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# Double dissociation between familiarity and recollection in Parkinson's disease as a function of encoding tasks☆

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ABSTRACT

Parkinson's disease (PD) is associated with episodic memory deficits, but their exact nature is unclear. Some dual-process studies have suggested that recollection is impaired and familiarity is spared in PD, yet others have found the opposite. Our goal was to investigate these memory processes in PD and determine whether the inconsistency among existing findings is related to differences in encoding conditions. We used a process-dissociation procedure with word pairs to estimate familiarity and recollection. In Experiment 1, we used a directed, deep, relational encoding condition (i.e., sentence generation), and in Experiment 2, we contrasted this encoding condition with a shallower, non-directed encoding condition (i.e., read condition). We found a double dissociation as a function of the encoding task: In the *sentence generation* encoding condition, recollection was impaired in the PD patients, but familiarity was spared. In contrast, in the *read* encoding condition, there was no group difference in recollection, but familiarity was impaired in the PD group. Within-subject comparisons revealed that both control and PD participants benefitted from the provision of a directed, deep relational encoding strategy. However, this benefit was manifested as an increase in recollection in the controls, but an increase in familiarity in the PD patients. These findings help to reconcile the extant literature and suggest that episodic memory deficits in PD are two-fold, involving: (1) difficulties instantiating encoding strategies independently, leading to deficits in familiarity, and (2) impaired recollection when encoding strategies are equated across groups. Our results highlight the importance of controlling encoding conditions between groups and of taking account of other variables that may influence the participants' performance, such as deficits associated with normal aging, which may mask deficits in neurodegenerative diseases in particular situations. More generally, our study raises the possibility that deficits in recollection or familiarity in patient populations are not immutably linked to the structure that is affected, as is typically assumed, but that such deficits may interact with type of encoding, and possibly with the nature of the retrieval process.



Parkinson's disease (PD) is a neurodegenerative disease that primarily compromises the dopaminergic system and related fronto-striatal circuitry. People with PD show significant motor symptoms but also cognitive difficulties, including executive and memory deficits (for review see Zgaljardic, Borod, Foldi, & Mattis, 2003). With respect to memory, greater deficits are often seen on free recall relative to recognition tasks, although deficits can also be seen on the latter (Whittington, Podd, & Kan, 2000). Dual-process models (for reviews see Eichenbaum, Yonelinas, & Ranganath, 2007; Yonelinas, 2002) provide an explanation of this dissociation. According to these models, free recall relies more heavily on recollection, a process that enables retrieval of contextual information, whereas recognition can additionally be supported by familiarity, which usually is a fast, automatic process characterized by a general feeling of oldness without conscious retrieval of contextual information. Thus, the dissociation between free recall and recognition in PD may reflect a selective or greater impairment of recollection relative to familiarity.

Surprisingly, however, findings using methods designed to provide more pure estimates of recollection and familiarity are mixed. On the one hand, three studies using the remember-know procedure in recognition memory have found impaired recollection but intact familiarity in PD (Barnes, Boubert, Harris, Lee, & David, 2003; Edelstyn, Mayes, Condon, Tunnicliffe, & Ellis, 2007; Edelstyn,

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Shepherd, Mayes, Sherman, & Ellis, 2010). Similarly, PD participants show greater deficits in source monitoring than in item recognition (Drag, Bieliauskas, Kaszniak, Bohnen, & Glisky, 2009). On the other hand, the exact opposite pattern of results, that is, marked impairments in familiarity but relatively intact recollection, has been found using converging methods, such as word-frequency, remember-know and process-dissociation procedures, across two studies (Davidson, Anaki, Saint-Cyr, Chow, & Moscovitch, 2006; Weiermann, Stephan, Kaelin-Lang, & Meier, 2010).

How can we reconcile these findings? A type 1 statistical error is unlikely to be the culprit given that both patterns have been replicated across tasks and studies. Differences in disease-related or patient characteristics may be important. Edelstyn et al. (2007) noted that the Davidson et al. (2006) patients appeared to be in the early stages of the disease and to have normal executive functions. However, in a subsequent study, Edelstyn et al. (2010) showed that disease severity and medication status (on or off) were associated with recollection, but not with familiarity. In addition, the degree of executive dysfunction was not correlated with either recollection or familiarity (Drag et al., 2009; Edelstyn et al., 2007). Thus, the patient-related variables investigated to date may help account for the presence or absence of recollection deficits in PD across studies, but cannot easily account for the variability in familiarity and, more crucially, for the selective familiarity deficit documented by Davidson et al. (2006) and Weiermann et al. (2010). It remains possible that the patients who participated in the latter studies differed fundamentally from those in the former studies, but the exact nature of this difference is not obvious.

Instead, differences in method may provide a more viable explanation for the disparity among existing findings. Although many aspects of the paradigms in the aforementioned studies have differed, a consistent distinction involves encoding conditions. In both Davidson et al. (2006) and Weiermann et al. (2010), participants were instructed to read words aloud and try to commit them to memory. Thus, encoding was intentional, but non-directed, in that participants could adopt whatever strategy they wished in addition to reading words. In contrast, the other aforementioned studies involved more directed, deep encoding processes in terms of levels-of-processing (Craik & Lockhart, 1972) [e.g., pleasantness ratings (Edelstyn et al., 2007; Edelstyn et al., 2010), likelihood of hearing target sentences on the radio (Drag et al., 2009), or estimation of drawing time of target pictures (Barnes et al., 2003)]. In other words, in this group of studies encoding strategy was equated across groups. This may be an important factor because PD patients are thought to have difficulties implementing the optimal encoding strategies spontaneously. This conjecture is supported by some studies showing PD patients' free recall deficits are reduced or even eliminated when both PD and control groups do not use optimal strategies because encoding is incidental (Vingerhoets, Vermeule, & Santens, 2005), or are explicitly provided with the optimal study strategies (Knoke, Taylor, & Saint-Cyr, 1998).

In the current study, our goal was to investigate recollection and familiarity in non-demented PD patients under different encoding conditions. To do so, we used a process-dissociation procedure combined with a verbal paired-associates paradigm previously validated in healthy older adults and patients with unilateral temporal lobe excisions (Cohn, Emrich, & Moscovitch, 2008; Cohn, McAndrews, & Moscovitch, 2009). In this paradigm, familiarity and recollection estimates are derived mathematically from participants' performance on two old-new recognition tests: (1) an associative recognition task, in which they must endorse studied word pairs (*intact pairs*) and reject all other pairs (*rearranged*, *half-old*, and *new* pairs), and (2) a pair recognition task, in which they are required to endorse pairs composed of two studied words regardless of their exact pairings (*intact* or *rearranged*), but reject pairs containing at least one unstudied word (*new* and *half-old* pairs). In Experiment 1, PD and healthy controls studied the word pairs using directed, deep relational encoding by creating a sentence out of each word pair *(sentence generation condition)*. In Experiment 2, we investigated the influence of encoding strategies more directly by contrasting two types of encoding conditions in a within-subject design. Each participant completed the verbal paired-associates paradigm under the same *sentence generation* condition used in Experiment 1 as well as under a *read* condition, which was a non-directed, more shallow encoding condition similar to that used by Davidson et al. (2006) and Weiermann et al. (2010). Specifically, participants were instructed to read each pair aloud and try to remember the pair for later recognition. Should the encoding instructions be the critical factors accounting for the discrepancies noted in the literature, we would expect a double dissociation: Our *sentence generation* condition should lead to impaired recollection and intact familiarity in the patients, whereas our *read condition* should lead to impaired familiarity and intact recollection. If we found this pattern it would help to reconcile the seemingly opposing sets of published findings. In addition, we asked whether any memory benefit provided by the deep, relational encoding strategy was due to increases in familiarity or recollection, and whether the benefit would be similar for PD patients and healthy controls.

## 1. Experiment 1

### 1.1. Method

#### 1.1.1. Participants

Eleven participants with PD, free of dementia and depression, were recruited from Baycrest Centre for Geriatric Care. Eleven age- and education-matched healthy control participants were recruited from the University of Toronto Adult pool. They received $10.00/h compensation for taking part in this study. Demographic information is provided in Table 1. The two groups did not differ with respect to age, education, or Mimi-Mental State Examination score (MMSE, Folstein, Folstein, & McHugh, 1975).

#### 1.1.2. Materials

A total of 192 seven-letter nouns and 192 six-letter nouns were combined to create semantically unrelated pairs. Each word had two possible pairings. Pairs were arranged into lists of 12 pairs equated on Kucera–Francis frequency ($M = 37.0$, range = 2–211). Lists were assigned to one of four types of items (new pairs, half-old pairs, rearranged pairs, and intact pairs) and to one of two test types (pair and associative recognition tests), counterbalanced across participants. A total of 120 pairs were included in the study phase, in addition to three buffer pairs placed at the beginning of the study phase and three buffer pairs placed at the end to reduce primacy and recency effects, respectively. The two recognition tasks included a total of 96 pairs of which 24 were *intact* pairs (previously studied pairs), 24 were *rearranged* pairs (studied words rearranged in novel pairings), 24 were *half-old* pairs (first or second word was studied but was combined with an unstudied word) and 24 were n*ew* pairs (pairs composed of non-studied words).

#### 1.1.3. Procedure

At study, participants were instructed to use an intentional deep relational encoding strategy. Specifically, they were to remember the words and their pairings for a later test, and were required to generate aloud a complete sentence that contained the two words and maintained both the form (i.e., singular noun) and order of the words as they appeared on the screen. Each pair was presented for 5 s followed by a fixation cross, which remained until the sentence was completed or until a reasonable delay had elapsed even if participants were unable to initiate or complete a sentence for that particular pair. On average, PD participants completed the study phase in 14 min and healthy controls completed it in 15 min. PD partic-

**Table 1**
Demographic characteristics.

| | *N* | Age | Education (years) | MMSE | Duration of illness (years) |
|---|---|---|---|---|---|
| *Experiment 1* | | | | | |
| PD | 11 | 67.0 | 14.7 | 29.0 | 6.4 |
| Controls | 11 | 66.7 | 15.1 | 29.1 | |
| *Experiment 2* | | | | | |
| PD | 9 | 66.0 | 16.4 | 29.3 | 7.5 |
| Controls | 9 | 64.4 | 15.9 | 29.1 | |

**Table 2**
Mean and standard deviation of "old" responses per item type for each recognition task.

| | Pair recognition task | | | | Associative recognition task | | | |
|---|---|---|---|---|---|---|---|---|
| | New | Half | Rearranged | Intact | New | Half | Rearranged | Intact |
| *Experiment 1* | | | | | | | | |
| PD – sentence | 0.22 (0.13) | 0.46 (0.21) | 0.67 (0.15) | 0.75 (0.12) | 0.10 (0.10) | 0.21 (0.15) | 0.42 (0.26) | 0.62 (0.14) |
| Controls – sentence | 0.17 (0.11) | 0.39 (0.14) | 0.70 (0.15) | 0.78 (0.15) | 0.06 (0.06) | 0.14 (0.14) | 0.25 (0.15) | 0.69 (0.09) |
| *Experiment 2* | | | | | | | | |
| PD – read | 0.25 (0.22) | 0.38 (0.19) | 0.52 (0.19) | 0.58 (0.18) | 0.22 (0.20) | 0.28 (0.16) | 0.38 (0.12) | 0.57 (0.17) |
| PD – sentence | 0.23 (0.18) | 0.40 (0.17) | 0.63 (0.16) | 0.71 (0.20) | 0.13 (0.12) | 0.17 (0.12) | 0.39 (0.25) | 0.65 (0.16) |
| Controls – read | 0.19 (0.14) | 0.38 (0.19) | 0.64 (0.20) | 0.64 (0.20) | 0.14 (0.15) | 0.25 (0.19) | 0.43 (0.20) | 0.57 (0.13) |
| Controls – sentence | 0.17 (0.18) | 0.39 (0.26) | 0.66 (0.20) | 0.73 (0.18) | 0.08 (0.13) | 0.20 (0.18) | 0.28 (0.19) | 0.64 (0.21) |

ipants and healthy controls were successful in generating sentences with 93% and 90% of the pairs, respectively.

Following the study phase, participants completed the pair recognition and the associative recognition tests in a counterbalanced order. Practice trials using the buffer items from the study phase were administered prior to each task to ensure that the instructions were understood. For the associative identification recognition task, participants were required to endorse pairs presented in their studied pairings (intact pairs) and reject all other pairs (*new*, *half-old* and *rearranged* pairs). For the pair recognition task, participants were required to endorse pairs composed of two studied words, regardless of their pairing (*intact* and *rearranged* pairs) and reject pairs containing at least one unstudied word (new and half-old pairs). Both speed and accuracy were emphasized. Participants keyed-in their "old" and "new" responses with their left and right index fingers using the "v" and "m" keys. Pairs were presented in a random order at all phases. E-Prime software was used for presentation and data collection.

#### 1.1.4. Results and discussion

The proportion of "old" responses to each pair type (*new*, *half-old*, *rearranged* and *intact*) in the pair and associative identification recognition tasks are presented in Table 2. We computed parameters of familiarity and recollection using an adaptation of the process-dissociation procedure (Jacoby, 1991; Yonelinas, Regehr, & Jacoby, 1995) that we had used previously with the current tasks (Cohn et al., 2008, 2009). This procedure, like other methods used to derive familiarity and recollection parameters (e.g., remember-know), is based on the assumption that recollection is a categorical process (i.e., present or absent) rather than a continuous one (for alternative views see Mickes, Wais, & Wixted, 2009; Onyper, Zhang, & Howard, 2010). In line with the categorical assumption, the estimate of recollection is based on the proportion items that are recollected and the estimate of familiarity is based on items that are not recollected. Thus, this method does not permit one to separate the respective contribution of each process to a unique response given to a single item, although it permits a more fine-grained analysis of the two processes relative to a task-based approach (e.g., comparing recognition to free recall).

In the current paradigm, the respective contributions of familiarity and recollection to recognition memory are estimated from the proportion of "old" responses to *rearranged* items in the pair task (which are hits resulting from either recollection or familiarity), and the proportion of "old" responses to *rearranged* pairs in the associative tasks (which are false alarms arising from familiarity in the absence of recollection). This method also takes into account potential differences in response bias by incorporating baseline false alarm rates to *new* items from each task in the calculations. Recollection is essentially the difference in the proportion of "old" responses to *rearranged* items between the two tasks corrected for response bias. Familiarity is the ability to discriminate *rearranged* from *new* items in the pair task that is not due to recollection. The familiarity estimate is based on signal detection theory and is expressed in $d'$.

Familiarity and recollection estimates are presented in Fig. 1. Non-parametric statistical tests were used to compare these estimates across groups because scores were not normally distributed in each group. Recollection was reduced in the PD group relative to healthy controls (Mann–Whitney $U = 92$; $p < 0.05$). In contrast, there was no significant difference between groups in familiarity (Mann–Whitney $U = 49$; $p = 0.45$).

These results replicate findings from studies of PD in which directed encoding conditions were used (Barnes et al., 2003; Drag et al., 2009; Edelstyn et al., 2007, 2010). Although they are in line with the idea that encoding condition may be an important variable in explaining why divergent findings exist in the literature, they do not provide direct evidence. We sought to test the impact of encoding conditions more directly in Experiment 2 by comparing recollection and familiarity in PD and control participants across two encoding conditions: one directed, deep relational encoding condition (sentence generation) and one non-directed, shallow condition (read condition). The two conditions were administered in a within-subject design, eliminating possible effects related to individual differences.

## 2. Experiment 2

### 2.1. Participants

Nine participants with PD, free of dementia and depression, and nine age and education-matched healthy control participants were recruited from Baycrest Centre for Geriatric Care and from the University of Toronto Adult pool. They received $10.00/h compensation for taking part in this study. Demographic information is provided in Table 1. The two groups did not differ with respect to age, education, or MMSE score.

### 2.2. Materials

A total of 384 seven-letter nouns and 384 six-letter nouns were combined to create semantically unrelated pairs. As in Experiment 1, each word had two possible pairings and pairs were arranged

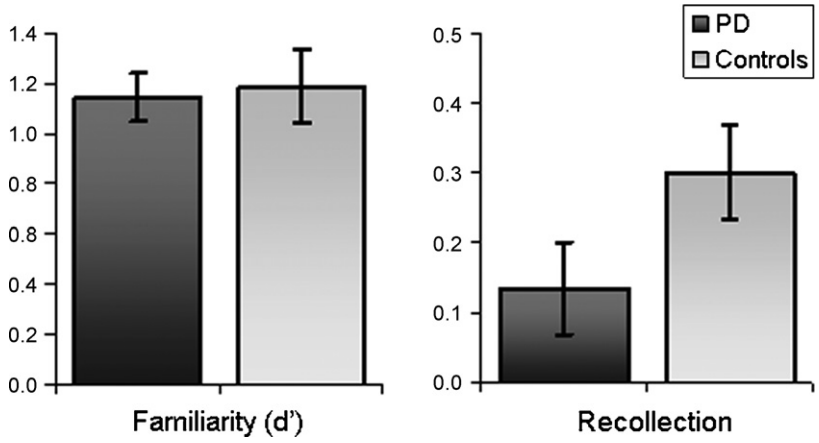


**Fig. 1.** Process dissociation procedure parameter estimates under sentence generation encoding in Experiment 1.

into lists of 12 pairs equated on Kucera–Francis frequency ($M = 36.3$, range = 1–211). Lists were assigned, in a counterbalanced manner, to one of two encoding conditions (read and sentence generation), one of four types of items and one of two test types (pair and associative recognition tests). The study phase for each encoding condition (read and sentence generation) included 120 pairs and six buffers and the each recognition task included 96 pairs (24 *intact* pairs, 24 *rearranged* pairs, 24 *half-old* pairs and 24 n*ew* pairs).

### 2.3. Procedure

Participants completed two study-test blocks in a counterbalanced order; one for the sentence generation encoding condition and one for the read condition. A 5–10 min break was given between blocks. The procedure for the sentence generation encoding condition was identical to that used in Experiment 1. On average, PD participants completed the study phase in 16 min and were able to generate sentences with 94% of the pairs, and healthy control participants completed the study in 15 min and generated sentences for 90% of the pairs. In the read condition, participants were instructed to remember the words and their pairings for a later memory test and were required to read each pair aloud. Pairs were presented for 5 s followed by a 1 s fixation cross. The duration of the study phase was approximately 13 min.

Each study phase was followed by a pair recognition task and an associative recognition task given in a counterbalanced order. The procedure for these tests was identical to that used in Experiment 1. Of note, the performance on the critical measures (i.e., estimates of familiarity and recollection) of participants from either group did not differ as a function of the order of administration of the encoding conditions.

### 2.4. Results and discussion

The proportion of "old" responses to each pair type (new, half-old, rearranged and intact) in the pair and associative identification recognition tasks for each group and each encoding condition are presented in Table 2 and familiarity and recollection estimates are presented in Fig. 2. Non-parametric statistical tests were used to conduct between group and within-subject comparisons.

In the sentence generation encoding condition, recollection was reduced in PD participants relative to controls (Mann–Whitney $U = 62$; $p = 0.057$), but familiarity was not significantly different between groups (Mann–Whitney $U = 43$; $p = 0.83$). These results replicate findings from Experiment 1. The reverse pattern was seen in the read encoding condition. In this condition, there was no significant group difference in recollection (Mann–Whitney $U = 34$; $p = 0.57$), but familiarity was reduced in the PD group relative to control participant (Mann–Whitney $U = 63$; $p < 0.05$). These results replicate those of Davidson et al. (2006). Taken together, our results provide evidence of a double dissociation between familiarity and recollection across encoding conditions in a group of PD patients.

Because our study included a within-subject design, we could also investigate if and how the provision of a deep, relational encoding strategy (i.e., sentence generation) influences familiarity and recollection relative to a shallower or less directed encoding strategy (i.e., read condition) in PD and control participants. We used Wilcoxon signed rank test to compare familiarity and recollection across the two encoding conditions in each participant group. In controls, recollection was greater in the sentence generation encoding task relative to the read task ($z = 1.96$, $p = 0.05$), but familiarity was not significantly different across encoding conditions ($z = 0.65$, $p = 0.52$). The reverse pattern was seen in PD participants. There was no significant difference in recollection between encoding conditions in the PD group ($z = 0.98$, $p = 0.32$), but familiarity was greater in the sentence generation encoding task relative to the read task ($z = 1.96$, $p = 0.05$). These results illustrate that both group benefitted from directed, deep relational encoding, but this improvement is mediated by different memory processes: recollection in the case of control participants and familiarity in the case of PD participants.

## 3. General discussion

Our results suggest that the nature of the encoding condition might be at the root of seemingly discordant patterns of recollection and familiarity in PD across extant studies which have used a variety of methods (e.g., recall vs. recognition, PDP, remember-know, source and item memory). Essentially, we demonstrated a double dissociation across two encoding conditions using the PDP: Recollection, but not familiarity, was impaired in PD participants under directed, deep, relational encoding (sentence generation), whilst familiarity, but not recollection, was impaired under a non-directed, shallower encoding condition (read condition). Interestingly, gains in performance were seen in both the PD and the healthy control groups in the *sentence generation* compared to the *read* condition, but these gains were specific to different processes. That is, familiarity improved in the PD group to a level similar to that of controls, whereas only recollection improved in the healthy control group.

Our study not only identify a key factor that provides a parsimonious explanation for the conflicting findings in the literature, but to our knowledge, is the first study to demonstrate a double dissociation between familiarity and recollection within the same groups of participants simply by varying the encoding conditions. While this dissociation requires further investigation, it potentially offers insight into the nature of the memory deficits in PD. We propose that these deficits are twofold, involving: (1) executive or strategic aspect of encoding, and (2) recollection per se. We address these two points in turn.

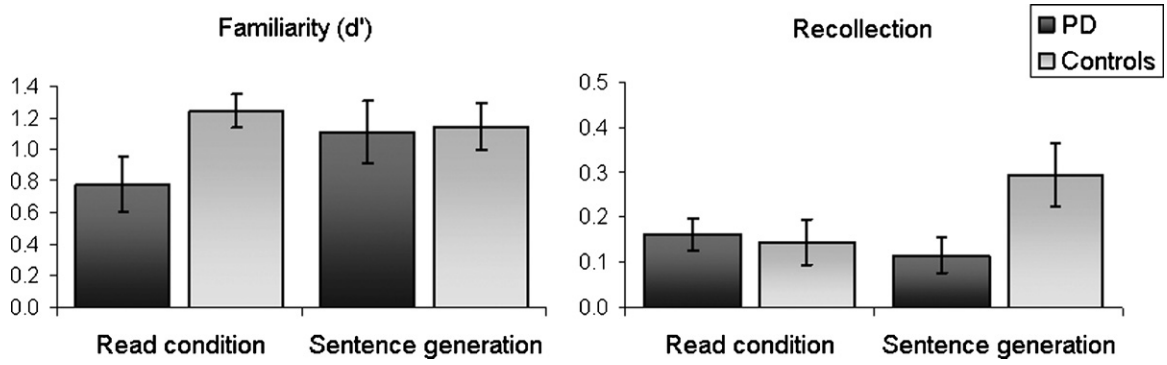


**Fig. 2.** Process dissociation procedure parameter estimates under two encoding conditions in Experiment 2.

As noted in the introduction, PD patients are often impaired at instantiating optimal encoding strategies. This is suggested by the (quasi)normalization of their performance on free recall tasks when the encoding strategy are equated across group either by explicitly providing these strategies to them (Knoke et al., 1998) or by reducing the likelihood of control participants using good strategies by making encoding incidental (Vingerhoets et al., 2005). In the current study, this strategy failure was associated with poor familiarity in the PD group under the read condition. On the surface, this condition provides a shallow strategy. However, this condition is also non-directed as the combined intentional nature of the encoding instruction and the slow rate of item presentation likely encouraged and permitted the instantiation of additional study strategies which are predicted to be of better quality in the control relative to the PD group. The mechanism by which this difference in strategy results in differences in familiarity is unclear. *Good* strategies likely involve deeper processing of information (Craik & Lockhart, 1972) and may also increase the attention resources invested in the task. Ample evidence suggests that both the level-of-processing of the information and attention influence familiarity to some degree in healthy individuals (for review see Yonelinas, 2002). These effects, especially those pertaining to attention, may be amplified in a population known to have attentional deficits (Serrano & Garcia-Borreguero, 2004; Sharpe, 1990).

One caveat regarding this explanation is that level-of-processing and attention have generally been shown to have a greater effect on recollection than on familiarity (for review see Yonelinas, 2002). If so, then how might we explain the absence of a group difference in recollection under shallow non-directed encoding? We propose that our findings, like those of Vingerhoets et al. (2005) under incidental encoding, should not be interpreted as evidence of intact recollection in PD in this condition, but rather as showing impaired recollection in controls that reduces them to the level found in PD. Indeed, the recollection scores obtained under the read condition are rather low (PD = 0.16 and controls = 0.15). Theses scores are comparable to those we have obtained from patients with memory impairment related to unilateral mesial temporal lobe resections (0.12 and 0.17 depending on whether the resection was on the right or left side (Cohn et al., 2009)). More compelling findings in support of a deficit in controls under shallow encoding are those obtained by Verfaellie and Treadwell (1993) using another variant of the PDP with densely amnesic participants (mainly Korsakoff) and alcoholic aged-matched controls. As expected, recollection was impaired in amnesic participants relative to control participants (0.01 vs. 0.33) under a deep encoding condition (i.e., solving anagrams). However, as in our read condition, recollection was equivalent, 0.11 for both groups, under a shallower read condition, a score that was significantly poorer relative to controls' performance under the deep condition. Given this pattern of results, it is inappropriate to describe memory in the shallow condition as 'intact' in individuals whose memory is otherwise severely impaired.

A variety of factors may contribute to memory reduction in controls. One is the encoding task that is used. Indeed, we have demonstrated that a read condition leads to poor associative memory in young adults, which is heavily reliant on recollection (Cohn & Moscovitch, 2007). Thus, this condition leads to poor recollection of associative information in all populations, including groups with optimal memory functioning. A second could be the strategies adopted by control participants at retrieval. For instance, they may have placed greater emphasis on familiarity than recollection to support their memory decision in the read condition. Such a strategy would result in underestimating their true recollection. Lastly, the age of the participants may be a factor. Recall that the healthy controls are matched in age to the PD group and that healthy aging is also associated with deficits in strategic encoding (Naveh-Benjamin, 2000; Naveh-Benjamin, Brav, & Levy, 2007). This age-related memory strategy difficulty may be milder than in PD (as are their difficulties with executive functions), resulting in a relatively selective recollection deficit.

Our second point is that PD is associated with an added recollection deficit which is greater in magnitude than that seen in normal aging, and which prevents them from capitalizing on good encoding strategies. Whereas providing a good encoding strategy to the control group (i.e., sentence generation) resulted in gains in recollection for them, no such benefit was seen in PD. Our results contrast with those of Knoke et al. (1998) in which the description of an optimal study strategy prior to encoding improved free recall in PD but had no beneficial effect for healthy controls. The reason for this discrepancy is unclear given the numerous differences in the methods used (e.g., type of encoding strategy, list-length, test format, numbers of repetition, etc.) Nevertheless, in our study, patients' recollection deficit seems independent from their strategic deficits at encoding, but we cannot determine for certain that deficits in the executive aspect of memory do not contribute to poor recollection scores given that strategies are also required at retrieval. Indeed, recollection is a rather effortful process, especially in the context of the paradigm used here. For instance, participants must arguably use a *recall-to-reject* strategy (using recollection in order to reject a familiar lure), in order to reject rearranged pairs in the associative recognition task. Despite this, these executive dysfunctions are unlikely to be the central reason for recollection deficits in PD, especially in light of low correlations between executive functions and recollection in PD (Drag et al., 2009; Edelstyn et al., 2007).

Alternatively, recollection deficit in PD may represent a *purer* memory deficit related to dysfunction of mesial temporal lobe (MTL) structures such as the hippocampus. The hippocampus is thought to be crucial in supporting recollection and surrounding cortices, such as the perirhinal, are thought to support familiarity according to some neurocognitive models of memory (for review see Eichenbaum et al., 2007). Recent volumetric MRI studies have documented atrophy in the hippocampus in PD, as well as correlation between hippocampal volume and memory function as measured on standardized neuropsychological recall tests (for review see Ibarretxe-Bilbao, Tolosa, Junque, & Marti, 2009). However, MTL atrophy is not limited to the hippocampus and correlations between recall and atrophy in neighboring MTL regions, including the amygdala, fusiform gyrus, uncus and middle temporal gyrus, have also been documented (Bouchard et al., 2008; Camicioli et al., 2009). To date, no studies have explored the relationship between the extent of the atrophy in MTL subregions and recollection and familiarity, or recall and recognition, in PD. The selective deficit in recollection under the sentence generation condition may suggest more focal hippocampal dysfunction in our PD group given that patients with more extensive MTL damage (i.e., left unilateral temporal lobe excision for the treatment of epilepsy) have a comparable recollection deficit but worse familiarity (Cohn et al., 2009).

## 4. Conclusion

We propose that PD is associated with deficits in the executive aspect of memory encoding due to fronto-striatal and MTL dysfunction, which leads to poor familiarity and recollection. When environmental support is provided in the form of deep relational encoding strategies, familiarity is much improved, but recollection remains impaired. This suggests that PD is also associated with a *purer* memory deficit likely related to hippocampal dysfunction. In addition, our study highlights the importance of controlling or equating encoding strategies between groups in order to isolate their contribution to the memory profile of PD patients and to investigate other aspects of memory functions. It is also a reminder

that the cognitive strengths and weaknesses associated with neurodegenerative conditions should be interpreted in light of the fact that the healthy controls also present with age-related memory dysfunctions that may mask deficits in patient groups in particular situations. More generally, our study raises the possibility that deficits in recollection or familiarity in patient populations are not immutably linked to the structure that is affected, as is typically assumed (see Eichenbaum et al., 2007, as an example). Instead our study suggests that such deficits may interact with type of encoding, and possibly with the nature of the retrieval process. If effects such as those reported in this study are true of other groups with memory disorders, the implication of our findings for neuropsychological theories of memory could be far-reaching.

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