) and blocks (1–5). Each block (1–5) represents 20 sequential card selections. Overall, DAT patients shifted more frequently than healthy controls ($p < 0.0001$).

in general participants shifted more frequently between decks in block 1 and 2 than in blocks 3–5 ($t$-tests, all $p < 0.06$). No other relevant difference emerged. Similar results were found when the analysis was performed on the frequency of shifts between single decks A, B, C and D (Table 2).

### 3.2.3. *Correlations between IGT performance and executive tasks*

Correlation analyses were performed between the IGT (frequency of advantageous choices in block 5, frequency of advantageous choices over the task, frequency of shifts between advantageous and disadvantageous decks over the task) and neuropsychological background tests of executive functions for each group separately. Results for the patient group indicated that the overall frequency of shifts between advantageous and disadvantageous decks positively correlated with performance in the *inhibitory control* subtest of the FAB ($r = 0.555$, $p < 0.05$). In a blockwise analysis this correlation was found only in block 3 ($r = 0.610$, $p < 0.05$), but not in other blocks. Performance in block 5 (number of advantageous choices) positively correlated with the digit span forward (NAI, $r = 0.679$, $p < 0.01$), the total score of the FAB ($r = 0.534$, $p < 0.05$), and the *inhibitory control* subtest (FAB, $r = 0.610$, $p < 0.01$). No correlations were found between performance in executive tasks and the frequency of advantageous choices over the task. For healthy controls, a significant correlation was found between the overall frequency of shifts between advantageous and disadvantageous decks and number of errors in the OMO test ($r = 0.522$, $p < 0.05$).

## 3.3. *PAG task*

### 3.3.1. *Choices in the PAG*

In a first step, the frequency of gambles (trials in which participants choose to gamble 100 €) was analysed by means of a repeated-measures ANOVA with probability (low, high) as within-subjects factor and group (DAT patients, controls) as between-subjects factor. The mean frequency of gambles between trials with a winning probability of $p = 0.125$ and $p = 0.375$ was computed for the low probability condition. The mean frequency of gambles between trials with $p = 0.625$ and $p = 0.875$ winning probabilities was calculated for the high probability condition. There was a highly significant main effect of probability ($F[1,40] = 136.19$, MSE = 63.27, $p < 0.0001$) and a significant probability × group interaction ($F[1,40] = 14.14$, MSE = 6.57, $p < 0.001$). No significant main effect of group was found. DAT patients chose to gamble more often than controls in the low probability condition, whereas the reverse pattern was found for the high probability condition (see Fig. 3).

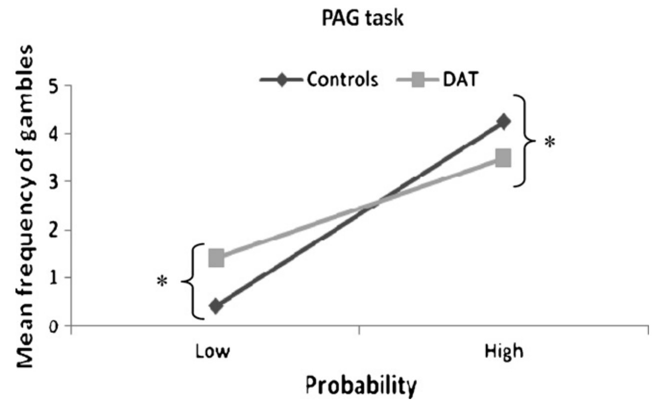


Fig. 3. Mean frequency of gambles in the Probability-Associated Gambling (PAG) task as a function of group (DAT patients, healthy controls) and probability (low, high). For the low probability, data of the conditions $p = 0.125$ and $p = 0.375$ are averaged together. For the high probability, data of the conditions $p = 0.625$ and $p = 0.875$ are considered together. Significant group differences are indicated by an asterisk (*).

In a second step, the frequency of gambles were analysed by means of a 4 (probability: $p = .125$, $p = .375$, $p = .625$, $p = .875$) × 2 (fix sum: −20, +20) × 2 (group: DAT patients, controls) repeated-measures ANOVA. Results demonstrated a highly significant main effect of probability ($F[3,120] = 107.38$, MSE = 87.12, $p < 0.0001$) and a significant probability × group interaction ($F[3,120] = 11.12$, MSE = 9.03, $p < 0.0001$; see Fig. 4). Other significant effects or interactions were not found. In the low probability conditions, DAT patients gambled more often than healthy participants (condition $p = 0.125$: $t[40] = -3,93$, $p < 0.01$; condition $p = 0.375$: $t[40] = -3.10$, $p < 0.01$). In contrast, they gambled less frequently in the highest winning probability condition (condition $p = 0.875$: $t[40] = 3.30$, $p < 0.01$; in the condition $p = 0.625$, differences were not significant; Table 2).

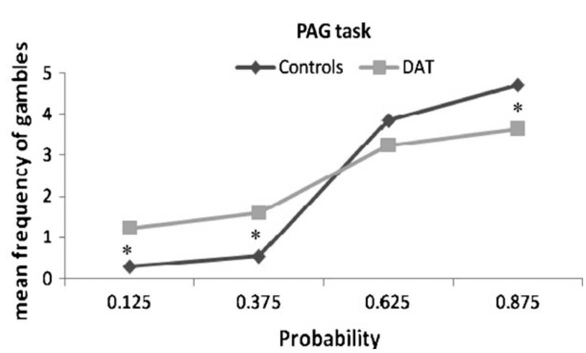


Fig. 4. Mean frequency of gambles in the Probability-Associated Gambling (PAG) task as a function of group (DAT patients, controls) and probability ($p = 0.125$, $p = 0.375$, $p = 0.625$, $p = 0.875$). Significant group differences are indicated by an asterisk (*).

### 3.3.2. Correlations between PAG performance and executive tasks

Pearson product-moment correlations between performance on the PAG task (frequency of gambles in the low and high probabilities conditions[2]) and neuropsychological background tests of executive functions were performed for each group separately. Patients' frequency of gambles in the low probability condition correlated inversely with performance in the *motor programming* subtest of the FAB ($r = -0.502$, $p < 0.05$). The frequency of gambles in the high probability condition positively correlated with the FAB total score ($r = 0.544$, $p < 0.05$) and the *motor programming* FAB subtest ($r = 0.594$, $p < 0.01$). No significant results were found for controls.

### 3.3.3. Correlations between performance on the gambling tasks and demographical variables (age, education, gender)

No significant correlations were found between decision-making performance on either the IGT or the PAG task and the demographical variables.

Furthermore, no significant correlations were detected between performance on the PAG task (frequency of gambles in the low and high probabilities conditions) and performance on the IGT (frequency of advantageous choices in block 5, frequency of advantageous choices over the task, frequency of shifts between advantageous and disadvantageous decks over the task).

## 4. Discussion

The present study investigated two types of decision making in mild DAT, decisions under ambiguity and decisions under risk. Both types of decisions are frequently encountered in everyday life. In cases of ambiguity, information on probability is missing or is conflicting and the expected utility of the different options is incalculable. In risky situations, outcomes can be predicted by well-defined or estimable probabilities. In the present study, a group of patients affected by mild DAT was assessed. Patients showed the typical cognitive profile of mild DAT. That means, compared to healthy individuals, patients had significantly lower scores on tests of verbal and figural memory, visuo-constructive abilities, object naming, mental calculation, and executive functions. No significant group differences were found in depression and anxiety scores.

Decision making under ambiguity was assessed by the IGT, decision making under risk with explicit rules and changing probabilities by the PAG task. Significant differences between mild DAT patients and healthy participants were found in the IGT. Overall, DAT patients selected the disadvantageous decks more frequently than controls. Regarding performance changes over the task, healthy participants showed a stronger tendency towards advantageous decks than DAT patients who chose significantly more cards from the disadvantageous decks in the later blocks. Moreover, mild DAT patients shifted more frequently between advantageous and disadvantageous decks as well as between decks in general. The number of advantageous choices in block 5 of the IGT correlated with the lower performance in the digit span forward and the FAB. Concerning the PAG task, mild DAT patients differed in their performance from healthy controls. DAT patients gambled more often in the low probability conditions and less frequently in the high winning probability conditions. Thus, their decisions were less advantageous than those of controls.

Decision making has gained increasing interest over the last years in neuropsychological as well as neuroimaging studies. Several brain imaging studies focused on single processing stages and variables in the decision process. Indeed, it has been suggested that the representation of values, the anticipation of gains and losses, the experience of gains and losses, the weighting of different options as well as the framing and editing of a situation is specifically supported by different brain structures (for a detailed review and discussion see Trepel, Fox, & Poldrack, 2005). Ventral and dorsal striatum, amygdala, VMPFC, cingulate cortex and dorsolateral prefrontal cortex are critically involved in the single processing steps. Few imaging studies specifically directed their attention on the processing differences between decisions under risk and decisions under ambiguity. Hsu et al. (2005) reported stronger activation in ambiguous situations relative to risk situations in the orbitofrontal cortex, the amygdala and the dorsomedial prefrontal cortex. Thus, areas more activated in the ambiguity condition overlap with regions critical for emotional processing and the integration of emotional and cognitive input (Hsu et al., 2005). The reverse contrast – stronger activation in the risk condition – yielded significant effects in the dorsal striatum. Dorsal striatal activations were also related to the expected value of the actual choices. Interestingly, time course of activation differed between amygdala and orbitofrontal cortex regions on the one side and the dorsal striatum region on the other side. Amygdala and orbitofrontal cortex were rapidly activated at the onset of the trial, while the dorsal striatum activity reacted more slowly and showed a later peak in activation than the amygdala (Hsu et al., 2005). Based on neuroimaging and lesion studies, Hsu et al. (2005) suggested a neural system for evaluating uncertainty. Under uncertainty the brain is alerted that information is missing, that choices carry unknown and potentially dangerous consequences, and that cognitive and behavioural resources must be mobilized in order to seek additional information (Hsu et al., 2005). A key role is attributed to the amygdala and the orbitofrontal cortex which receive rapid multi-sensory input and contribute in detecting salient and relevant stimuli from uncertain values. A recent study, however, emphasized different roles of the amygdala and the orbitofrontal cortex in taking choices. Lesions of the amygdala lead to greater impulsivity and decreased preference for large rewards when these were delayed (Winstanley, Theobald, Cardinal, & Robbins, 2004). This effect was not observed for orbitofrontal cortex lesions.

In the present study both types of decision making under uncertainty were assessed, decisions under risk (PAG) and decisions under ambiguity (IGT). As pointed out by neu-

[2] Low probability: $p = 0.125$ and $p = 0.375$ collapsed. High probability: $p = 0.625$ and $p = 0.875$ collapsed. Data were analysed without distinction between trials where the fix sum was +20 € and trials where the fix sum was −20 €.

ropsychological and neuroimaging studies, these two types of decisions put differential load on cognitive function and rely on different neural circuits. We will first discuss DAT patients' performance on the IGT, then performance on the PAG task. In the IGT, mild DAT patients proved to have difficulties in the processing of ambiguity, a finding which is consistent with the early DAT-related pathological changes in the basal forebrain (Braak & Braak, 1991), the degeneration of the ventromedial frontal cortex (Chu et al., 1997; Herholz, Salmon, Perani et al., 2002) and the degeneration of the amygdala (Hamann et al., 2002; Mori et al., 1999). As outlined above, major importance has been attributed to these structures in the processing of uncertainty in neuroimaging studies (Hsu et al., 2005). Damage to the amygdala has also been shown to alter decision making in previous neuropsychological studies (Bechara et al., 1999; Brand, Grabenhorst, et al., 2007). Brand, Grabenhorst, et al. (2007) reported that patients with selective amygdala damage show reduced performance in decisions under ambiguity (as measured by the IGT) as well as in decisions under risk (as measured by the GDT) replicating a finding by Bechara et al. (1999) who reported impaired decision making in a sample of five patients with amygdala damage.

However, several cognitive components may have contributed to DAT patients' difficulties in the IGT, including deficits in executive functions or in memory. As pointed out by Huettel, Stowe, Gordon, Warner, and Platt (2006), a key requirement for successful dealing with ambiguity is flexibility and rule induction, capacities linked to the dorsolateral prefrontal cortex. In the present study, DAT patients selected disadvantageous decks more often than controls and shifted more frequently between decks indicating that decisions in the IGT were taken randomly. Patients failed to establish an advantageous strategy and to develop a consistent response pattern over time. Difficulties in strategy development and set maintenance are typically associated with dysfunction of the dorsolateral prefrontal cortex and are found in mild-to-moderate stages of DAT (Lafleche & Albert, 1995; Perry & Hodges, 1999; Von Gunten, Bouras, Kovari, Giannakopoulos, & Hof, 2006). In the present study, we found no correlation between performance on the IGT and the OMO task where participants have to generate and maintain rules. A significant correlation was found between the number of advantageous choices in block 5 of the IGT and the FAB (total score and inhibitory control subtest). This result suggests that inhibition is involved in successfully performing the IGT. Furthermore, a significant correlation was found between block 5 of the IGT and the digit span forward. The correlation between working memory and performance on the IGT is in accordance with a study by Bechara et al. (1998, 2001). Indeed, representation of the different options in working memory may be crucial for successful decision making. The divergent findings in the literature regarding the role of executive functions in the IGT might be contingent on which scores are used in the analysis. Brand, Recknor, et al. (2007) demonstrated that in a large sample of healthy subjects, only the last blocks of trials were correlated with measures of executive functions. They concluded that, when the overall sum of advantageous decks is taken into account, correlations may be more moderate. It might be possible that figuring out the rules for gains and losses at the beginning of the task is primarily associated with reversal learning, because the disadvantageous decks offer high gains at the beginning of the task and participants have to learn that these decks are disadvantageous, leading to losses in the long run. As the task proceeds, when rules become more explicit and have to be followed, executive functions gain importance. Our findings are in line with this explanation, showing correlations between executive functions and IGT performance in the last block, but not over the whole task.

Further to executive deficits, memory decline may also have contributed to DAT patients' disadvantageous decisions and low response consistency. It may be suspected that in the IGT, DAT patients showed more rapid forgetting and therefore paid less attention to previous wins and losses than healthy participants. However, the relevance of explicit memory in the successful performance of the IGT has been controversially discussed. Some studies have claimed that access to explicit memory is not required for learning in the IGT. Typically, individuals show a trend towards advantageous responses before they consciously recognize which decks are the good ones (Bechara et al., 1998). Moreover, severely amnesic patients may show good performance and learning in the IGT (Turnbull & Evans, 2006). Different results have been reported by Gutbrod et al. (2006). In their study, amnesic patients showed severe deficits in the IGT. However, the amnesic group assessed by Gutbrod et al. (2006) included patients with lesions to the thalamus, the amygdala or the caudate nucleus. Thus, deficits in the IGT might be due to dysfunction of the limbic and striatal systems. The different outcomes of the studies may also be grounded in their experimental design. While in the Turnbull et al.'s study the feedback was provided immediately after the choice, in the study by Gutbrod et al. (2006) the feedback was given after a delay of 10 s. As Gutbrod et al. suggested, the different delay may critically influence the implicit learning of amnesic patients in the IGT. In the present study, each choice was followed by a feedback without any delay. Thus, impairments in explicit memory should not have interfered with DAT performance on the IGT.

As regards the PAG task, DAT patients proved to have difficulties in decisions under risk. Decisions under risk put stronger load on the dorsal striatum (Hsu et al., 2005) than decisions under ambiguity. The striatal system undergoes pathological changes in DAT and may account for deficient processing of risk, and of wins and losses expectations. Volume of the caudate nucleus was found to be proportionate to whole brain atrophy and to be reduced in DAT patients as compared to controls and patients with Parkinson's disease (Almeida et al., 2003). The PAG task requires participants to explicitly estimate probability. Estimation of probability involves drawing inferences, numerical processing and estimation of the presented quantities (e.g., number of red and blue cubes). Difficulties understanding proportions and mathematical relations are frequently found in patients with left parietal lesions (e.g., Delazer & Benke, 1997) and in neurodegenerative diseases affecting parietal structures (Delazer, Karner, Zamarian, Donnemiller, & Benke, 2006). DAT has been found to affect various numerical skills such as counting processes (Delazer, Karner, Proell, & Benke, 2006; Seron et al., 1991), transcoding from one numerical code to another (Kessler & Kalbe, 1996; Tegner & Nyback, 1990), simple and complex calculation, calculation procedures (Carlomagno et al., 1999; Deloche et al., 1995; Mantovan, Delazer, Ermani, & Denes, 1999), as well as every-day numerical skills (Martini, Domahs, Benke, & Delazer, 2003; Zamarian et al., 2007). Recent studies have found impaired cognitive estimation in patients affected by DAT (Brand, Kalbe, Fujiwara, Huber, & Markowitsch, 2003; Della Sala, MacPherson, Phillips, Sacco, & Spinnler, 2004; Levinoff et al., 2006) and by Korsakoff syndrome (Brand, Fujiwara, et al., 2003). Thus, reduced estimation abilities may have contributed to DAT patients' difficulties in the PAG task. The PAG task correlated with only one executive task in the patient group. Performance on the motor programming subtest of the FAB was associated inversely with the frequency of gambles in the low probability conditions but positively with the frequency of gambles in the high probability conditions. That means, advantageous behaviour – different for low and high probability – correlated with the FAB subtest. The inverse correlation between gambling frequency and FAB subtest in the low probability condition may indicate that a lack of inhibition and control leads to disadvantageous gambling in this condition in DAT patients.

In the present study 80% of the DAT patients and control subjects were females. Thus, results may be biased by gender effects. Indeed, some studies reported that men perform better than women on the IGT (Bolla, Eldreth, Matochik, & Cadet, 2004; Overman, 2004), while the opposite effect has been found in children (Garon & Moore, 2004). Contrarily, a number of recent studies did not find gender effects in healthy old adults (Denburg et al., 2005; Fein, McGillivray & Finn, 2007; Zamarian, Sinz, Bonatti, Gamboz, & Delazer, submitted for publication). Consistent with these findings, in our sample no significant correlations between decision-making performance and gender were detected.

In conclusion, the present study is, to the best of our knowledge, the first one assessing decisions under risk and decisions under ambiguity in mild DAT patients. Deficits were found in both domains as compared to healthy controls. In decisions under risk, DAT patients showed difficulties in accurately estimating different winning probabilities and adapting to different decision-making situations. Performance was neither characterized by a too risky response style as observed in other patient groups (for example, Korsakoff or Parkinson patients; Brand et al., 2004; Brand, Fujiwara, et al., 2005), nor by too conservative behaviour. In decisions under ambiguity, DAT patients compared to controls chose significantly more cards from the disadvantageous decks and failed to develop an advantageous response pattern over the task, indicating an inability to identify rules and establish advantageous strategies. These results might contribute to a better understanding of the difficulties experienced by patients in a mild stage of DAT. Despite their cognitive impairment, DAT patients have to face important and complex decisions. Every-day decisions under risk, for example evaluating the benefits and side effects of medical treatments or considering the advantages and costs of health insurance, may be problematic for this patient group. Problems seem to be even more pronounced when decisions have to be taken under ambiguity. DAT patients aware of their cognitive decline have to face decisions under extreme ambiguity. Since progress of the disease and impact on daily living is difficult to predict, DAT patients continuously have to take decisions where information is missing. These decisions regard, for example, consulting a memory clinic, accepting medical treatment, arranging the housing situation and financial issues. Decisions under ambiguity are not easy for elderly people when precise information is missing or when conflicting evidence has to be processed. As suggested by the present investigation, these complications may be more pronounced in mild DAT patients who continuously have to take decisions in an ambiguous and uncertain living situation.

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