Title: Fluency-based memory decisions in Alzheimer's Disease: A matter of source detection?

Running Title: Fluency-based memory in AD

Word Count: 8668

Abstract

Objective: The primary aim of this study was to test whether differences in the ability of patients with Alzheimer Disease (AD) and healthy participants to detect alternative sources of fluency can account for differences observed in the use of fluency - i.e., the ease with which information is processed - as a cue for memory.

Method: Twenty-two patients with AD and 22 matched controls were presented with three forced-choice visual recognition tests. In each test, an external source of fluency was provided by manipulating the perceptual quality of the items during the test phase. The detectability of the perceptual manipulation varied in each test (i.e., 10%, 20%, or 30% contrast reduction were given).

Results: Data indicated that AD patients rely on fluency in a similar extent than older adults as long as they demonstrate intact detection of differences in the perceptual quality of the items. Specifically, it appears that patients' ability to visually discriminate stimuli differing in terms of their perceptual quality is critical for patients to be able to implement strategies to appropriately use or correctly disqualify fluency during a recognition task.

Conclusion: Overall, these findings suggest that the disruption of some basic cognitive processes could prevent AD patients to experience fluency in a similar extent than healthy controls. However, when the ability to detect differences in the perceptual quality of the stimuli was taken into account, patients appeared to be as able as controls to rely on fluency to guide their memory decisions.

Keywords: Alzheimer Disease; Recognition Memory; Familiarity; Fluency

Public Significance Statements: Although memory deficit is one of the core symptom is Alzheimer Disease (AD), studies suggest that some memory processes may be preserved in AD. This study is an attempt to determine why AD patients do not take full advantage of these spared memory abilities. Our results suggest that processes outside of the memory domain may account for this difficulty.

Introduction

Memory deficits stand in the foreground from the earliest Alzheimer Disease (AD) stages. However, not all forms of episodic memory are equally impaired. For instance, in one study, patients with AD showed some ability to discriminate studied from unstudied word, but were at chance when they had to identify the color in which each recognized word was previously presented (Tendolkar et al., 1999). Within the dual-process account, such dissociations could be interpreted as evidence that AD leads to more pronounced deficits in recollection – i.e., typically defined as the ability to mentally relive past events in vivid details – than in familiarity – i.e., defined as a vague feeling of "oldness" associated with past experiences (Yonelinas et al., 2002). However, while studies usually show consistent results regarding the impairment of recollection (e.g., Ally, Gold, & Budson, 2009; Westerberg et al., 2006), data are far from being so clear when it comes to familiarity. Indeed, although some studies display results in favor of an alteration of familiarity (Ally et al., 2009; Westerberg et al., 2006; Wolk, Signoff, & DeKosky, 2008), others find evidence in favor of a preservation of familiarity (Embree, Budson, & Ally, 2012; O'Connor & Ally, 2010). Even more intriguing, it has been found that the same sample of patients with Mild Cognitive Impairment, who are at high risk of developing AD, demonstrated impaired familiarity in one task and preserved familiarity in another task (Besson et al., 2015).

The latter finding suggest that, in order to understand the effect of AD pathology on familiarity, it is necessary to pay attention to the mechanisms underlying familiarity-based memory decisions with the aim of determining whether a selective alteration of these mechanisms could account for the discrepant findings obtained in the literature. One mechanism that is usually supposed to account for the feeling of familiarity is processing fluency – i.e., the ease with which information is processed. The idea is the following: because previous exposure to an item generally enhances processing fluency, people learn to interpret the feeling of fluency as a sign of prior encounter with a stimulus. This attribution of fluency to past experience creates the feeling of familiarity (Jacoby & Dallas, 1981; Kelley & Rhodes, 2002; Whittlesea, 1993). Specifically, research documenting the circumstances under which

processing fluency can generate a subjective feeling of familiarity has revealed that several steps have to be completed for people to make familiarity-based memory decisions: (a) participants have to understand at some general level that fluency is a cue that can be used to inform memory judgments, (b) they have to experience a feeling of fluency when processing a stimulus, and (c) they have to attribute this feeling of fluency to their memory (Jacoby, Kelley, & Dywan, 1989). In other words, fluency experiencers have to decide whether fluency can be used as a source of evidence when making a memory decision (Whittlesea & Williams, 1998). If the two first steps are not fulfilled or if attributional processes are too stringent, fluency will not give rise to a feeling of familiarity. On the reverse, if the two first steps are fulfilled, but that attributional processes are too lax, participants will become over-reliant on fluency, increasing the frequency of memory errors.

Using perceptual priming tasks, several authors have already established that the ability to experience fluency when processing a stimulus is preserved in AD (Ballesteros & Reales, 2004; Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991). Similarly, several studies have found that patients can strategically control the fluency attribution in exactly the same way as healthy older adults (Ballesteros, Reales, & Mayas, 2007; Fleischman, 2007; Fleischman et al., 2005; O'Connor & Ally, 2010; Simon, Bastin, Salmon, & Willems, 2018; Willems, Germain, Salmon, & Van der Linden, 2009, but see Algarabel et al., 2009 for an exception). In this context, if all the steps of a mature fluency use are spared in AD, how can the inconsistent findings reported in the literature be explained?

An emerging answer to this question could possibly be found in recent research conducted in patients with amnesia. Indeed, studies with amnesic patients have revealed a pattern of results that, at first sight, appears as impaired or abnormal recognition memory performance, but could actually be due to subtle metacognitive changes at the level of attribution processes that are very adaptive for patients' day-to-day functioning (Geurten, Bastin, Salmon, & Willems, 2019; Geurten & Willems, 2017; Ozubko & Yonelinas, 2014). Specifically, Geurten and Willems (2017; Exp 1) examined the influence of the introduction of an alternative (non-mnemonic) source of fluency on patients' recognition decisions

by manipulating the perceptual quality of stimuli during a forced-choice recognition test. They found that amnesic patients disqualified fluency as a cue to memory as if they detected the external source of fluency. On the reverse, healthy participants were shown to faithfully rely on the absolute level of fluency when making their memory decisions, suggesting that they detected the alternative source less readily (see also Geurten et al., 2019). These results indicated that amnesic patients implement more effective strategies than control participants to track biasing fluency sources, leading them to rely on fluency only when they can attribute it to pre-exposure with a high level of confidence.

In this context, we therefore propose that similar metacognitive changes occur in AD. This could explain, at least partly, variable patterns of familiarity-based performance across studies by postulating that in some studies, patients relied on fluency to guide their memory judgements whereas in others, they disqualified it as a relevant source for memory decisions. Therefore, the aim of the present study was to determine whether differences in the ability of AD patients and healthy controls to detect alternative sources of fluency can account for differences observed in the use of fluency. To test this, patients with mild AD and matched controls were presented with three forced-choice recognition tests in which they had to discriminate studied from unstudied unfamiliar drawings. In addition to exposure-related fluency, the influence of an additional (non-mnemonic) source of fluency was investigated by manipulating the perceptual quality of either the studied (target) or the unstudied (distractor) items during each of the three test phases. To do so, we prepared three types of target-distractor pairs by combining stimuli with high and low visual quality. Indeed, according to previous studies, pictures with a high figure-ground contrast are perceived as clearer and easier to process than low-contrast ones (Checkosky & Whitlock, 1973; Whittlesea, Jacoby, & Girard, 1990). Importantly, in the present study, the detectability of the contrast reduction varied in each of the three recognition tests (i.e., picture included in the three tests were respectively given a 10%, 20%, or 30% contrast reduction).

In a previous study using a similar paradigm on patients with amnesia, Geurten et al. (2019) showed that fluency due to pre-exposure influenced patients' responses only when the perceptual

manipulation was barely noticeable (10% contrast reduction) while it influenced control participants both when the external manipulation was barely noticeable (10% contrast reduction) and merely detectable (20% contrast reduction). In line with these results, we thus expect participants to produce a greater correct recognition rate for targets with higher picture quality when the picture quality manipulation remains undetected (Jacoby & Whitehouse, 1989). However, when the perceptual manipulation is detected and judged to be the principal source of the feeling of fluency, we expect participants to attribute fluency to this external source (Whittlesea & Williams, 2000). The critical point, here, is that the level of contrast reduction at which the alternative source will be detected is expected to differ between patients and controls. Indeed, if patients with AD implement strategies to more effectively detect alternative sources of fluency, like amnesic patients do, we hypothesize that they would demonstrate reluctance to use fluency at a low level of contrast reduction (i.e., when the external source is relatively difficult to detect; i.e., 20% contrast reduction) while healthy participants would only disqualify fluency at a high level of contrast reduction (i.e., when the external source is easily detectable; i.e., 30% contrast reduction). Finally, if attributional processes are truly preserved in AD, we expect both groups of participants to be able to rely on fluency at a very low level of contrast reduction (i.e., when the alternative source is barely noticeable; i.e., 10% contrast reduction). To test this, the difference between participants' rates of correct recognition for targets with higher picture quality and for targets with lower picture quality will be compared in each experimental test.

However, as opposed to patients with isolated memory impairments, patients with AD also demonstrate a decline in other cognitive functions. An alteration of these functions could prevent them to detect alternative sources of fluency as effectively as patients with isolated memory deficits. Specifically, visual discrimination problems (i.e., including the identification of overlapping shapes, contrast sensibility, or color perception) and diminished attentional resources which are very common in AD (Arnaoutoglou et al., 2017; Cormack, Tovee, & Ballard, 2000; Gilmore & Whitehouse, 1995; Levinoff, Li, Murtha, & Chertkow, 2004; Ruiz-Rizza et al., 2017) could reduce the likelihood of patients to track down the perceptual manipulation. Consequently, it is possible that the ability of patients with

AD to regulate their use of fluency depends on their general ability to detect perceptual differences between stimuli. If this hypothesis is confirmed, we expect patients' score on a contrast detection task to predict their use or disqualification of the fluency cue in each of our recognition tests.

Method

Participants

The AD group was composed of 22 patients (8 females) with mild AD (MMSE between 20 and 27), recruited from the Memory Center of the Department of Neurology of CHU Liège (Belgium). Their age ranged from 64 to 88 years and their education level ranged from 9 to 17 years. Patients were diagnosed as having major neurocognitive disorder according to the Diagnostic and Statistical Manual of mental disorders (DSM-V) and criteria for clinically probable Alzheimer Disease following the NIA-AA recommendations (McKhann et al., 2011), with hippocampal atrophy as biomarker of degeneration. Compared to a database of healthy older adults who underwent the same T1 and T2-weighted MRI as the patients, the AD group showed significant volume reduction in the hippocampus. The patients had no mental retardation, no history of psychiatric or neurological illness. They were not engaged in substance abuse and were free of medication that could negatively affect cognitive functioning. They also had normal or corrected to normal vision. The Free and Cued Selective Remembering test (FCSRT; 1997) of episodic memory was used to ensure that all patients truly demonstrated significant memory impairments.

Moreover, one healthy participant was matched with each AD patient for age, gender (n = 22; 8 females), and education level. They were all non-institutionalized, alert, and subject to the same exclusion criteria as the AD group. They were recruited by word-to-mouth. Their age ranged from 66 to 88 years and their education level ranged from 7 to 17 years. The control and the patient groups did not differ significantly in age or education, all *ps* > .75. No older adults were excluded as they all had scores above 27 (M = 29.1) at the Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975).

Patients and controls characteristics are displayed in Table 1. None of them received any compensation for their participation.

< Table 1 >

Required sample size was determined a priori to reach a predicted power of .80 (alpha = .05, beta = .20) for a triple interaction of small-to-medium effect size, *f* = .20 (Cohen, 1988) with two within-participant factors. This effect size was estimated on the basis of similar research in laboratory settings examining fluency use and fluency disqualification in AD (Willems et al., 2009).

Materials

The stimuli were taken from the study of Geurten and Willems (2017). Specifically, three series of 60 drawings with limited pre-experimental familiarity were created from abstract paintings and randomly assigned to one recognition test. Thirty figures of each series were randomly assigned to Set A. The 30 remaining pictures of each series were assigned to Set B. Set A served as targets and Set B as distractors for the first half of the participants. Set B served as targets and Set A as distractors for the other half of the participants.

A high-fluency and low-fluency version of each drawing was created by manipulating the figure-ground contrast quality of the figures. To do so, we used the same method as the one employed by Reber, Winkielman, and Schwarz (1998) who degraded both the picture foreground and the picture background. This manipulation has repeatedly been shown to influence processing fluency through its impact on various types of judgments inside and outside the memory domain (e.g., Reber, Schwarz, & Winkielman, 2004; Willems & Van der Linden, 2006). Whatever the test, the high-contrast version of the figures was always the same (i.e., white on black). However, the quality of the low-fluency version of each abstract picture varied as a function of the test. In the first test, figures were given a 10% contrast reduction so the external manipulation of fluency was barely noticeable. In the second test, figures were given a 20% contrast-reduction so the fluency manipulation was detectable but without

attracting participants' attention (Willems & Van der Linden, 2006). In the third test, figures were given a 30% contrast reduction so this external source of fluency was clearly visible.

< Figure 1 >

For each of the three test phases, 30 pairs of target-distractor figures were prepared based on the 60 figures: 10 Target+/Distractor– (i.e., targets had high alternative fluency), 10 Target=/Distractor= (i.e., there was no alternative fluency), and 10 Target–/Distractor+ (i.e., distractors had high alternative fluency) pairs (see Figure 1). The "+" symbol indicated that the stimulus had a high perceptual fluency while the "-" indicated that the stimulus had a low perceptual fluency. Stimuli that were assigned to these three contrast conditions were counterbalanced between subjects.

Procedure

The study was conducted in accordance with the ethics committee of the participating institution (CHU of Liège, Belgium). Written consent was obtained before the study start. Participants were tested individually in a quiet room. Specifically, participants were asked to complete three forced-choice recognition memory tests and one contrast detection test. The three recognition memory tasks were administered in the following order: (a) the 10% contrast reduction test in which the fluency manipulation was barely noticeable, (b) the 20% contrast reduction test in which the fluency manipulation was detectable, and (c) the 30% contrast reduction test in which the contrast manipulation was visible. These three tasks were administered in that specific order so that the inevitable detection of the contrast manipulation in the 30% contrast reduction test would not induce participants to look for contrast differences in the other tests. The three recognition tests were composed of two experimental phases (i.e., a study phase and a test phase) and separated by approximatively 10-minute delays filled with questionnaire completion.

The procedure of both the study and the test phases of the recognition tests were the same as the one described in the paper of Geurten and Willems (2017).

Study phase. Participants were shown 30 to-be-studied white-on-black figures, four times each, in random order. Each study stimulus was presented in the center of the screen for 50 ms, followed by a 17-ms interval. A paradigm of rapid serial visual presentation (RSVP; Potter & Levy, 1969) was used in order to promote fluency-based recognition and reduce the influence of recollection processes (Whittlesea, Masson, & Hughes, 2005).

Test phase. A visual forced-choice recognition memory test immediately followed the study phase. Participants were randomly presented with the 30 target-distractor pairs (10 Target+/Distractor-, 10 Target-/Distractor+, and 10 Target=/Distractor=). Both figures of each pair were presented simultaneously to each participant for 2000 ms followed by a self-spaced interstimulus interval. The side of the screen in which the target stimulus was displayed was randomized over the trials. Participants were asked to point to the drawing they had previously seen.

Contrast detection. Once the three recognition tests were completed, participants were randomly presented with 45 target-distractor pairs of abstract pictures (i.e., 15 pairs retrieved from each recognition test) and were asked to judge which of the two pictures was of better perceptual quality. This procedure was used to examine whether AD patients and healthy participants differed in their ability to detect alternative sources of fluency when their attention is focused on the picture's perceptual quality.

Results

Both classical and Bayesian analyses were conducted. For classical statistics, differences were considered as significant when the p value was $< .05$, unless otherwise mentioned. For Bayesian statistics, we reported the value of Bayes factor in favor of the alternative hypothesis (B_{10}). Lee and Wagenmakers (2014) proposed the following decision criteria: Bayes factors greater than 3 represent substantial evidence for the alternative hypothesis. Bayes factors lower than 1/3 evidence against the alternative. Anything between 1/3 and 3 indicates that more evidence is needed. In the current

experiments, Bayesian tests were conducted using the default priors from our software program JASP (see van de Schoot & Depaoli, 2014).

Contrast Detection Rate

A 2 (Group: controls or AD) x 3 (Contrast reduction: 10%, 20%, 30%) mixed-factor ANOVA on the proportion of correct responses was carried out to determine whether the ability of participants to detect the perceptual manipulation differed across groups as a function of the contrast reduction. The results revealed that the effect of contrast reduction was significant, $F(2,84) = 699.66$, $p < .001$, $\eta^2_p = .94$, $B_{10} = 65.91^{61}$. Specifically, the high-contrast stimuli were selected more often after a 30% contrast reduction (*Mean* = .97) than after a 20% contrast reduction (*Mean* = .66), and after a 10% contrast reduction (*Mean* = .56). Moreover, data also showed that controls (*Mean* = .75) detect the perceptual manipulation at a higher rate than AD patients (*Mean* = .70), $F(1,42) = 23.8$, $p < .001$, $\eta^2_p = .36$, $B_{10} = 9.64$. Finally, the Group x Contrast interaction also came out significant, $F(2,84) = 6.32$, $p = .003$, $\eta^2_p = .13$, $B_{10} = 96.79$. This interaction resulted from the fact that controls showed a higher detection rate than AD patients after a 10% (*Mean* = .59 vs. .53; *SD* = .05 vs. .07), $F(1,42) = 13.91$, $p<.001$, $B_{10} = 49.92$, and a 20% (*Mean* = .70 vs. .62; *SD* = .06 vs. .08), $F(1,42) = 12.79$, $p<.001$, $B_{10} = 34.28$, contrast reduction while no differences were found after the 30% contrast reduction (*Mean* = .97 vs. .97 ; *SD* = .02 vs. .02), $F(1,42) = 0.22$, $p = .64$, $B_{10} < 0.33$.

Correct Recognition Rate

A 2 (Group: controls or AD) x 3 (Contrast reduction: 10%, 20%, 30%) x 3 (Target fluency: Target+/Distractor–, Target=/Distractor=, Target–/Distractor+) mixed-factor ANOVA was carried out to examine the influence of the perceptual fluency manipulation on participants' correct recognition decisions. Contrast reduction and target fluency were the two within-participant factors. The results revealed a Contrast reduction x Target fluency interaction, $F(4, 164) = 4.54$, $p = .002$, $\eta^2_p = .10$, $B_{10} = 2.09$. The Group x Contrast reduction x Target fluency triple interaction was not significant, $F(4, 164) = 1.76$, $p = .13$, $\eta^2_p = .04$, $B_{10} = 1.05$. However, due to our strong hypotheses regarding subtle differences

in fluency use between our two groups, we examined more closely this triple interaction. A classical Bonferroni correction was applied in order not to increase type 1 error. Planned comparison revealed that in the 30% contrast reduction test (i.e., obvious manipulation), both groups gave fewer correct "old" responses when the competing source induced a strong feeling of fluency (Target+/Distractor–) than when it induced a weak feeling of fluency (Target–/Distractor+), M = .43 vs. .59, SD = .22 vs. .23, $F(1,41) = 6.23$, $p = .01$, $\eta^2_p = .17$, $B_{10} = 11.57$, and M = .47 vs. .61, SD = .16 vs. .17, $F(1,42) = 8.48$, $p = .008$, $\eta^2_p = .30$, $B_{10} = 19.27$, for controls and AD patients respectively. Conversely, an opposite profile was observed between our two groups after a 10% contrast reduction test (i.e., barely noticeable manipulation) and a 20% contrast reduction (i.e., detectable manipulation). Specifically, in the 10% contrast reduction test, controls produced more correct "old" responses when the targets induced a strong feeling of fluency (Target+/Distractor–) as compared to when it induced a weak feeling of fluency (Target–/Distractor+) (M = .57 vs. .43; SD = .13 vs. .18), $F(1,41) = 8.24$, $p = .006$, $\eta^2_p = .24$, $B_{10} = 5.67$. This difference was not significant in patients with AD (M = .55 vs. .54; SD = .14 vs. .16), $F(1,41) = 0.04$, $p = .85$, $B_{10} < 0.33$. On the reverse, in the 20% contrast reduction test, our data showed that the controls produced less correct "old" responses when the targets induced a strong feeling of fluency than when it induced a weak feeling of fluency (M = .59 vs. .41; SD = .16 vs. .13), $F(1,41) = 4.53$, $p = .02$, $\eta^2_p = .21$, $B_{10} = 4.22$, while no significant differences were found in patients with AD (M = .50 vs. .48; SD = .17 vs. .15), $F(1,41) = 0.07$, $p = .80$, $B_{10} < 0.33$. No other result reached significance, $F < 1.7$ (see Figure 2).

< Figure 2 >

Relations between Fluency Use and Contrast Detection

Given the differences observed between our two groups in terms of contrast detection rate, we chose to examine whether this variable could influence how participants rely on fluency across our three recognition tests. The goal of the following analyses was to assess whether participants' use of fluency was related to their level of contrast detection in each test. To test this, participants' tendency to rely

on fluency was estimated by subtracting the rate of correct recognitions when the visual manipulation induced a weak feeling of fluency for targets (Target+/Distractor–) from the rate of correct recognitions when the visual manipulation induced a strong feeling of fluency for targets (Target–/Distractor+) in each of the three recognition tests. A positive score indicated a reliance on the fluency cue while a negative score indicated a disqualification of the fluency cue.

In the 10% contrast reduction test (see Figure 3), simple regression analyses revealed that contrast detection rate positively predicted fluency use in patients with AD, β = .66, p = .001, B_{10} = 47.01, but not in controls, β = -.07, p = .75, B_{10} = 0.39. To better characterize these findings, we split our group of AD patients into two subgroups. Patients with a contrast detection rate higher than the mean were put in a "good detection" group (*Mean* = .58; n = 9). Patients with a contrast reduction rate lower than the mean were put in a "poor detection" group (*Mean* = .49; n = 13). A t test was conducted to compare these two groups on their score of fluency use. Results indicated that, when the contrast manipulation is barely noticeable, AD patients who were able to detect the contrast reduction manipulation – at least when explicitly asked to do so – rely on fluency more often (*Mean* = .12; SD = .25) than patients who were not able to detect the manipulation (detection rate at chance level) (*Mean* = -.05: SD = .14), $t(20)$ = 2.07, p = .04, B_{10} = 4.71. Interestingly, when the score of the fluency use of these two subgroups was compared with the score of fluency use of the control group (*Mean* = .14; SD = .16), a significant difference was found with the group of patients who were not able to detect the perceptual manipulation, *Mean* = -0.5, $t(33)$ = 2.52, p = .017, B_{10} = 6.77. However, no differences were found with the patients who were able to detect the perceptual manipulation, *Mean* = .12, $t(29)$ = 0.03, p = .97, $B_{10} < 0.33$.

< Figure 3 >

In the 20% contrast reduction test (see Figure 3), data indicated that participants' tendency to rely on fluency was negatively predicted by contrast detection rate in AD patients, β = -.59, p = .005, B_{10} = 9.28, but not in controls, β = -.21, p = .35, B_{10} = 0.54. The results of the t test conducted to compare the

ability of the "good detection" subgroup (*Mean* = .66; *n* = 13) and the "poor detection" subgroup (*Mean* = .55; *n* = 9) to rely on fluency suggest that, when the contrast manipulation is detectable, participants who were less able to detect the perceptual manipulation were more likely to rely on fluency (Mean = .17; SD = .29) than patients who showed a good ability to detect the perceptual manipulation (*Mean* = -.10; SD = .18), $t(20) = 2.52$, $p = .02$, $B_{10} = 5{,}28$. Accordingly, the latter group appeared to show a tendency toward a disqualification of the fluency cue. When the score for fluency use of these two subgroups was compared with the score of fluency use of the control participants (*Mean* = -.11; SD = .22), a difference was observed with the patients who showed a poor ability to detect the perceptual manipulation, *Mean* = .17, $t(29) = 2.81$, $p = .009$, $B_{10} = 10.93$, but not with the patients showing a good ability to detect the perceptual manipulation, *Mean* = -.10, $t(33) = 0.38$, $p = .70$, $B_{10} < 0.33$.

Finally, in the 30% contrast reduction test, contrast detection was not shown to be related to the score of fluency use either in the control group or in the patients group, all *ps* > .50. However, in the latter case, the rate of contrast detection was nearly perfect in both groups (*Mean* = .97).

Discussion

The primary goal of the present study was to explore whether changes in how patients with AD detect alternative sources of fluency could explain their apparent inability to make memory decisions on the basis of a feeling of familiarity that are sometimes found in the literature. Overall, our data seem to indicate that there is a behavioral difference in how patients with AD and healthy older adults use fluency as a cue to guide their recognition judgments. However, it seems that this difference is better explained by a decrease in the ability to visually detect the fluency manipulation than by an impairment of the ability to strategically rely on fluency. In the following sections, the importance of these results to improve our understanding of both normal and pathological aging will be discussed.

Fluency in Older Adults

Regarding our findings in healthy aging, our hypotheses are mostly confirmed. As in many studies in which participants remains unconscious of the artificial manipulation of their processing experience (e.g., Jacoby & Whitehouse, 1989; Willems & Van der Linden, 2006), our results revealed that, in the 10% contrast reduction, older participants gave more correct responses on pairs where recognition of the target was facilitated by high contrast picture than on pairs where the processing of the distractor was facilitated. This pattern suggests that when the perceptual manipulation is sufficient to have an effect, but subtle enough not to capture the attention, older adults rely on fluency to guide their memory decisions. On the reverse, when the perceptual manipulation was clearly visible (i.e., in the 30% contrast reduction), our data revealed that participants better performed on pairs where the distractor was made easier to process than on pairs where the target was made easier to process. These results are consistent with the discrepancy-attribution framework according to which, high processing fluency is interpreted as a sign of memory when the degree of fluency that is experimented is surprisingly greater than expected given the context, but is disqualified as a cue for memory when an external source producing more fluency expectations than past experience is detected (Whittlesea & Williams, 2000, 2001a, 2001b; Willems & Van der Linden, 2006).

A surprising finding, however, concerns the pattern of results observed in the 20% contrast-reduction. In previous studies conducted in young adults, participants were shown to perform better on pairs where the processing fluency of the target was high than on pairs where the processing fluency of the distractor was high, suggesting that these participants were not able to detect the external manipulation at a medium level of contrast reduction (Geurten at al., 2019; Geurten & Willems, 2017; Willems & Van der Linden, 2006). In the present study, however, older adults showed the reverse pattern: a poorer recognition performance for pairs where the processing of the target was facilitated by higher picture quality, but better recognition performance for pairs where the processing of the distractor was facilitated by higher picture quality.

According to the discrepancy-attribution hypothesis, the latter findings suggest that older adults have detected the perceptual manipulation and judged it as the source of their feeling of fluency, leading them to disqualify fluency as a relevant memory cue. These findings are important because exactly the same results were observed in amnestic patients (Geurten et al., 2019; Geurten & Willems, 2017). According to Geurten et al. (2019; Geurten & Willems, 2017), this pattern resulted from the fact that patients with amnesia progressively start to track alternative sources of fluency in order to reduce the frequency of fluency-based memory illusions that occur more often in their daily life due to an impairment of their recollection processes (Bastin et al., 2004; Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1998). Interestingly, this hypothesis could also explain the results of the present experiment. Indeed, although recollection processes of older adults are not as severely impaired as those of amnesic patients, declines in recollection-based memory is well-established in healthy aging (e.g., Cohn, Emrich, & Moscovitch, 2008; McCabe, Roediger, McDaniel, & Balota, 2009; see Koen & Yonelinas, 2014 for a meta-analysis). Consequently, it is possible that, like amnesic patients, older adults start to implement strategies during the recognition test (e.g., to allocate resources to the detection of perceptual differences between stimuli) in an attempt to compensate for impaired recollection processes. These strategic processes probably aim at helping them to decide whether their feeling of fluency results from prior exposure or from another source.

Fluency in Patients with AD

At first sight, the results obtained in AD seem to indicate that our patients do not rely on fluency as a cue for memory when the external manipulation is barely noticeable (10% contrast reduction) or detectable (20% contrast-reduction), but are able to disqualify it when the fluency manipulation is obvious (30% contrast reduction). However, a finer-grained analysis of these results suggests that the ability of AD patients to rely on fluency actually depend on their perceptual detection skills.

Specifically, in the 10% contrast reduction test, patients who showed a high detection rate when explicitly asked to judge the differences in perceptual quality between stimuli performed better on

pairs where the processing fluency of the target was high than on pairs where the processing fluency of the distractor was high. The latter pattern illustrates the typical use of absolute fluency as a cue for memory. On the reverse, patients who were at chance when asked to explicitly judge the perceptual quality of the items show no significant reliance on fluency. Given their low rate of contrast detection, we assume that contrast reduction was simply not perceptible enough for them to experience a feeling of fluency.

In the 20% contrast reduction test, patients who showed a high level of contrast detection better performed on pairs where the distractor was made easier to process than on pairs where the target was made easier to process, a pattern that is classically observed when fluency is disregarded as a relevant cue to guide recognition judgments. Conversely, patients who showed a low (but above chance) level of contrast detection gave more correct responses on pairs where recognition of the target was facilitated by high contrast picture than on pairs where the processing of the distractor was facilitated, a pattern that is usually obtained when fluency is actually used as a cue for memory. As previously mentioned, in the 30% contrast reduction, all patients reveal a pattern consistent with a disqualification of the fluency cue.

Overall, these results suggest that, at an equivalent contrast detection rate, AD patients appear to rely on fluency in a similar extent than healthy older adults. Indeed, fluency is used to guide memory decisions by all participants when the rate of contrast detection is at around .55-.60. For healthy participants and patients with high detection skills, this rate is achieved when the items were given a 10% contrast reduction while for patients with a low detection rate, this rate is only reached when items were given a 20% contrast reduction. Similarly, all participants seem to be able to disqualify fluency when an alternative source is detected. This result is crucial because it corroborated previous findings in the field showing the preservation of subtle attributional processes in AD (Ballesteros et al., 2007; Fleischman, 2007; Fleischman et al., 2005; O'Connor & Ally, 2010; Willems et al., 2009). This confirms that AD patients can strategically use their metacognitive expectations to control their

fluency decisions in the same way as healthy older adults. However, the level of contrast reduction at which the fluency cue is disqualified in AD varied as a function of the patients' ability to detect the perceptual manipulation. Specifically, it appears that the disqualification occurs when the detection rate reaches .65-.70. The ability of patients to visually discriminate between stimuli of different perceptual quality or to pay attention to subtle perceptual manipulation thus appears to be a critical prerequisite for patients to be able to implement strategies to appropriately disqualify perceptual fluency to regulate their memory errors. This hypothesis is all the more interesting as data in healthy aging have recently revealed that some part of the age-related differences observed in memory performance could be explained by visual perception changes rather than by memory discrimination difficulties (Davidson et al., 2018). To our knowledge, however, this postulate is still to be tested in AD patients.

In this context, it is important to note that, in most previous experiments studying fluency-based memory decisions in AD, the experimental manipulation was calibrated on performance obtained by healthy participants. Specifically, authors did not systematically check whether a paradigm that was previously successful to induce a feeling of fluency in healthy aging was also able to enhance processing fluency in AD patients. Yet, it appears that, at least in some cases, manipulations enabling to induce a feeling of fluency in healthy aging are not necessarily able to induce a similar phenomenological experience in AD. Consequently, it is possible that some of the inconsistent findings reported in the literature regarding how patients with AD use perceptual fluency in memory tasks do not result from a real inability to rely on it, but from the fact that the experimental manipulation was probably not sufficient for them to experience a feeling of fluency. This could possibly explain why, despite a preservation of their attributional processes, AD patients sometimes exhibit a pattern of results suggesting that they are not able to rely on a feeling of familiarity when making memory decisions.

In conclusion, the present study raises a number of interesting considerations that some future studies may fruitfully address. For instance, future experiments should also determine whether the current

results could generalize to tests in which the recognition performance is above chance. Indeed, in the present study, participants perform mostly at chance in the control condition (T=D=). Although further investigations should be conducted to formally test this issue, some responses are already available in the literature. For instance, in studies where a counterfeit encoding is used (i.e., a procedure where participants are told that stimuli are presented in a subliminal manner at study when, in fact, there are not), participants' performance is usually at chance on subsequent tests. Despite this, however, data reveal similar variations in fluency effects after a counterfeit encoding than after a classic encoding condition that leads to above-chance recognition performance (e.g., Lloyd, Westerman, & Miller, 2003; Westerman, Miller, & Lloyd, 2003).

Another interesting line of research would be to determine the exact neuroanatomical and neuropsychological profile of the patients who behave like healthy participants (i.e., patients with a good ability to detect the contrast reduction) and those who did not (i.e., patients with poor ability to detect the contrast reduction). In this study, the only information we had regarding the characterization of these two subgroups is that they did not significantly differ in terms of hippocampal atrophy, MMSE scores, or verbal memory skills. Further investigations of visual perception and attention skills should thus be conducted to help us to better understand what types of patients had difficulties to detect the perceptual manipulation. Indeed, as the division of our sample into subgroups was made a posteriori on the basis of the results of the regression analyses, a new sample of AD patients should be recruited in order to confirm and further explore the current findings. In the same line, a closer investigation of patients' eye problems should be conducted. Although, in the present study, we carried out a thorough medical history on that topic, we did not perform full ophthalmic testing to ensure that patients' sight correction was perfectly up-to-date.

Another limitation of the present experiment is that the three recognitions tests (10%, 20%, and 30% contrast reduction) were always presented in the same order. This confounding of test order may have influenced our results through, for example, an increase of proactive interference for the last tests.

Even though the global performance of our participants was shown to remain stable across tests, which seems to rule out the possibility of an interference effect, our results should nevertheless be replicated using other types of designs. One possibility to overcome this problem could be, for example, to replace the block design used in this experiment by a between-subject design where three groups of patients saw pairs of stimuli with either a 10%, a 20% or a 30% contrast reduction at test. Finally, future studies could also be carried out to determine whether the performance of our patients in the experiment could be related to performance for another sort of recognition task relying on familiarity (e.g., a task where the fluency manipulation is not perceptual, for example).

Regardless of these limitations, however, our results could already have major implications. From a theoretical perspective, our findings could help to resolve the conceptual debate on the question of whether and when familiarity is impaired in AD. Specifically, our study adds to the small amount of literature showing that attributional processes – which have long been assumed to account for the emergence of familiarity (Jacoby & Dallas, 1981) – are probably not impaired in AD. Specifically, our results indicated that, like healthy older adults, patients seem to be able to adequately regulate their fluency use in order to reduce their memory errors, but that an alteration of basic cognitive operations may prevent them to do so when the external source of fluency is difficult to detect.

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Table 1.

Demographic Data and Neuropsychological Performance.

	Healthy Controls	AD
Age (years)	77.1 (5.1)	77.1 (5.9)
Education (Years)	12.1 (3.9)	12.5 (2.5)
Sex (male : female)	13:8	13:8
MMSE	29.1 (1.3)	24.6 (2.4)*
FCSRT – Immediate (3 recalls)	44.73 (2.81)	23.18 (16.32)*
FCSRT - Delayed	13.82 (1.62)	7.36 (4.72)*

Note. AD = Alzheimer Disease; MMSE = Mini Mental State Examination; FCSRT = Free and Cued Selective Remembering test. * Significant differences between groups with a $p < .001$

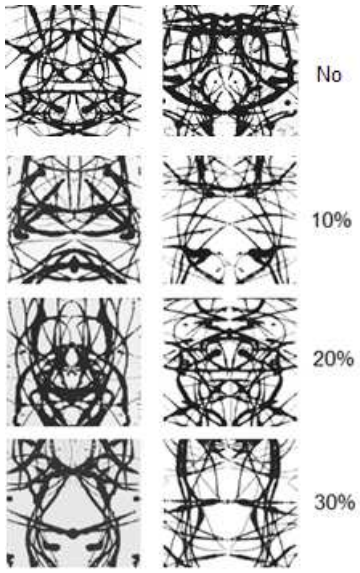

Figure 1. Examples of pairs of abstract pictures used in each contrast reduction test. The items with the reduced contrast are on the left. The control pairs (no contrast reduction) were the same in the three tests.

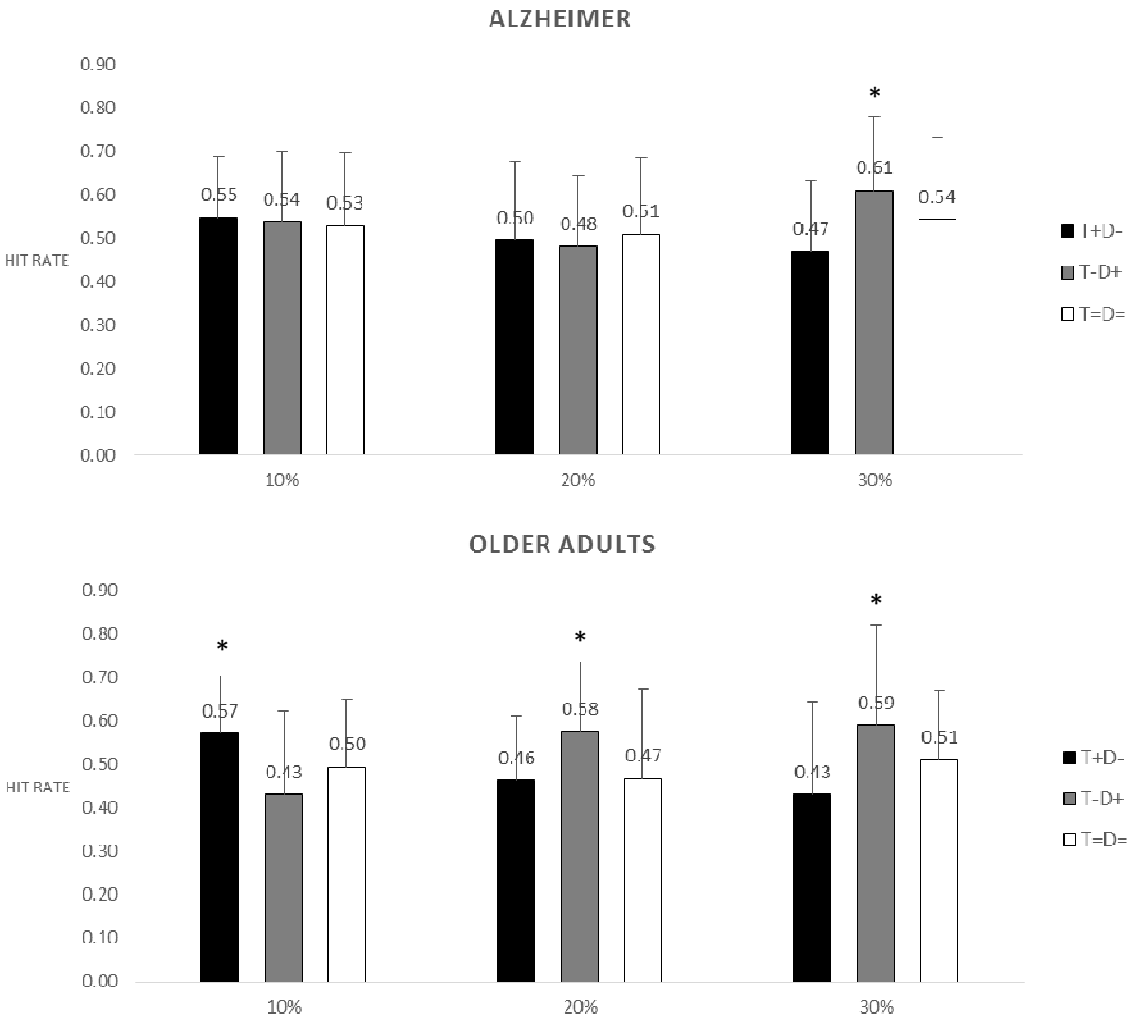

Figure 2. Mean proportion of "Old" responses for targets in the three contrast reduction tests (10%, 20%, and 30%) and the three picture quality (T+/D–: high-contrast target, low-contrast distractor; T=/D=: high-contrast target, high-contrast distractor; T–/D+: low-contrast target, high-contrast distractor) for each group (Control vs. AD). Error bars display the standard deviations. * p<.05 = Hit rate higher than chance.

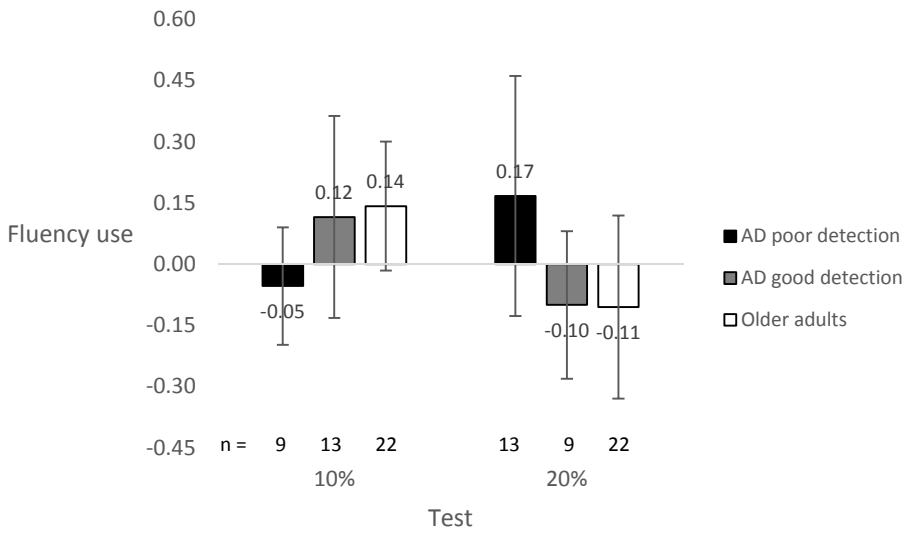

Figure 3. Mean score of fluency use in the 10% and 20% contrast reduction tests for the two subgroups of AD patients (i.e., with good vs. poor contrast detection rate). This score was computed by subtracting the proportion of "Old" responses for targets with a high contrast picture quality from the proportion of "Old" responses for targets with a low contrast picture quality. Error bars display the standard deviations; n = the number of participants in each groups.