

# A multidimensional approach to impulsivity changes in mild Alzheimer's disease and control participants: Cognitive correlates

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**Introduction:** Impulsive behaviors are frequently described in brain-damaged patients, including patients with Alzheimer's disease (AD). However, few studies have examined impulsivity changes and associated cognitive impairments in AD and healthy controls. Consequently, the first aim of this study was to compare patients with mild AD and matched controls on four dimensions of impulsivity (urgency, lack of premeditation, lack of perseverance, and sensation seeking) recently highlighted in the literature. The second objective was to examine the association between impulsivity changes and cognitive performances on executive/attentional tasks in mild AD and healthy controls.

**Methods:** Thirty patients with mild AD and 30 matched controls were administered a battery of tests that assessed executive and attention processes. In addition, informants of each patient and control completed a short questionnaire designed to assess the changes on the four dimensions of impulsivity (Rochat et al., 2008).

**Results:** Patients with mild AD had higher scores than controls on lack of premeditation and lack of perseverance dimensions of impulsivity, whereas the two groups did not differ on urgency and sensation seeking. Furthermore, patients showed significant decreased performances on measures of inhibition of prepotent responses, set-shifting, and working memory, as well as higher variability of reaction times (RTs) than matched controls. Regression analyses computed on the whole sample emphasized that difficulties in inhibition of prepotent responses significantly predicted higher lack of premeditation, and larger variability of RTs and set-shifting difficulties significantly predicted higher lack of perseverance, even when global cognitive functioning, general processing speed, working memory, and age were controlled for. Urgency and sensation seeking were not associated with any variables.

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**Conclusions:** These results provide valuable insight into the nature of brain systems and cognitive processes underlying impulsive behaviors. In addition, they open up interesting prospects for better comprehension of behavioral and psychological symptoms of AD.

## 1. Introduction

Impulsive behaviors are common in brain-damaged patients, including those with neurodegenerative diseases such as Alzheimer's disease (AD; Holmes et al., 1993). Indeed, recent factor analyses conducted on the Neuropsychiatric Inventory (Cummings et al., 1994) collected from a large sample of AD patients have all identified factors called "behavioural dyscontrol" (Hollingsworth et al., 2006), "hyperactivity" (Aalten et al., 2007), or "psychomotor syndrome" (Spalletta et al., 2010) that globally encompass the same symptoms (e.g., agitation, irritability, aggressivity, disinhibition, euphoria, appetite disturbances, aberrant motor behaviors). These symptoms are frequently described even in the early phase of the disease and explain a substantial part of variance of the total behavioral and psychological symptoms of dementia. Furthermore, several studies described decision making impairments in these patients (e.g., Delazer et al., 2007), which may lead them to become victims of fraud or deceptive advertisements. We thus assume that a multidimensional approach to impulsivity as defined in the UPPS Impulsive Behavior scale (UPPS; Whiteside and Lynam, 2001) might open up interesting prospects for better comprehension of these behavioral and psychological symptoms. To our knowledge, few studies have examined impulsivity changes in AD and healthy controls, at least from a multidimensional perspective, and the cognitive impairments associated with impulsivity changes in AD and healthy controls remain poorly understood.

Some authors have underscored the need to consider impulsivity as a multifaceted construct (e.g., Evenden, 1999). From this perspective, Whiteside and Lynam (2001) administered several widely used measures of impulsivity and the Revised NEO Personality Inventory (NEO-PI-R; Costa and McCrae, 1992) to a large sample of undergraduate students. Whiteside and Lynam's (2001) central argument is that although some impulsivity traits result in similar overt behaviors (i.e., acting without forethought), their etiologies may be heterogeneous. A factor analysis conducted on these questionnaires resulted in a four-factor solution, which was the basis for the creation of the UPPS. The four dimensions of impulsivity measured by the UPPS were labeled urgency ("the tendency to experience strong reactions, frequently under conditions of negative affect"); (lack of) premeditation ("the tendency to think and reflect on the consequences of an act before engaging in that act"); (lack of) perseverance ("the ability to remain focused on a task that may be boring or difficult"); and sensation seeking ("the tendency to enjoy and pursue activities that are exciting and openness to trying new experiences"). In addition, each of the four factors of impulsivity strongly correlated with a specific factor of the NEO-PI-R. Indeed, urgency was related to the impulsivity facet of neuroticism, lack of premeditation and lack of perseverance to low

scores on two facets of conscientiousness (deliberation and self-discipline, respectively), and sensation seeking to the excitement-seeking facet of extraversion (Whiteside and Lynam, 2001).

Many studies using this multidimensional conception of impulsivity have stressed relationships between the four dimensions of impulsivity and several psychopathological states and problematic behaviors. More specifically, urgency has been related to borderline personality disorders (e.g., Whiteside and Lynam, 2003), tobacco craving (Billieux et al., 2007), compulsive buying (Billieux et al., 2008a), bulimia nervosa (e.g., Claes et al., 2005), alcohol and drug abuse (e.g., Anestis et al., 2007; Verdejo-García et al., 2007), problem gambling (e.g., Smith et al., 2007), and obsessive-compulsive symptoms (Zermatten and Van der Linden, 2008). Lack of premeditation has been closely related to anti-social personality and psychopathic features (Miller et al., 2003; Whiteside and Lynam, 2003; Whiteside et al., 2005), as well as to problem gambling (Smith et al., 2007), bulimia (Smith et al., 2007), substance use, and risky sex (Miller et al., 2003). Lack of perseverance may represent an important dimension of predominantly inattentive subtypes of attention-deficit hyperactivity disorder (Miller et al., 2003; Whiteside and Lynam, 2001). Finally, sensation seeking has been associated with delinquent acts, drug and alcohol use, and risky sexual behaviors (Miller et al., 2003). Sustaining the validity of the UPPS model, several studies have demonstrated that the various impulsivity facets are differentially involved in problematic behaviors. For instance, sensation seeking has been related to the frequency of engaging in risky behaviors (e.g., gambling frequency and drinking quantity/frequency), whereas urgency and lack of premeditation have been specifically associated with problematic levels of engagement in those behaviors (e.g., adverse consequences resulting from gambling such as financial problems, chasing behaviors; Smith et al., 2007).

A further step toward a better understanding of impulsive behaviors was to examine the psychological mechanisms underlying each of these dimensions of impulsivity. It has been suggested that three dimensions of impulsivity (urgency, lack of premeditation, lack of perseverance) relate to self-control abilities (such as inhibition processes and decision making), whereas sensation seeking might be associated with motivational processes (Bechara and Van der Linden, 2005; Billieux et al., 2008b; Van der Linden et al., 2006). More specifically, several studies conducted on healthy young adults from the community emphasized that urgency was associated with difficulties in inhibition of prepotent response (Gay et al., 2008) or with a combination of difficulties to inhibit prepotent responses in emotional contexts and decision making under risky conditions (Billieux et al., 2010). These studies also indicated that lack of perseverance was associated with difficulties

in resisting proactive interference in working memory (WM) (Gay et al., 2008, 2010) and that lack of premeditation was associated with poor decision making (Zermatten et al., 2005).

Recently, the four-factor structure of a short version of the UPPS Impulsive Behavior scale, specifically designed to assess impulsivity changes occurring in the course of neurodegenerative diseases, was supported by exploratory and confirmatory factor analysis in a sample of 82 patients with AD (Rochat et al., 2008). More specifically, a significant increase in urgency, lack of premeditation, and lack of perseverance was noted, whereas a decrease in sensation seeking was observed in these patients (Rochat et al., 2008). Furthermore, this increase of impulsivity on urgency, lack of premeditation, and lack of perseverance was not associated with global cognitive impairment as assessed by the Mini Mental State Examination (MMSE; Folstein et al., 1975) or the Mattis Dementia Rating scale (Mattis, 1976), whereas lower sensation seeking was associated with a lower score on the MMSE (see Rochat et al., 2008). This multidimensional aspect of impulsivity has also been recently confirmed with a similar short form of the UPPS in a sample of 82 patients with moderate-to-severe traumatic brain injury (Rochat et al., 2010). On the whole, by emphasizing the need to consider four distinct impulsivity-related traits instead of a unique trait, these results open up interesting prospects for better comprehension and assessment of impulsive-related disorders frequently described in persons with brain damage.

In addition, the changes observed in patients with AD on the urgency, lack of perseverance, and lack of premeditation subscales of the UPPS are congruent with studies showing that executive and attentional impairments are frequently observed in AD, even in the early phase of the disease (e.g., Collette and Van der Linden, 2004). Indeed, numerous studies have demonstrated that AD patients showed deficits in inhibition and interference resolution (e.g., Amieva et al., 2004; Collette et al., 2009), task switching (e.g., Belleville et al., 2008), and central executive of the WM (e.g., Collette et al., 1999). In this context, and in line with Gay et al. (2008), we might expect that participants with difficulties in inhibition of prepotent responses have more changes on the urgency dimension of impulsivity. In addition, the difficulties that patients with AD experience in performing complex tasks might result from shifting impairments. Indeed, set-shifting is required when individuals need to shift attention or response patterns based on different rules. We might thus expect set-shifting difficulties to be specifically associated with lack of perseverance because switching impairments lead to stereotyped or invariable responses, which may ultimately preclude the achievement of boring and/or complex tasks.

Another cognitive process that might be relevant to better comprehension of impulsivity is sustained attention. More specifically, numerous studies suggest that variability of reaction times (RTs) provides a valuable index of periodic lapses of attention that result from difficulties in maintaining or sustaining attention on task goals due to executive dysfunction (e.g., Bellgrove et al., 2005; Johnson et al., 2007; Stuss et al., 2003; Unsworth et al., 2010). In particular, there is evidence for changes in variability of RTs in very mild (Clinical Dementia Rating scale of .5) AD (e.g., Duchek et al., 2009). Tse et al. (2010) also demonstrated that higher neuroticism and lower conscientiousness in patients with AD were associated with an

increased variability of RTs. According to these authors, low conscientiousness might lead to difficulties in remaining focused on a task and thus the goals of the task need to be reactivated more frequently, whereas neuroticism might be associated with difficulties in inhibiting irrelevant information (e.g., negative thoughts about one's own performances), in both cases resulting in an increase of RTs (Tse et al., 2010). Thus, we expected that the neuroticism-related dimension of impulsivity, namely, urgency, as well as the conscientiousness-related dimensions of impulsivity, namely, lack of premeditation and lack of perseverance, relate to higher variability of RTs.

To the best of our knowledge, no studies have examined impulsivity changes from a multidimensional perspective and their associated cognitive impairments in patients with AD and in healthy controls. Consequently, the objectives of the current study are twofold. First, we aimed to compare impulsivity changes on the short form of the UPPS Impulsive Behavior scale (informants' version) between patients with mild AD and matched control participants. Because mild AD is frequently characterized by marked executive/attentional impairments, it is hypothesized that patients should demonstrate higher urgency, lack of premeditation, and lack of perseverance than matched controls. Second, we aimed to examine the cognitive mechanisms underlying impulsivity changes in both patients and controls. To this end, we used a Go/NoGo paradigm, the Sustained Attention to Response Task (SART; Robertson et al., 1997), in which the participant must withhold a response to an infrequent target. The SART was chosen because (1) it provides a valid measure of everyday attentional failures (Robertson et al., 1997), and (2) it has a sustained attention component required to maintain task set during the intertarget intervals, as well as a response inhibition component required to suppress inappropriate response tendencies (O'Connell et al., 2009). Furthermore, the Trail Making Test part B (TMT B; Reitan and Wolfson, 1985) was used to assess set-shifting abilities. Several previous studies have demonstrated that performances on the TMT B are impaired in the very early stages of AD (e.g., Lonie et al., 2009; Stokholm et al., 2006). Thus, we more specifically hypothesized that (1) urgency relates to difficulties in inhibition of prepotent responses in the SART, thus corroborating previous studies conducted in healthy young adults from the community (Gay et al., 2008); (2) lack of perseverance relates to set-shifting difficulties in the TMT B; and (3) the dimensions of impulsivity associated with neuroticism and low conscientiousness, that is, lack of premeditation and lack of perseverance, as well as urgency, should relate to sustained attention difficulties that result in higher variability of RTs in the SART (see Tse et al., 2010). Finally, to control for individual differences in global WM and global cognitive functioning, we used the Letter–Number Sequencing Task (WAIS III; Wechsler, 1997) and the MMSE (Folstein et al., 1975).

## 2. Methods

### 2.1. Participants

A total of 60 participants took part in the study. Thirty nonconsecutive patients were recruited in the Geneva Memory Clinic and the Neuropsychology Unit, both at the University

Hospital of Geneva, Switzerland. All the patients met the National Institute of Neurological and Communicative Diseases and Stroke/Alzheimer's Disease and Related Disorders Association criteria for probable AD (McKhann et al., 1984) on the basis of a detailed medical, neurological, and neuropsychological examination, and all were at the early stage of the disease (Clinical Dementia Rating scale, stage 1; see Hughes et al., 1982). The patients' ages ranged from 60 to 81 years [ $M = 72.03$ , (standard deviation – SD) = 5.90] and their years of education from 8 to 16 ( $M = 13.01$ , SD = 1.95). The control group consisted of 30 participants with a mean age of 72.05 (SD = 7.50) and years of schooling of 12.60 (SD = 2.77). Control participants were recruited from the general population and were matched for age, gender, and years of schooling with the patients. The control group had no neurological or psychiatric history. In both groups, overall cognitive functioning was assessed with the MMSE (Folstein et al., 1975). Only participants for whom a close relative (e.g., a spouse or adult children) could complete the informants' version of a questionnaire assessing impulsivity changes were included in the study. All participants and relatives spoke French fluently. All subjects gave their written consent to participate, and the study was approved by the ethics committee of the University Hospital of Geneva.

## 2.2. Impulsivity measure

To assess the multidimensional construct of impulsivity, we used a short version of the UPPS Impulsive Behavior scale, containing 16 items (4 per factor; Rochat et al., 2008). The informants' version of this scale, recently validated on a sample of 82 AD patients by using exploratory and confirmatory factor analyses (Rochat et al., 2008), assesses impulsivity changes that might occur on the four components of impulsivity (urgency, lack of premeditation, lack of perseverance, and sensation seeking) in the course of a neurodegenerative disease. Each informant had to assess impulsivity changes on a 5-point Likert scale (from –2 "much less than 10 years ago" to +2 "much more than 10 years ago"). The total score ranges from –8 to +8 on each subscale. Thus, a positive score indicates an increase of impulsivity, a negative score indicates a decrease of impulsivity, and a score of 0 indicates no changes compared with 10 years ago. In the validation study, the reliability score of each of the four factors was acceptable to very good (Cronbach's alpha from .75 to .95; Rochat et al., 2008).

## 2.3. Cognitive measures

### 2.3.1. SART (adapted from Gay et al., 2008; Robertson et al., 1997)

This Go/NoGo task involves withholding a key press in response to a rare target (the digit "3" among all digits). Participants were required to respond, as fast and as accurately as possible, with a response button to all digits except the 3. Digits were presented for 900 msec and then replaced by a duration mask (composed of an "X" presented within a ring) for 1000 msec. Digits and mask were white and appeared against a black background. A practice block of 18 digits (including two targets) was performed before the participants began the real task in which 234 digits were presented. During the practice phase, participants received immediate feedback when making

a mistake. During the real task, each digit appeared 26 times (which makes the target number 3 a low-probability target of 1/9 or 11%) in a quasi-random order and in one of five randomly allocated digit sizes. Three dependent variables were computed: the number of commission errors (false alarms) as a measure of inhibition of prepotent responses; the mean of RTs for correct responses as a measure of processing speed; and a coefficient of variation (CoV; see Duchek et al., 2009) of RTs computed by dividing the SD by the mean of RTs as a measure of sustained attention. This coefficient has been chosen instead of SD because means and SDs are highly correlated (e.g., Faust et al., 1999). Consequently, measures of intraindividual variability need to take into account overall differences in mean performance. In addition, the CoV appears to be a sensitive marker for early AD (Duchek et al., 2009).

### 2.3.2. TMT (Reitan and Wolfson, 1985)

The TMT consists of two parts. Part A requires tracing a line that links numbers in ascending order, while part B requires participants to connect numbers and letters alternately in their respective sequence. Completion time for part A and B was taken into account.

### 2.3.3. Letter–Number Sequencing Task

(WAIS III; Wechsler, 1997)

In this task, designed to assess verbal WM (both retention and manipulation of information), participants heard lists of numbers and letters mixed in random order and presented in increasing length, from two to eight units. Participants were first asked to repeat the numbers from each list, starting with the lowest to the highest, and then to repeat the letters in alphabetical order. The dependant variable was the number of correctly repeated sequences. An elevated score indicated better verbal WM performance.

## 2.4. Data analyses

Data analyses were performed at two levels. First, analyses of variance (ANOVAs) were performed in order to compare impulsivity changes on the four dimensions of impulsivity in patients versus controls. We also used a 95% confidence interval (CI) to determine whether impulsivity changes observed on each facet of impulsivity significantly differ from 0 within each group of participants. In addition, t-tests for independent samples were used to compare the two groups on the various executive/attentional measures. Finally, Pearson's correlations were used to evaluate the relationships between variables within each group. Note that nonparametric analyses (Mann–Whitney U and Spearman Rank-order correlation) were used when assumptions for using parametric tests were violated and/or when exploratory analyses identified outliers. Second, beyond the usual approach of considering AD as a discrete category that is qualitatively distinct from normal aging, we also considered AD as part of the upper end of a continuum that differs only quantitatively (but not qualitatively) from normal aging. Indeed, a recent study conducted on more than 10,000 participants with or without dementia recently demonstrated, by using taxometrics and latent mode factor analysis on a wide range of cognitive tasks (including the TMT B for assessing executive functioning), that dementia refers to a dimensional (lying along

a continuum) rather than a categorical (representing a distinct entity) construct (Walters, 2010). Therefore, it appears that differences between patients with dementia and older adults without dementia on cognitive tasks are quantitative (continuum) rather than qualitative (distinct entity; Walters, 2010; see also Collette et al., 2009). Thus, beyond group comparisons or within groups analyses, we also performed correlation analyses and multiple linear regression analyses on the whole sample to find out which cognitive processes best predict changes on the various dimensions of impulsivity. All analyses were two-tailed, with an alpha level set at .05.

### 3. Results

#### 3.1. Sample characteristics

A series of t-tests for independent samples revealed that the two groups did not differ significantly either in age,  $t(58) = 1.02$ ,  $p = .31$ , or in education,  $t(58) = .81$ ,  $p = .42$ , whereas they did differ on the MMSE,  $t(58) = -7.00$ ,  $p < .0001$ , indicating that the controls ( $M = 27.87$ ;  $SD = 1.61$ ) had better global cognitive functioning than the patients ( $M = 23.27$ ;  $SD = 3.24$ ).

#### 3.2. Internal reliabilities

The Cronbach's alphas ranged from .71 to .91 (Table 1) and indicated that all four subscales have acceptable to very good internal reliability, whether for participants in the clinical group or for those in the control group.

#### 3.3. Group comparisons

ANOVA performed to examine differences on the four dimensions of impulsivity showed a significant group effect,  $F(4,55) = 2.98$ ,  $p < .05$ ,  $\eta_p^2 = .18$ . Tukey's honestly significant difference (HSD) post hoc tests indicated that patients had significantly higher changes on lack of premeditation ( $p < .01$ ) and on lack of perseverance ( $p < .01$ ) than did controls, whereas the two groups did not differ on urgency ( $p = .35$ ) or sensation-seeking change scores ( $p = .65$ ) (Table 1 for the raw scores). The 95% CI described in Table 1 indicated (1) a significant increase on urgency and lack of perseverance for patients, whereas the increase observed for lack of premeditation did not differ from 0; (2) a significant increase on lack of perseverance and a significant decrease of lack of premeditation for controls, whereas the increase observed for urgency did not significantly differ from 0; and (3) a significant decrease of sensation seeking for both groups.

Because the assumption of homogeneity of variance was violated for some variables (Levene's test  $p < .05$ ), Mann-Whitney U tests were used to compare group performances on the RTs of the Go/NoGo task, the TMT part A and B completion time, and the CoV of RTs in the Go/NoGo task. The t-tests for independent samples were used for the other variables. Results of the group comparisons (Table 2) indicated that the groups significantly differ on the Letter-Number Sequencing Task, the TMT part B completion time, and on both the number of false alarms and the CoV of the RTs of the Go/NoGo task. These results showed that patients have more

difficulties than control participants on these tasks assessing executive functioning, as well as a higher variability of RTs in the Go/NoGo task. However, the groups did not significantly differ on global processing speed in the Go/NoGo task and in the TMT part A.

#### 3.4. Correlation analyses

Table 3 describes the correlations obtained between the cognitive measures and the four dimensions of impulsivity. Note that partial correlations were conducted to examine the relationships between TMT part B completion time and impulsivity factors while controlling for TMT part A completion time. For AD patients, lack of perseverance is positively associated with a larger variation of RTs in the Go/NoGo task. A positive trend was also found between lack of perseverance and set-shifting difficulties in the TMT part B, whereas a negative trend was found between this dimension of impulsivity and WM performances. In addition, lack of premeditation positively and significantly correlates with the numbers of false alarms and with a larger variation of RTs in the Go/NoGo task. Sensation seeking and urgency did not significantly correlate with any variables. For controls, except for a positive relationship between the TMT part B and lack of perseverance, no other correlations reached statistical significance. For the whole sample, lack of perseverance was negatively associated with MMSE and WM and positively related to variability of RTs and performances on the TMT part B; lack of premeditation was positively associated with number of false alarms in the Go/NoGo task and performances on the TMT part B and negatively associated with WM performances. No other correlations reached statistical significance.<sup>1</sup>

#### 3.5. Regression analyses

In line with a dimensional approach to dementia (Walters, 2010), the regression analyses were performed on the whole

<sup>1</sup> Following a referee's suggestion, we have further analyzed the variability of RTs in the Go/NoGo task by fitting subjects' correct RT distribution into an ex-Gaussian distribution using the quantile maximum likelihood estimation procedure in QMPE 2.18 (e.g., Cousineau et al., 2004) as Tse et al. (2010) did. In particular, we have examined whether the tail of the distribution of RTs (as indicated by the tau parameter in ex-Gaussian fit) might be more sensitive to the impulsivity measures than the CoV or false alarm measure. Analysis of variance shows that there was no significant difference between the groups for the three ex-Gaussian parameters ( $\mu$ ,  $\sigma$ ,  $\tau$ ),  $F(3, 56) = 1.21$ ,  $p = .32$ ,  $\eta_p^2 = .06$ . In addition, the tau parameter did not significantly correlate with any dimensions of impulsivity (urgency:  $r = -.04$ ,  $p = .78$ ; lack of premeditation:  $r = .16$ ,  $p = .23$ ; lack of perseverance:  $r = -.12$ ,  $p = .35$ ; sensation seeking:  $r = .12$ ,  $p = .35$ ). Thus, contrary to the results of Tse et al. (2010), our results failed to show a significant difference on the tau parameter between AD patients and controls. In addition, the tau parameter is less sensitive to the dimensions of impulsivity than CoV or false alarms in the SART task. Although unexpected at first sight, this result might be explained by the nature of the cognitive task used in the current study versus those used by Tse et al. (2010). Indeed, Go trials in the SART task are quite similar to a simple RT task, which is much easier than the Stroop task, the Simon task, and the switching task used by Tse et al. (2010), because these tasks probably tap the attentional control system to a higher degree.

**Table 1 – Means (SDs) and 95% CI of impulsivity change scores for AD and control participants.**

Factor	Patients			Controls		
	M (SD)	95% CI	$\alpha$	M (SD)	95% CI	$\alpha$
Urgency	1.67 (2.41)	.77, 2.57 <sup>a</sup>	.75	.93 (3.54)	-.39, 2.26	.91
Lack of premeditation	1.03 (3.70)	-.34, 2.41	.80	-1.23 (2.71)	-.24, -.22 <sup>a</sup>	.81
Lack of perseverance	2.93 (2.92)	1.84, 4.03 <sup>a</sup>	.86	1.00 (2.30)	.14, 1.86 <sup>a</sup>	.84
Sensation seeking	-2.93 (2.76)	-3.96, -1.91 <sup>a</sup>	.71	-2.77 (2.43)	-3.67, -1.85 <sup>a</sup>	.70

a Note. The absence of 0 in the CI indicates that the observed changes are significantly different from 0.

sample of participants in order to examine the specific contribution of executive/attentional processes in the various dimensions of impulsivity while controlling for age, WM performances, general processing speed, and global cognitive functioning. Consequently, multiple linear regression analyses were performed with each dimension of impulsivity as the criterion and with the MMSE, WM, number of false alarms in the Go/NoGo task, TMT part A, TMT part B, and Go/NoGo CoV as independent variables. In particular, the TMT part A was included as a predictor in order to control for general processing speed. However, when performing the regression analyses with the TMT part A and B, particular attention was paid to signs of multicollinearity because of the strong correlation between these two variables ( $\rho = .60$ ,  $p < .01$ ). Thus, to control for the presence of multicollinearity, we used the variance inflation factor (VIF), which shows how much the variance of the coefficient estimate is being inflated by multicollinearity, and the tolerance score. According to Allison (1999), VIF values over 2.5 and tolerance below .40 are considered problematic for multicollinearity. In our case, the VIF was 2.97 and the tolerance amounted to .33 for the TMT part B when the dimensions of impulsivity were included as the criterion. These indices are quite problematic according to Allison's criteria, and even mean centering the variables did not reduce multicollinearity. Consequently, as multicollinearity might here be explained by the strong correlation between the TMT part A and part B, we chose to remove the TMT part A from the analyses. However, to take into account general processing speed, we included a measure other than the TMT part A in the multiple linear regression models, that is, the mean of RTs on the Go trials in the Go/NoGo task. Consequently, new multiple linear regression analyses were performed with the mean of RTs on the Go

trials as a predictor. Note that RTs were transformed by using natural logarithm to decrease the skewness of their distribution. Individuals with residuals greater than three SDs were examined as possible outliers. In addition, multivariate outliers were examined by using Mahalanobis distance. One case was identified as a multivariate outlier (Mahalanobis distances between 21.73 and 34.86) and was removed from the data set. Results revealed that lack of premeditation was significantly predicted only by the number of false alarms in the Go/NoGo task [ $\beta = .44$ ;  $t(51) = 2.48$ ;  $p < .05$ ],  $F(7, 51) = 3.22$ ,  $p < .01$ ,  $adjR^2 = .21$ . In addition, lack of perseverance was significantly predicted by both the TMT part B completion time [ $\beta = .45$ ;  $t(51) = 2.66$ ;  $p < .05$ ] and the Go/NoGo CoV [ $\beta = .39$ ,  $t(51) = 2.57$ ;  $p < .05$ ],  $F(7, 51) = 3.94$ ,  $p < .01$ ,  $adjR^2 = .26$ . Note that exploration of the residuals suggested that they were normally distributed and that no multicollinearity was emphasized (all VIF  $< 2.50$  and tolerance indices  $> .40$ ). Urgency and sensation seeking were not significantly associated with any variables, although a trend was found between urgency and the variability of RTs in the Go/NoGo task [ $\beta = .34$ ;  $t(51) = 1.90$ ;  $p = .06$ ].

Finally, another argument confirmed that executive impairments are specifically associated with impulsivity, even when global cognitive processing (including processing speed) is controlled for. Indeed, to examine whether the link between lack of perseverance and the TMT part B is mainly due to the switching component of the TMT part B, and not to other general cognitive processing also involved in the TMT part A (processing speed, visuoperceptual abilities), we computed a new regression with the TMT part B-A completion time (instead of the TMT part B). Although questionable because of the low reliability of difference scores, the TMT B-A minimizes visuoperceptual and WM demands, providing a relatively pure

**Table 2 – Means, SDs, and results of group comparisons on the executive measures for patients and control participants (t-tests for independent sample or Mann-Whitney U).**

Measure	Patients		Controls	t/Z	$p$
	M (SD)				
Go/no-go false alarms	5.13 (3.81)		2.40 (2.11)	3.44	<.01
Go/no-go RTs	486.10 (86.04)		488.26 (49.16)	Z = -.67	.50
Go/no-go CoV	.23 (.05)		.20 (.04)	Z = 2.23	<.05
TMT part A (completion time)	60.70 (35.98)		43.90 (10.47)	Z = 1.74	.08
TMT part B (completion time)	245.63 (135.42)		110.33 (44.49)	Z = 4.10	<.0001
Letter-Number Sequencing Task	6.31 (2.19)		9.10 (1.88)	-5.25	<.0001

Note. Two-tailed test.

**Table 3 – Correlation analyses for patients with mild AD, healthy controls, and the whole sample.**

Variable	Group	Urgency	Lack of premeditation	Lack of perseverance	Sensation seeking
Age	AD	.10	.09	.24	.25
	Controls	.07	-.18	-.14	-.15
	Both	.10	.01	.09	.08
Years of schooling	AD	.15	.06	.24	-.28
	Controls	.01	.04	.09	.08
	Both	.07	.08	.18	-.20
MMSE	AD	-.19	-.00	-.16	-.06
	Controls	-.06	.22	-.11	.22
	Both	-.17	-.19	-.34**	.04
Go/NoGo false alarms	AD	.22	.38*	.04	-.26
	Controls	.00	.09	.24	-.19
	Both	.15	.39**	.23	-.22
Go/NoGo RT total	AD	-.25	.00	.29	.09
	Controls	.06	-.22	-.19	-.03
	Both	-.08	-.07	.06	.04
Go/NoGo CoV	AD	.26	.55**	.44*	-.11
	Controls	.26	-.21	.28	-.18
	Both	.28	.28	.44**	-.14
TMT part B	AD	-.12	.03	.40°	-.25
	Controls	.37	.37	.57**	-.23
	Both	.29	.44*	.54*	-.40°
Letter–Number Sequence	AD	-.03	-.15	-.35°	-.19
	Controls	-.14	-.17	.07	.31
	Both	-.14	-.31*	-.34*	.06

Note. \*\* $p < .01$ ; \* $p < .05$ ; ° $p < .10$ . Spearman Rank-order correlation was used for correlations with Go/NoGo CoV, total RTs, and TMT part B. For all other variables, zero-order correlation (Pearson's  $r$ ) was used. Note that partial correlations were used for TMT part B and impulsivity factors, with the TMT part A score being partialled out. MMSE = Mini Mental State Examination.

indicator of task-switching ability (Sanchez-Cubillo et al., 2009). The results confirmed that lack of perseverance was still significantly predicted by both the TMT part B-A [ $\beta = .38$ ;  $t(51) = 2.33$ ;  $p < .05$ ] and the Go/NoGo Cov [ $\beta = .37$ ,  $t(51) = 2.36$ ;  $p < .05$ ],  $F(7, 51) = 3.61$ ,  $p < .01$ , adjR<sup>2</sup> = .24. Therefore, we are confident that the link between lack of perseverance and the TMT part B is mainly due to the switching component of the TMT part B and not to other general cognitive processing.

#### 4. Discussion

This study aimed to compare impulsivity changes on four dimensions of impulsivity in patients with mild AD and matched controls and to examine the cognitive processes underlying impulsivity changes in these participants. The main results of the study emphasized the following: (1) informants considered patients more impulsive than controls for both lack of premeditation and lack of perseverance, but the groups did not differ on urgency and sensation seeking; (2) patients with AD had lower performances on all the executive measures, as well as higher variability of RTs than matched controls; and (3) lack of perseverance was significantly predicted by both set-shifting difficulties and larger variability of RTs, whereas lack of premeditation was significantly predicted by difficulties in inhibition of prepotent responses even when age, WM, general processing speed, and global cognitive functioning were controlled for.

First, in accordance with recent studies exploring personality traits associated with AD (Duberstein et al., 2011; Duchek

et al., 2007; Wilson et al., 2007), our results showed that impulsivity traits related to low conscientiousness, that is, lack of premeditation and lack of perseverance, are significantly higher in patients with AD than in controls. These results are in line with a longitudinal clinicopathological cohort study with up to 12 years of annual follow-up conducted on 997 older Catholic nuns, in which a high level of conscientiousness was associated with a reduced risk for developing AD, even when age, education, gender, other personality traits, or vascular conditions were controlled for (Wilson et al., 2007).

In addition, we observed an increase on urgency, lack of perseverance, and lack of premeditation<sup>2</sup> and a decrease on sensation seeking in patients with AD, which corroborated previous findings (see Rochat et al., 2008). However, in contrast to the findings of Rochat et al. (2008), in the current study there was no relationship between the decrease of sensation seeking and global cognitive functioning. One explanation might be that the range of severity of global cognitive impairments (MMSE) differs between the two studies (9–29 in Rochat et al.'s study vs 17–29 in the current study). Tentatively, the decrease of sensation seeking could be associated with a combination of severe cognitive impairments on a wide range of cognitive

<sup>2</sup> The mean on lack of premeditation was 1.03 (SD = 3.70) in the current study, whereas it was 1.42 (SD = 4.20) in the study of Rochat et al. (2008). In addition, in a sample of 51 patients with AD (and 51 matched controls), it was also found that the increase observed on urgency, lack of perseverance, and lack of premeditation significantly differs from 0 (L. Rochat et al., unpublished data, 2010). It is thus possible that the small sample size and associated lack of statistical power explains why the increase on lack of premeditation in the current study did not significantly differ from 0.

functions (memory, executive functions, attention, etc.) that impedes patients from engaging in risky behaviors. An alternative, although related explanation, would be that patients with low MMSE scores (or a moderate level of dementia) require increased supervision from their caregivers in daily living, which limits the possibility of their taking risks. Finally, our results partially contrast with those of Duchek et al. (2007) and Duberstein et al. (2011) who showed that patients with mild AD had not only lower conscientiousness, but also a higher level of neuroticism than did healthy controls. We did not, however, find any statistical differences between controls and patients on the neuroticism-related facet of impulsivity, namely, urgency. One explanation may be that urgency corresponds to a narrower construct than does neuroticism. Indeed, as demonstrated by Whiteside and Lynam (2001), urgency is specifically associated with the "impulsivity" facet of neuroticism, but neuroticism is a broader construct that also includes other facets related to predisposition toward negative affect expressed through anxiety, depression, vulnerability, and hostility (see Costa and McCrae, 1992).

One of the main results of the current study is in regard to the relationships between lack of perseverance and both set-shifting difficulties and variability of RTs. First, inability to shift cognitive sets or to shift attention to the most critical aspects of the situation might result in stereotyped or invariable responses that are not appropriate to the situation. In this context, and corroborating our hypothesis, individuals with set-shifting impairments might have difficulties in finding alternative ways to resolve a complex situation, which ultimately results in difficulties in completing boring and/or difficult tasks. Second, higher variability of RTs constituted another significant predictor of lack of perseverance. Higher within-task variability probably results from a breakdown of an executive/attentional control system that can no longer sustain attention or maintain the goals of a task across time and inhibit irrelevant information (Duchek et al., 2009; West et al., 2002). In this way, our results are in line with a recent study conducted on a sample of healthy young adults from the community that indicated that lack of perseverance was associated with difficulties in resisting proactive interference in WM (Gay et al., 2008), that is, in resisting the intrusion into memory of information that was previously relevant but has since become irrelevant (see Friedman and Miyake, 2004), such as intrusive thoughts or memories. From this perspective, the higher variability of RTs might be explained by difficulties in inhibiting intrusive thoughts and memories that provoke lapses or drifts of attention away from the task, which in turn make the achievement of a boring and/or complex task particularly difficult. Our results are partially in line with those of Tse et al. (2010), who showed that both low conscientiousness and high neuroticism in very mild AD (Clinical Dementia Rating scale of .5) were related to higher variability of RTs. Indeed, in the current study, neither the dimension of impulsivity related to neuroticism (i.e., urgency) nor one of the two dimensions of impulsivity related to conscientiousness (i.e., lack of premeditation) were predicted by variability of RTs. Our results thus suggest that a particular dimension of impulsivity (lack of perseverance) associated with a specific facet of conscientiousness (self-discipline) is specifically related to sustained attention difficulties as assessed by a measure of the variability of RTs.

Contrary to our expectations, urgency was not associated with the number of false alarms in the Go/NoGo task, whereas lack of premeditation was. The absence of significant relationships between inhibition of prepotent responses and urgency is worth comment. Two studies have shown mixed results regarding the relationship between commission errors in a Go/NoGo task and urgency. Indeed, Gay et al. (2008) found such an association in a sample of healthy young adults, whereas Perales et al. (2009) did not. A direct comparison of these studies and the current one is difficult because of methodological differences, such as the type of participants (young vs older adults with or without AD), sample size, and impulsivity assessment (impulsivity changes vs global trait). However, in our view, the main argument underlying the absence of relationships between urgency and inhibition relates to the absence of emotional material in the Go/NoGo task used in the current study. Indeed, on the one hand, urgency has been conceptualized as a tendency to act impulsively in an emotional context (Cyders and Smith, 2008), and, on the other hand, several studies have shown that emotional contexts might interfere with the ability to inhibit prepotent responses (Schulz et al., 2007; Verbruggen and De Houwer, 2007). In addition, from a neuroanatomical point of view, emotional dyscontrol episodes resulting from high urgency might be the consequence of a dysfunctional interaction between the prefrontal or cingulate brain systems involved in cognitive control and the subcortical brain systems involved in emotion generation, such as the amygdala (e.g., Ochsner and Gross, 2005). In particular, a recent study showed that symptoms of irritability and agitation in patients with AD were associated with amygdala hyperresponsiveness to the human face when expressing neutral or negative emotions that might result from direct effects of AD pathology in the amygdala and/or indirect effects in regions that modulate amygdala activity such as the prefrontal cortex (Wright et al., 2007). These results tentatively suggest that cognitive control processes such as inhibition of prepotent responses are no longer effective in inhibiting amygdala activation in response to emotionally laden stimuli in patients with AD (e.g., Scheibe and Carstensen, 2010). In this context, further studies should more specifically examine the relationships between urgency and inhibition of prepotent responses in emotional contexts in patients with AD and healthy controls.

The positive relationship found between lack of premeditation and impairments in inhibition of prepotent response is of main interest as well. In our view, the dual processes of thinking and reasoning theory (see Evans, 2003) constitute a relevant theoretical framework to understand the relationship found between difficulties of prepotent response inhibition and lack of premeditation. Indeed, this theory proposes a distinction between an automatic and an analytical or deliberative system. More specifically, choices resulting from the automatic system depend on rapid and parallel processes produced via associative learning, and they remain unconscious until the decision is made. This automatic system does not recruit controlled or executive processes. By contrast, the analytical system is slower, sequential, requires controlled cognitive processes such as executive functions and WM, and allows abstract and hypothetical thinking. Thus, our results suggest that impairment in inhibition of prepotent response preclude the

activation of this demanding analytical, deliberative processing, which is necessary to consider the immediate benefits in relation to the future costs of an action when making a decision. Instead, the automatic system remains active, resulting in unplanned actions that might have detrimental consequences for individuals. These data are in line with studies showing that difficulties in inhibiting prepotent responses have been associated with poorer decision making in a laboratory task (Billieux et al., 2010; Noël et al., 2007). These results might also help us to understand why older adults have less ability to make decisions in laboratory tasks (e.g., Delazer et al., 2007; Zamarian et al., 2008) and why they might thus be more susceptible to misleading or deceptive advertisements or fraud. However, further studies should specifically examine the relationships between inhibition of prepotent responses, decision making, and the premeditation dimension of impulsivity in older adults with or without neurodegenerative conditions.

Some limitations to the study should be discussed. First, our sample of patients is small, and therefore the results can be generalized only with caution. In the same vein, the absence of significant changes on lack of premeditation within the group of patients in the current study might be explained by the small sample size of patients. In addition, it might be argued that the significant decrease of lack of premeditation over time in healthy controls, and not in AD, contradicts the rationale of pooling both populations for correlation analyses. This observation might even be considered as an indication of "domain-related" successful aging rather than an indication of a general continuum between aging and AD. However, the distribution of premeditation scores across the whole sample does not indicate a bimodal distribution (which would confirm lack of premeditation as domain related successful aging rather than an indication of a general continuum), but instead a normal distribution. These data are congruent with the hypothesis of a continuum between aging and dementia (see Walters, 2010). Even if the UPPS impulsivity model sheds relevant new light on the multidimensional aspects of impulsivity, further characterization of each of the four dimensions is required, and the overlap between some dimensions (e.g., urgency and lack of premeditation) needs to be clarified. Second, the few significant relationships between executive/attentional measures and impulsivity in control participants suggest that the tasks used in the current study may lack sensitivity to highlight interindividual differences in healthy participants. However, these results might also indicate that other processes contribute to the increase or decrease observed on some dimensions of impulsivity in participants, such as compensatory mechanisms (e.g., Freund, 2006; Park and Reuter-Lorenz, 2009; Phillips and Andrés, 2010) or improvement of emotional experience in aging (e.g., Carstensen et al., 2011).

To conclude, although AD is characterized by a progressive cognitive decline, behavioral symptoms frequently occur even in the early phases of the disease. The current results suggest that a multifaceted approach to impulsivity could be of interest in understanding these symptoms. Further studies should, however, specifically examine how the various dimensions of impulsivity, and associated cognitive mechanisms, relate to broader behavioral disorders in AD patients. In addition, by more specifically identifying the cognitive processes associated with changes observed on various

dimensions of impulsivity, the current study provides valuable insights into the nature of brain systems and cognitive processes underlying impulsiveness.

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