

Future thinking in Parkinson's disease: An executive function?

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ABSTRACT

Contrary to what was originally thought (Hassabis, Kumaran, Vann, & Maguire, 2007) recent data have shown that imagining the future is not entirely dependent on the hippocampus (Squire et al., 2010) and neuroimaging studies have demonstrated a frontopolar activation during future thinking tasks (Okuda et al., 2003). The present study investigated whether the performance of people with Parkinson's disease (PD) on future simulation tasks was dependent on memory or executive control. Thirty-one PD patients, asked to imagine possible future scenarios, generated fewer future episodic details than matched controls. The seven patients who clearly performed below the range of controls in future thinking, were also significantly poorer on the Frontal Assessment Battery (FAB), a battery assessing executive control, but showed no deficits in immediate or delayed memory tests. These results suggest that poor performance in the future thinking task is associated with poor executive control and less so with memory impairment. Flexible searching activities of past details might be crucial capacities for envisaging one's own future.

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1. Introduction

The human brain is continuously engaged in devising simulations that approximate real future events (de Vito & Della Sala, 2011; Ingvar, 1979). Most people can shift their perspective from the immediate environment to richly imagined hypothetical future situations. This skill, labelled "episodic future thinking" (Atance & O'Neill, 2001), allows humans to place themselves in potential scenarios by using imagination.

It has long been posited that an intimate relation underpins episodic past and future thoughts: "It may be said that we have no grasp of the future without an equal and corresponding outlook over the past" (Bergson, 1913, pp. 69–70). Bartlett (1932) noticed that remembering is not entirely distinct from imagining or from constructive thinking, but it has a close linkage with them. In 1973 it was already "abundantly clear that human behaviour is active in character, that it is determined not only by past experiences, but also by plans and designs formulating the future" (Luria, 1973, p. 13). Therefore, when people with memory disorders cannot completely rely on their past, their future remains "hazier, more vague and more confused" (Lidz, 1942, p. 596).

Consistent with these early intuitions, the presence of a common core network, which underlies autobiographical episodic remembering and future thinking, has been recently experimentally supported (for a review see Schacter, Addis, & Buckner, 2008; Szpunar, 2010). Certain cortical areas (specifically the medial prefrontal cortex, posterior regions in the medial and lateral parietal cortex, the lateral temporal cortex, and the medial temporal lobe including the hippocampus) have been shown to be associated with episodic memory and imagination of the future (e.g., Hassabis, Kumaran, Vann, & Maguire, 2007; Schacter, Addis, & Buckner, 2007; Schacter & Addis, 2009). This evidence has led to the claim that we need to access past experiences in order to anticipate future events (Schacter et al., 2008; Schacter & Addis, 2007; Szpunar, 2010).

Patient studies have corroborated this hypothesis. It has been noted, for example, that amnesic patients (O.S., Lidz, 1942; K.C., Tulving, 1985; D.B., Klein, Loftus, & Kihlstrom, 2002), seemed almost mentally locked in a permanent present, since the preceding events were "not available to meet the new" ones (Lidz, 1942, p. 595). The famous patient H.M., who became amnesic in 1953 after the bilateral resection of medial temporal lobe structures, was interviewed in 1992 by Suzanne Corkin. When asked "What do you think you'll do tomorrow?", he answered "Whatever is beneficial", since he "had no database to consult" to respond about his personal future (S. Corkin, personal communication, 01/26/11).

Similarly, Hassabis et al. (2007) reported on five memory-impaired patients with a bilateral hippocampus damage, four of

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whom had difficulty constructing detailed and spatially coherent fictitious scenarios. Lastly, patients with Alzheimer's disease (AD; Addis, Sacchetti, Ally, Budson, & Schacter, 2009) presented impairments in envisaging new experiences.

However, it is still unclear which cognitive functions, other than episodic memory, are necessary prerequisites for imagining one's own future and whether the hippocampus plays the crucial role in the construction of future scenes (Squire et al., 2010). The findings gleaned from the literature are controversial. Hassabis et al. (2007) reported that focal amnesics had trouble constructing novel events. Likewise, patients suffering from amnesic MCI generated fewer details in a future thinking task than their matched controls (Gamboz et al., 2010). On the other hand, Squire et al. (2010) reported that patients suffering from hippocampal lesions, despite their impairment in recollecting recent personal memories, performed similarly to controls when simulating future episodes. The authors concluded that difficulty in imagining the future is unlikely to be due only to pure amnesia if the past-future network of brain areas postulated by Schacter et al. (2007) is largely spared.

Moreover, neuroimaging studies have indicated a frontopolar activation during future thoughts. Compared to the construction of past episodes, future thinking tasks recruit several additional regions, such as the frontopolar cortex and left ventrolateral prefrontal cortex (Addis, Wong, & Schacter, 2007). Okuda et al. (2003) demonstrated that specific frontal polar areas, including Brodmann's area 10 (BA 10), were more activated when imagining the future than when remembering the past. In particular, the activity of the right frontopolar cortex (BA 10) positively correlates with the amount of detail comprising the future events (Addis & Schacter, 2008). Furthermore, damage to the prefrontal cortex can impair the conscious awareness of one's continued experience in a subjective time. This ability, also known as chronesthesia, might be closely related to the capacity of projecting one's self toward the future (for a review see Wheeler, Stuss, & Tulving, 1997; Szpunar, 2011).

According to this idea, some authors noted strong correlations between tasks generating event-related details and tasks engaging executive functions. Addis, Wong, and Schacter (2008) observed that the episodic specificity of past recollections and future constructions correlates with a standardized measure of executive control, the Backward Digit Span task, known to activate the dorsolateral prefrontal cortex (Hoshi et al., 2000). Furthermore, a new task was devised by Summerfield, Hassabis, and Maguire (2010), in order to better investigate the process of constructing coherent and vivid scenarios. The participants of this study were instructed to begin the trial clearing their imagination. Then, they were auditorily presented with single scene elements (from three to six) in a serial manner. They had to imagine the first element in a "clean state" (i.e., with no context) and, successively, they had to combine each single element together with the previous ones to build up naturalistic scenes of increasing complexity. In this study, fMRI showed the activation of the different areas of the core network (Schacter et al., 2007), being engaged and disengaged, as required during each step. The hippocampus and the dorsolateral prefrontal cortex were both significantly activated during the oral presentation of the first element. The addition of the second element required an increasing activity of the dorsolateral prefrontal cortex (maybe to allow the maintenance of the two elements in working memory, as the authors suggested). However, crucially, in this phase, the hippocampus (together with other areas of the core network activated during the first step) down-regulated. With the introduction of the third element, the authors observed a greater activity in additional regions (i.e., the medial parietal cortex) and once more an up-regulation of many areas, like the hippocampus, activated during the first phase, but down-regulated in the second phase. Such observations provide us with clues as to the possible alternative

role played in the scene construction by hippocampus-related memory functions and by frontally based executive functions.

Taken together, these lines of evidence suggest that executive functioning plays an essential part in the production and recombination of event-related details. Should this be the case, an executive dysfunction ought to cause some degree of impairment in the simulation of episodic future events, even when episodic memory is spared.

We sought to further our understanding of this issue by testing people with Parkinson's disease (PD). PD is a neurodegenerative disorder that progresses slowly and is characterized by degeneration of the dopaminergic system. A wide range of cognitive impairments is often associated with PD, the most prominent of which is a dysexecutive syndrome (Bosboom, Stoffers, & Wolters, 2004; Rowe et al., 2002). Our patients were selected for being at the very early stages of the disease (no later than the second stage, according to Hohen and Yahr's classification, 1967). Their magnetic resonance imaging had to be normal.

The present study assesses for the first time episodic future thinking in PD patients. The choice of this particular population, early non amnesic PD, was directly linked to the question posed in our study as to whether people with no overt memory problems, and who might have other mild cognitive deficits, could nonetheless present with future thinking deficits.

More specifically, the main goal of the current study was to assess whether or not patients with no memory deficits may present with impairment in future thinking and whether this impairment might be specific, sparing other tasks requiring event generation. Mental time travel into the past was included because it implies a search for a combination of information and it allowed us to ascertain whether or not participants were still able to retrieve personal memories. The key experimental variable was mental time travel into the future, which might place a considerable demand on executive functions, given that a future event can be constructed from a combination of an infinite assortment of information that is to be monitored and re-combined within precise restrictions (e.g., plausibility, time) (Anderson, Dewhurst, & Nash, 2012). Imagination of fictitious, non-temporal events was included because it implies a more open-ended and generative capacity of scene construction, given that the events, in this case, might also be implausible and unlikely and are not to be restricted to a specific time frame. We predicted that future thinking might be more cognitively demanding than a simple scene construction, since it implies a flexible search within past autobiographical memories by taking into account more restrictions, hence more monitoring, than a scene construction task. Thus, it might involve different and distinctive cognitive sub-processes.

2. Method

2.1. Participants

Thirty-one old adults affected by PD and 31 healthy controls took part in this experiment.

The participants with PD were selected from a larger panel at the Parkinson and Movement Disorder Centre, Department of Neurological Sciences (Federico II University, Naples). The diagnosis of PD fulfilled the UK Parkinson's disease Society Brain Bank clinical diagnostic criteria (Gibb & Lees, 1988). All patients were under anti-parkinsonian treatment at a stable and optimized daily dosage during the 4 weeks prior to study entry. Exclusion criteria were: (1) dementia according to clinical diagnostic criteria for dementia associated with PD (Emre et al., 2007); (2) major depression according DSM-IV criteria for current major depression (American Psychiatric Association, 1994); (3) clinically significant or unstable medical condition including serious cardiovascular or cerebrovascular disease; and (4) anti-cholinergic or neuroleptic treatment.

According to Hohen and Yahr's classification (1967), our PD patients were to be at no later than the second stage of Parkinson's disease. More specifically, 16 of them were at stage 2; 11 of them were at stage 1.5 and 4 of them were at the stage 1. Their magnetic resonances were normal. None of our patients had detectable MTL damage, as evinced by structural MRI scans.

Twenty of our PD patients were under a treatment comprising both levodopa ($M_{\text{mg}}=477.5$; $SD_{\text{mg}}=260.3$) and other dopamine-agonists ($M_{\text{mg}}=297.5$; $SD_{\text{mg}}=212.42$); 6 of them were taking only dopamine-agonists ($M_{\text{mg}}=321.66$; $SD_{\text{mg}}=63.37$) and 5 of them were being treated only with levodopa ($M_{\text{mg}}=460$; $SD_{\text{mg}}=178.18$).

Furthermore, specific tests were selected from the Mental Deterioration Battery (MDB; Carlesimo, Caltagirone, & Gainotti, 1996) in order to recruit solely people with (a) no deficit in the immediate and delayed recall test (Rey's 15 word Immediate Recall and Delayed Recall; scores, respectively, above 28.53 and 4.69); (b) spared logical reasoning (Raven's Progressive Matrices' 47; scores above 18.96); and (c) a fluent language (Phonological Verbal Fluency; scores above 17.35). Moreover, the participants should have a score of at least 30, i.e., above cut-off, on the Attentional Matrices, which assesses attention by means of timed visual search (Della Sala, Laiacona, Spinnler, & Ubezio, 1992).

The healthy individuals were members of different, non-academic, local associations. We did not recruit people under psychoactive pharmacological treatment likely to modify normal memory abilities or people with a history of neurological and psychiatric disorders.

No honorarium was offered to participants. Before starting the testing session, they were asked to sign an informed written consent form. The study procedures were approved by the local ethical committee and were carried out in accordance with the Declaration of Helsinki.

There were no significant differences (all $p > 0.05$) between PD patients and controls on demographic variables such as age (PD, $M=64.4$, $SD=6.7$; controls, $M=67.9$, $SD=8.5$) and education (PD, $M=11.0$, $SD=4.3$; controls, $M=11.5$, $SD=4.2$), or the MMSE scores (PD, $M=27.5$, $SD=1.7$; controls, $M=26.9$, $SD=0.9$).

2.2. Materials and experimental procedure

Each testing was carried out in one single session. All participants were tested individually and sat facing the same experimenter in a quiet testing environment.

PD patients and controls first performed a "description task", whereby they were required to describe the testing room (that was maintained unchanged during the study) in as much detail as possible. This test aimed to ascertain that the two groups did not differ in the production of scene-related details when describing settings in general (rather than specific imaginary or remembered scenes).

The Frontal Assessment Battery (FAB; Dubois, Slachevsky, Litvan, & Pillon, 2000) was also administered, with the aim of exploring, by means of six subtests, some skills related to frontal lobe functions, in particular conceptualization, mental flexibility, and inhibitory control. It should be noted that since the PD patients recruited for the study did not present with deficits in verbal fluency, visual search or logical reasoning, known to be associated with frontal activation (Prabhakaran, Smith, Desmond, Glover, & Gabrieli, 1997), the FAB battery was meant to identify minor executive disturbances, and we did not expect a large subgroup to be impaired.

Finally, participants were given the experimental battery. They were initially briefed that they would be required to mentally re-experience and pre-experience twelve autobiographical episodes (eight "temporal", i.e., occurred or occurring within the past or next year; four "non temporal", i.e., that are never going to occur) in response to randomly presented cue words (for the "temporal" events) or short verbal cues (for the "non temporal" episodes). Participants were given an explicit temporal frame with each future/past cue (i.e., next year/last year).

Aiming at eliciting the "temporal" (past or future) events, two sets of eight words, matched for familiarity, frequency, imageability, and concreteness, were selected from Italian norms (Burani, Barca, & Arduino, 2001). Within each list, the words were randomly assigned to the two temporal directions and rotated in the past/future conditions. Then, each participant was given one of these two sets. The experimenter further explained that the events had to be remembered or imagined in as much detail as possible. Participants also were encouraged to produce temporally and contextually specific events and to vividly imagine novel and plausible future episodes, given their current plans. This procedure followed those of D'Argembeau and van der Linden (2004) and of Addis, Wong, & Schacter (2008).

In order to elicit the "non temporal" events, we used ten short sentences, which outlined a variety of common-place scenarios (e.g., "Imagine you are standing in an open field by the banks of a river" or "Imagine you are standing on the deck of a ship

leaving port on a voyage"). The short descriptions were randomly assigned across the participants. Participants were instructed to richly invent new fictitious experiences, never occurred before, and not temporal in nature and to describe them in as many details as possible. The events had to be contextually specific, but not necessarily plausible or even possible. The procedure and the short verbal cues were adapted from the paradigm devised by Hassabis et al. (2007).

The order of presentation of temporal connotation (past, future, non temporal) was counterbalanced.

The cues were displayed, one at a time, on the computer screen with the instructions about the temporal direction (remember or imagine in the future or invent fictitious experiences). Once an episode had been recalled or imagined, it was recounted by the participant. There was no time limit. Participants were allowed to keep on verbally illustrating the event until they thought that nothing else could be added. We maintained constant the prompting procedure for the control group and the patients group. When participants stopped talking, the experimenter asked only once whether there was any further detail that they would have liked to add.

Recollections and simulations were digitally recorded to enable later transcriptions and subsequent scoring of participants' responses.

After the transcription, a trained rater, who was blind to the hypothesis of the study, used the standardized scoring procedure developed by Levine, Svoboda, Hay, Winocur, and Moscovitch (2002) to systematically parse the details generated in the past and future events. This allowed the rater first to segment the main event (i.e., the most talked about, with a brief timeframe) into details and then to distinguish between (a) internal details (i.e., episodic information pertaining to the main event, specific to time and place) and (b) external details (general knowledge related to the event). A second rater, trained for this purpose, then scored 20 protocols from the original participants: 10 from the PD sample and 10 from the controls. The inter-rater reliability (r) between the original rater and the new rater was 0.94.

Internal details were further categorized into: (a) event (happenings, individuals present, physical/emotional actions and reactions, weather), (b) place (information about the environment where the event occurred), (c) time (date, season, month, day of the week, time of day), (d) perceptual (sensory information, body position) and (e) emotion (emotional state, thoughts).

External details were categorized into: (a) external event (specific details from other incidents, from all of the above categories, external to the main event), (b) semantic (general knowledge or facts, ongoing events, extended states of being), (c) repetition (unsolicited repetition of details), and (d) other (metacognitive statements, editorializing).

3. Results

The entire group of patients presented with a mean on the FAB of 14.14 (± 2.04). Thirteen patients scored below the cut-off (i.e., below 13.5) and 18 patients scored above the cut-off (i.e., above 13.5). The full outcome of the FAB is reported in Table 1, showing the results from each of its subcomponents. It is worth noting that the total score on the FAB did not correlate with any of the experimental variables. However, there was a significant correlation ($r=0.36$, $p<0.05$) between the subtest assessing the Sensitivity to Interference and the scores on the future thinking measure.

The amount of detail reported about the testing room was not significantly different between PD patients and controls (PD, $M=11.8$, $SD=8.6$; controls, $M=13.5$, $SD=5.0$), $t(60)=-0.9$, n.s. (see Fig. 1).

On the experimental procedure, considering the three conditions together, PD patients and controls generated an equivalent number of details (PD, $M=14.5$, $SD=6.4$; controls, $M=15.7$, $SD=5.8$), $t(60)=-0.7$, n.s.

Table 1

The table reports the mean (standard deviation) of the results obtained at the six subtests of the FAB, i.e., conceptualization (C), mental flexibility (MF), motor programming (MP), sensitivity to interference (STI), inhibitory control (IC), and environmental autonomy (EA), by the whole patient group (total); by the subgroup of executive patients (E; who scored above the cut-off of 13.5 at the FAB) vs. the subgroup of dysexecutive (D; who scored below the cut-off of 13.5 at the FAB); and by the subgroups of the 24 patients who obtained higher FT scores (Hi-FT) and the 7 patients who performed poorer (Po-FT).

PD	C	MF	MP	STI	IC	EA	FAB total
Total (n 31)	1.7 (0.7)	2.5 (0.6)	2.3 (0.7)	2.7 (0.7)	1.8 (0.9)	3 (0)	14.1 (2.04)
Groups (FAB)							
E (n 18)	2.05 (0.7)	2.8 (0.42)	2.7 (0.46)	2.9 (0.3)	2.05 (0.9)	3 (0)	15.5 (1.3)
D (n 13)	1.4 (0.6)	2.2 (0.7)	1.7 (0.7)	2.5 (0.9)	1.4 (0.6)	3 (0)	12.3 (1.2)
Groups (FT)							
Hi-FT (n 24)	1.91 (0.7)	2.6 (0.6)	2.4 (0.6)	2.9 (0.2)	1.8 (0.9)	3 (0)	14.6 (1.8)
Po-FT (n 7)	1.3 (0.7)	2.3 (0.7)	1.8 (0.9)	2 (1.1)	1.7 (0.9)	3 (0)	12.5 (1.9)

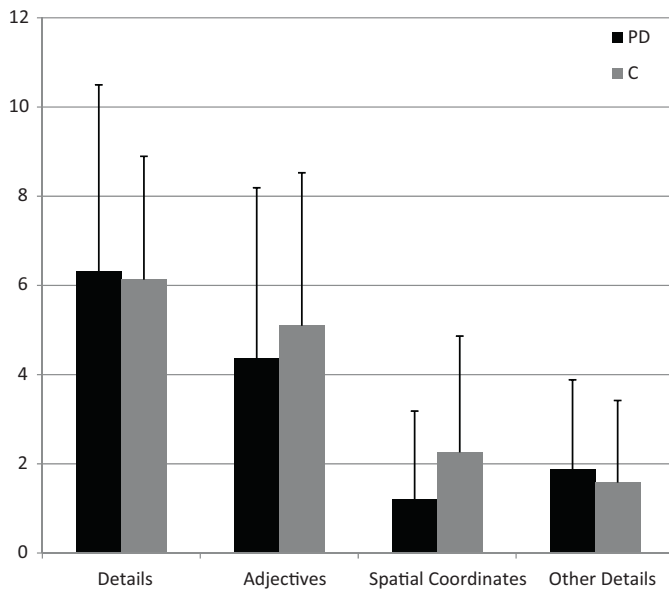


Fig. 1. Mean number of the details that PD patients (PD) and controls (C) used in the description task. Error bars indicate standard deviations.

A 2 (Group: PD vs. Controls) $\times$ 2 (Details: Internal vs. External) $\times$ 3 (Temporal Connotation: Past vs. Future vs. Non temporal) mixed analysis of variance (ANOVA), with Group as a between-subjects factor, and Details and Temporal Connotation as within-subjects factors, was conducted on the mean number of details generated by PD and controls (see Fig. 2).

The results showed a highly significant main effect of Details, $F(1, 60) = 165.9$, $p < 0.001$, $\eta_p^2 = 0.73$, indicating that, on the whole, participants produced more internal ($M = 11.4$, $SD = 4.9$) than external details ($M = 3.7$, $SD = 2.8$). The interaction between Details and Groups, $F(1, 60) = 15.16$, $p < 0.001$, $\eta_p^2 = 0.2$, was also significant; post hoc t -tests suggested that the amount of internal detail generated by PD patients ($M = 9.9$, $SD = 4.7$) was significantly less than that produced by controls ($M = 12.8$, $SD = 4.7$), $t(60) = -2.4$, $p < 0.02$, $\eta^2 = 0.09$, whereas the number of external details in PD patients' reports ($M = 4.5$, $SD = 3.3$) was greater compared to the number of external details recounted by controls ($M = 2.8$, $SD = 1.9$), $t(60) = 2.5$, $p < 0.02$, $\eta^2 = 0.09$. The interaction between Details and Temporal

Connotation was also significant, $F(1, 60) = 6.8$, $p < 0.005$, $\eta_p^2 = 0.1$; post hoc t -tests indicated that both groups produced more internal details when remembering past episodes ($M = 12.3$, $SD = 5.2$) than when imagining future events ($M = 9.4$, $SD = 5.6$), $t(61) = 4.9$, $p < 0.001$, $\eta^2 = 0.29$, and more internal details when inventing non temporal events ($M = 12.4$, $SD = 6.4$) than when imagining future events ($M = 9.4$, $SD = 5.6$), $t(61) = -4.4$, $p < 0.001$, $\eta^2 = 0.24$. Finally, the three-way interaction concerning Groups, Details and Temporal Connotation was also significant, $F(1, 60) = 6.45$, $p < 0.005$, $\eta_p^2 = 0.9$. With the aim of better explaining the latter interaction, two different follow-up ANOVA were carried out for internal and external details. As regards the internal details, the results revealed main effects of both Group, $F(1, 60) = 5.9$, $p < 0.05$, $\eta_p^2 = 0.09$ and Temporal Connotation, $F(1, 60) = 13.8$, $p < 0.001$, $\eta_p^2 = 0.18$. These indicate that PD patients generated less internal details compared to controls and that, overall, more internal details were generated for past ($M = 12.3$, $SD = 5.2$) and non-temporal ($M = 12.4$, $SD = 6.4$) events than for future events ($M = 9.4$, $SD = 5.6$). It is important to note that, overall, an equivalent amount of the subtype of internal details previously labelled as "events" (mainly happenings and physical/emotional actions and reactions of the individuals present in the episode) was generated in future ($M = 3.8$, $SD = 2.3$) and non temporal ($M = 3.4$, $SD = 1.9$) tasks, whereas, overall, more "perceptual" internal details (mainly sensory information) were produced in non temporal ($M = 5.9$, $SD = 3.6$) than in future ($M = 2.9$, $SD = 2.2$) tasks, $t(61) = -5.8$, $p < 0.001$, $\eta^2 = 0.36$. The mean number of the subcategories of internal details produced for past, future and non-temporal events by PD patients and controls are presented in Fig. 3.

A significant interaction between Group and Temporal Connotation, $F(1, 60) = 3.1$, $p < 0.05$, $\eta_p^2 = 0.5$, indicates that PD patients produced fewer internal details compared to controls for future events (PD, $M = 7.0$, $SD = 4.1$; controls, $M = 11.8$, $SD = 5.9$), $t(60) = -3.6$, $p < 0.002$, $\eta^2 = 0.18$. In particular, the difference between the two groups for future events was highly significant for the subtype of internal details regarded as "events" (PD, $M = 2.9$, $SD = 1.6$; controls, $M = 4.8$, $SD = 2.4$), $t(60) = -3.5$, $p < 0.002$, $\eta^2 = 0.17$. The ANOVA conducted on external details showed a main effect of the Group, $F(1, 60) = 6.3$, $p < 0.02$, $\eta_p^2 = 0.9$, indicating that PD patients generated an increased number of external details as compared to controls. The interaction between Group and Temporal Connotation was also significant, $F(1, 60) = 6.0$, $p < 0.005$, $\eta_p^2 = 0.09$, indicating that the group of PD patients produced more external details than controls for past (PD, $M = 4.7$, $SD = 3.5$; controls, $M = 2.6$,

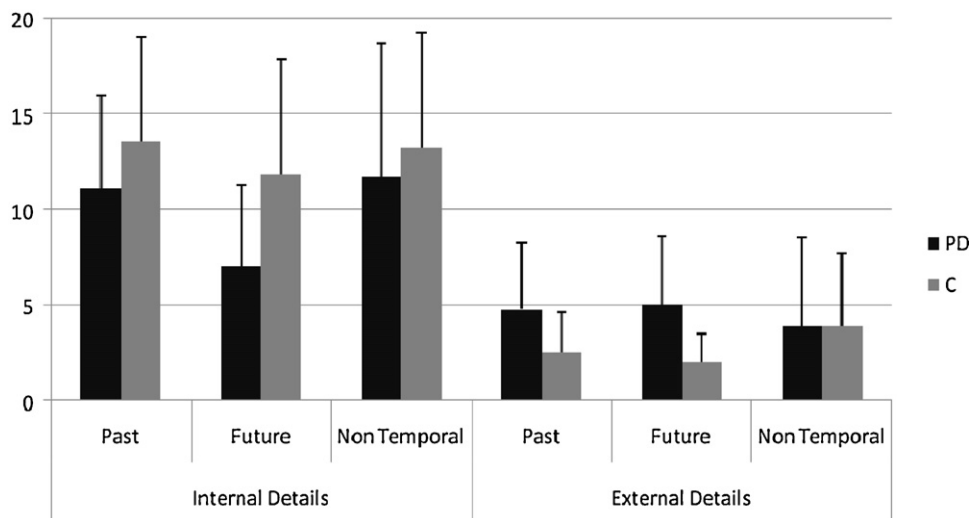


Fig. 2. Mean number of internal and external details produced for past, future, and non-temporal events by PD patients (PD) and controls (C). Error bars indicate standard deviations.

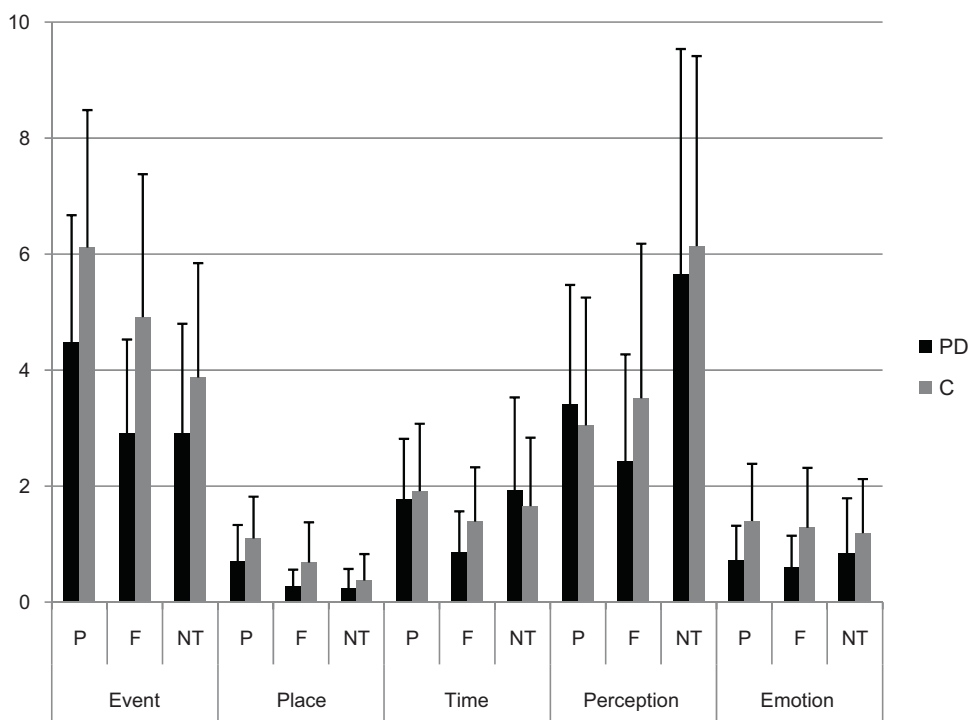


Fig. 3. Mean number of the subcategories (i.e., event, place, time, perception and emotion) of internal details produced for past (P), future (F), and non-temporal (NT) events by PD patients (PD) and controls (C). Error bars indicate standard deviations.

SD = 2.0), $t(60) = 3.0$, $p < 0.005$, $\eta^2 = 0.18$, and for future (PD, $M = 5.0$, SD = 3.6; controls, $M = 2.0$, SD = 1.4) events, $t(60) = 4.3$, $p < 0.001$, $\eta^2 = 0.24$.

The control and the PD groups produced an equal number of repetitions in all the experimental conditions.

We also ran an ANOVA including only past and future scores. It showed a significant Group $\times$ Past/Future interaction for internal details ($F(60) = 3.73$, $p = 0.05$). Post hoc tests comparing the past and future condition showed that PD patients performed significantly better on the past task ($M = 11.08$; SD = 4.86) than on the future task ($M = 7.04$; SD = 4.18), $t(31) = 6.25$, $p < 0.001$. On the other hand, controls' performances in the past condition ($M = 13.6$; SD = 5.32) and in the future condition ($M = 11.81$; SD = 5.93) did not significantly differ.

In order to further explore the performance of the PD group, a subgroup of seven patients was selected, on the basis of the number of internal details recounted in future thinking. More specifically, these seven patients clearly performed out with the range of controls in the future task (the lowest mean reported in the control group was 3.5), reporting a mean of internal details of 2.3 (SD = 1.2). Their performance on the future task ($M = 2.3$, SD = 1.2) significantly diverged from the remaining 24 PD patients ($M = 8.4$, SD = 3.7), $t(29) = 4.2$, $p < 0.001$, $\eta^2 = 0.23$.

Interestingly, the mean score achieved on the FAB by the subgroup of 7 dysexecutive PD patients ($M = 12.5$, SD = 1.9) was significantly lower compared to the rest of the group ($M = 14.6$, SD = 1.8), $t(29) = 2.6$, $p < 0.02$, $\eta^2 = 0.10$. A further analysis also revealed a significant difference on the Sensitivity to Interference FAB subtest between this subgroup and the rest of the PD group ($t(29) = 3.66$, $p < 0.002$).

There were no significant differences (all $ps > 0.05$) between the two subgroups when compared on variables concerning age, education, duration of disease, or the MMSE.

For completeness, we also compared the performance of the group of dysexecutive (D) and executive (E). They did not differ on any of the experimental conditions. Group D scored significantly

worse than the controls solely in the future condition, $t(47) = -2.86$, $p < 0.01$. The same pattern was observed for group E's performance, $t(42) = -2.78$, $p < 0.01$. The two groups (E and D) did not show significant differences on the past or on the non-temporal task, when compared to controls.

It is worth noting that medication did not account for any variance in performance within our patient group. We found no differences between the performances of three subgroups of patients (i.e., 20 who were under treatment with levodopa and other dopamine-agonists; 6 who were taking only dopamine-agonists; and 5 who were being treated only with levodopa) on any of the experimental conditions (past, future and non-temporal) (all $ps > 0.05$). Moreover, the three subgroups' performances did not differ on the FAB (all $ps > 0.05$), and more specifically, they did not show any reliable differences in any of the FAB subtests (all $ps > 0.05$).

Finally, an example narrative from one control (C01) and two example narratives from two different patients (P01 and P02) are reported.

3.1. Imagine an event that might happen to you in the next year with the word "table"

C01's response: "We are sitting at a table with a group of people. I have just stopped cooking and in this moment I'm serving spaghetti. One of my friends appreciates the consistency of the pasta and I rebuke him, because he has tasted before everyone is sitting, he replies for fun "Daniele, you are always so fussy!". We are sitting, I uncork the bottle of wine and leave it oxygenating before serving. A friend of mine asks for white wine, and I have just uncorked red wine. Another friend says that she does not like that type of tomato sauce, she would prefer another sauce to dress the spaghetti. My mother enters the kitchen, a friend stands up to say hi, another friend also turns towards my mother and, in turning her head, throws her long hair on the face of the person sitting close to her. This person looks annoyed, since he

has got glasses, that were about to fall from his face, but my friend turns towards him and gently caresses his face, so that he brightens up”

P01's response: “Ok. . . so a very simple episode. I'm in pizzeria to eat pizza with my relatives and the table is not stable and all the dishes with the pizzas fall and we laugh at the end. And we are all around the table”.

P02's response: “If you say table. I always think of a dining table. So the table in the kitchen. We are waiting for the other daughter coming back from the university. She is late and so we are waiting for her to eat. The table has already been set, there is the other daughter, my wife who's preparing, the water is boiling, the television is on. . . my wife is cooking pasta”

4. Discussion

The main question from which this study originated was whether difficulties in future thinking could be observed in the absence of impairments in episodic memory and in imagination of fictitious events. The patients with PD who entered this study did not present with memory deficits and performed normally on past memories and non temporal constructive simulations, whereas they were impaired on episodic future thinking. That is, PD patients' simulation problems were limited to future events and did not include fictitious scenarios. Furthermore, our results showed that, compared to controls, PD patients reported fewer internal, event-related details in their simulations of future events, whereas they reported more semantic details both when recollecting the past and imagining future episodes.

General differences in conversational, narrative style cannot easily account for these results, given that PD patients and controls generated overall the same amount of detail considering the three experimental tasks together (Past, Future, and Non Temporal). In addition, the PD patients performed within normal limits on the Phonological Verbal Fluency task (which evaluates the richness of lexical production). Dopaminergic medication did not explain any variance in performance within the PD group. This result is in line with what was observed by [Shohamy, Myers, Geghamanc, Sage, and Gluck \(2006\)](#), who documented that Parkinson's patients, when “challenged to generalize what they had learned to a novel context, performed as well as controls, regardless of whether they were tested ‘on’ or ‘off’ dopaminergic medication” (p. 781). These findings are relevant to our study, given that some degree of generalization and extrapolation is necessary for predicting future events that are not exact replicas of past memories ([Hegdè, 2007](#)).

Moreover, the two groups, PD patients and controls, did not differ in the number of details when they were asked to describe the testing room (description task). Similar results were observed by [Race, Keane, and Verfaellie \(2011\)](#) in eight amnesic patients with a medial temporal lobe damage. Although these patients were impaired at remembering the past and imagining the future, they showed no deficits when required to look at drawings of commonplace scenarios and to construct stories about what was happening in the scenes. The authors suggested that medial temporal lobe damage might not affect the narrative construction when the to-be-described elements are “readily available”. This might be also the case of our patients.

In line with the hypothesis that a deficit in future thinking does not merely reflect a narrative construction impairment ([Race et al., 2011](#)), our data emphasize striking differences not only between time periods (past and future), but also between constructing non-temporal experiences and future thinking tasks. Indeed, our patients showed no deficits at the description task, in the non-temporal condition and in the past condition, which speaks against

a general reduction in specificity as a possible account for our results.

The possibility of a dissociation between performances in past memories and future thinking has recently gained ground. [Squire et al. \(2010\)](#) reported on five densely amnesic patients, whose capacity to imagine the future was preserved. In particular, patient G.P., who showed a remarkable deficit in remembering remote and recent episodes, was nonetheless fully intact at envisaging the future (see also [Squire, McDuffb, & Frascino, 2011](#)). [Berryhill, Picasso, Arnold, Drowos, and Olson \(2010\)](#) assessed patients with unilateral prefrontal lesions, who had spared autobiographical memory but showed a moderate deficit on a constructed experience task. [Wheiler, Suchan, Koch, Schwarz, and Daum \(2011\)](#) have documented differences in the impairments of memory and imagination, underlining an asymmetric demand on cognitive processes, and, particularly, on executive functions in two patients with lesions in the medial dorsal thalamus. However, these two recent studies focussed on patients' deficits at “coherently integrating relevant memory elements in a successful collage” ([Berryhill et al., 2010](#), p. 1392). This is not the case in our own study. In fact, our patients' collages were successful when they were asked to imagine fictitious events. Thus, our patients proved able to integrate relevant memory details into coherent scenarios. Our study shows a specific asymmetry between past and future events and between future plausible and fictitious events. Furthermore, it attempts to make a more explicit and specific link between FT impairments and executive dysfunction, investigating the subcomponents underling these impairments. The association that we observed (between FT performance and the Sensitivity to Interference FAB subtest) contributes to explaining the divergence between the spared ability to imagine new fictitious experiences and the compromised ability to imagine familiar future episodes. Our patients had a normal ability to access and select elements from their memory, as testified by their normal performances on the scene construction task, which involves a high recombination demand. They could, in fact, easily imagine a completely novel event, which is less prone to being affected by interferences of similar past episodes. Their deficits stemmed from a failure to construct a slightly different variation of an experienced event. When they tried to imagine a more familiar and plausible future experience they complained about susceptibility to interference, which prevented them from distancing themselves from analogous pre-occurred experiences.

The seven PD patients with FT impairments clearly expressed their own incapability to take distance from their memories in favour of the imagination of completely novel scenarios, “Strangely, when I try to imagine the restaurant where my granddaughter is going to get married, the restaurant where my daughter got married comes up into my mind”, said a patient. And another one complained, “Although I do try to imagine something new, I end up with remembering a past event. I can't help it”. Their spared memories are paradoxically considered by these patients as an obstacle to overcome when they aim at performing the future thinking task. The difficulty in reshuffling details from different memories is translated by one of our patients with the feeling that some scenarios “stay still” in mind, as they cannot be fragmented into pieces to be differently used. Such a feeling reflects the default mechanisms underlying a flexible search inside memory repositories. This essential role is indeed played by executive functions.

Therefore, the present study first documents the dissociation between spared episodic memory and the impaired envisaging of future episodes raising the possibility of the involvement of executive functions in generating episodic future thinking (see also [Squire et al., 2010](#)). The PD patients recruited for the current study were, indeed, exempt from other cognitive deficits likely to disrupt their performances.

This dissociation might be due to the greater neural activity that the ability to simulate future events necessitates (Addis et al., 2007; Okuda et al., 2003). Okuda et al. (2003) revealed that specific frontal polar regions were more active when participants thought and reported their future prospects. Recently, Anderson et al. (2012) have suggested that future thinking might be considered more effortful than past memory. Executive functions underlie both processes by monitoring and combining the different details, but future thinking is supposed to place a greater demand on executive functions. And this would explain why, in the case of executive dysfunction, patients show a severe impairment in future imagining, albeit the spared ability to reconstruct their past.

Moreover, the current study shows a selective involvement of specific and distinctive executive sub-functions in the generation of episodic future scenarios, raising the possibility that future thinking is a more costly ability than event generation, likely to be impaired even when the ability to construct experiences *per se* is intact.

At this point, some other potential explanations for this dissociation need to be discussed.

A possible alternative interpretation of the difference between the two tasks (non-temporal and future) might be the involvement of self-related processes present in the future thoughts but not in the non-temporal constructions. A problem in processing conscious awareness of one's own "continued existence" (Szpunar, 2011) in a subjective time could have been at the root of the difference documented in our study, as this deficit could have interfered solely with the attempt to project oneself towards the future. However, this would imply that PD patients presented with clear disorientation in time, which was not detected by the detailed clinical interview nor did they confabulate or show time-based incongruence in their reports.

An alternative account could capitalize on the different procedures that hallmark the two tasks (future thinking, cued by single-words, and non-temporal construction, prompted with full-sentence descriptor). Addis et al. (2007) observed that a greater activation, shown during future tasks, in comparison to past tasks, was evident solely during the initial phase of event generation, the so-called construction phase. Accordingly, in the non-temporal condition, when a full-sentence descriptor was provided, the construction phase might have been facilitated. Basically, the non-temporal condition required the elaboration of a ready scenario, instead of the *ex novo* construction of a complex scenario. The part played by the task used when testing non-temporal or future events is still debated (see Maguire & Hassabis, 2011). Of course, since the temporal connotation and the type of cue differ, one would need to better disentangle their respective components. It is possible, in fact, that an impairment at constructing scenarios might be detected with one type of cue but not with a different cue. Patient H.C., for instance, was found to be impaired (Kwan, Carson, Addis, & Rosenbaum, 2010) and unimpaired (Hurley, Maguire, & Vargha-Khadem, 2011) in two independent studies that used different methodologies.

Our data show that single-word cues elicit clear future thinking deficits in non-amnesic PD patients, and that this specific deficit is further exacerbated by the presence of executive impairments.

Berryhill et al. (2010) maintained that performing event-generation tasks necessitates a widespread range of cognitive functions. Consequently, they raised the possibility that "any kind of cortical brain damage impairs constructed experiences" (p. 1391). Our findings empirically showed that future thinking performance is a more cognitively demanding ability than event generation, given that it implies a flexible, but more monitored and controlled, search within past autobiographical memories, than a scene construction task. For this reason, it might involve different and distinctive cognitive sub-processes. This findings do not exclude the possibility that people rely on their past to

imagine their future. However, we observed that, even when past memories are spared and people can reconstruct their past and elaborate a complex scenario, they might still have difficulties in simulating their future. Thus, we suggest that future thinking benefits from the orchestrated participation of a larger network than that underlying a simple event generation task, and future thinking deficits do not represent a specific feature of amnesia.

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