Memory and Consciousness in Alzheimer’s Disease

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Abstract: Human memory can be split into familiarity and recollection processes which contribute to different aspects of memory function. These separate processes result in different experiential states. In this review, we examine how this dominant theoretical framework can explain the subjective experience of people with Alzheimer’s disease, the profile of their memory impairments and their inability to reflect on their performance metacognitively. We conclude with a brief overview of the brain regions supporting conscious experience of memory, and propose that the memory and awareness deficits seen in Alzheimer’s disease could be conceived of as a deficit in autonoetic consciousness. A future priority for research is to take these robust constructs into research programmes examining rehabilitation and pharmacological intervention.

Keywords: Recollection, familiarity, awareness, metacognition.

1. OVERVIEW

People with Alzheimer’s disease seem to have information which is inaccessible to recall, such as an inability to name the prime minister, but which is available for recognition, such as correctly picking out Gordon Brown from a set of alternatives. Such a discrepancy between recall and recognition has been cited as evidence of a specific form of memory deficit in AD since patients have memory for a word (recognising it as the correct answer), and yet they cannot retrieve it spontaneously, or recall it. Clinically, tests of recall are more sensitive to Alzheimer brain changes than are tests of recognition [1].

Considering this difference in recall and recognition, the relationship between consciousness and memory is in question. How is it that the patient cannot on the one hand report something, but know it when prompted? In this review we aim to illustrate that there exists a complex relationship between consciousness and memory, and that in Alzheimer’s disease, this relationship breaks down, according to known patterns of neuropathology. We propose that Alzheimer’s disease results in a disconnection between medial temporal and frontal areas and that this leads to a specific deficit in recollection, which is characterised by certain subjective feelings, and evocative, associated and personal information coming to mind during memory retrieval (See Table 1).

The concept of recollection is a relatively recent theoretical development [2] and helps us understand other issues in memory and awareness more generally in Alzheimer’s. In short, the emergent view is that memory function is supported by conscious states, and that a full understanding of memory function is only possible through understanding the experience of what comes to mind in memory [3]. We examine to what extent consciousness and awareness influence memory function and real world behaviours.

2. MEMORY IN ALZHEIMER’S DISEASE

In Alzheimer’s disease, memory impairment is the earliest and most severe cognitive deficit. The commonest means of demonstrating this deficit is to evaluate the number of previously encountered items that can be recovered after a retention interval [1, 4, 5]. Such tests have been shown to be particularly sensitive at detecting pre-clinical changes in memory in people who develop Alzheimer’s disease [6-8]. Additionally, neuroimaging studies have converged on temporoparietal and hippocampal areas as being particularly involved in Alzheimer’s disease. These regions are known to be crucial in learning of new information [9]. Convit et al. [10] demonstrated with volumetric MRI that atrophy in the medial occipito-temporal and the middle and inferior temporal gyri are associated with progression to Alzheimer’s disease. Similarly, pre-morbid volumetric measurements of the hippocampus predict progression [11].

Thus, a large literature points to the fact that people with Alzheimer’s have particular difficulties in retrieving material learnt in previous episodes, and this relates to underlying neuropathology. Cognitive Neuropsychologists see this memory deficit as episodic, relating to a specific study episode. That is, people with Alzheimer’s disease have particular difficulties in learning and recalling recently encountered information, as opposed to material encountered and acquired premorbidly. However, rather than considering the types of materials and tasks which delineate different forms of memory impairment, a contemporary focus is the experiential state during memory retrieval – the state of awareness associated with the act of remembering. Because this conceptualisation opens up new fields of research and has utility in understanding disorders such as Alzheimer’s disease, it is this emergent field that we review here.

This subjective approach was developed by Tulving [12]. He classified memory on the basis of experience, arguing that without considering experience you could not investigate cognition [13]. ‘Self knowing’ or ‘autonoetic’ memory described a memory where the first person experience was of...
‘remembering’. Memory without self-knowledge ‘noetic’ is often described as ‘knowing’ (See Table 1). Episodic memories are self-knowing – that is, some aspect of the memory includes its source, an awareness of its origin, a feeling of pastness, a conscious evaluation of itself, what Koriat and Goldsmith [13] call ‘contextual detail’. As an example, the memory of what one had for breakfast and the circumstances surrounding it, is episodic. Semantic memories concern conceptual knowledge, or facts, such as “Kelloggs is a brand of breakfast cereal.” Using these concepts of remembering and knowing yields many insights into memory dysfunction [14], education [15] and the aging process [16] (For reviews see [17, 18]). Henson et al. [19] have demonstrated that these two subjective states derive from separate brain regions. In particular, hippocampal structures are preferentially engaged for memory decisions based on this form of recollection [20] and hippocampal structures are more active for items which are more strongly ‘remembered’ [21].

One implication of this view is that memory proficiency is dependent upon conscious processes; healthy memory is influenced by reflective monitoring processes and guided by experiential states. For instance, the feeling of remembering arguably guides memory processes acting at retrieval, and influences how confident one feels about that memory, and whether the experient searches for extra detail. If information is retrieved with only a vague feeling of familiarity, one will be less certain of its veracity and less able to draw on information in support of that memory [22]. As developed below, vague feelings may lead the experient to produce false memories.

### 3. MEMORY AND CONSCIOUSNESS IN ALZHEIMER’S DISEASE

#### 3.1. Memory Awareness

Pinker [23] suggests that consciousness comprises three distinct parts: Sentience, Access to Information and Self-Knowledge. Sentience describes subjective experience, phenomenal awareness, feelings of what something seems like. Access to information considers the ability to report ongoing mental experience or operations. Self-knowledge considers whether an organism can know itself and its impact on the world. These concepts are somewhat difficult to measure because of their subjective nature, but the memory literature has focussed on one easily operationalised measure – the accuracy of people’s predictions of their memory, and memory awareness. Each type of prediction is reviewed in turn and the main findings summarized in Table 2.

In everyday life, the ability to know, or to be aware, that one will be able or not to retrieve information is very well described by the tip-of-the-tongue phenomenon (TOT). The TOT is a striking state of awareness – a common and dramatic word-finding failure where a person is temporarily unable to produce a well-known word, despite feeling certain that one knows the word [24]. This phenomenon has not been widely explored in Alzheimer’s disease and the studies have found contradictory results; one study shows that Alzheimer’s disease patients have more TOT states [25] and the other shows that Alzheimer’s patients do not produce more [26]. This issue is one which should be a priority for future research: people who have TOT experiences can be worried that they are a sign of dementia.

Other measures have received more attention in the Alzheimer’s disease literature [22], and are more concrete. If consciousness is impaired in Alzheimer’s disease one would expect that the access to information or self awareness would be impaired. This is easily measured by examining how estimates of performance relate to actual performance. The most common measure consists of asking a participant to predict their future memory performance [27] for currently inaccessible information, the Feeling-of-Knowing (FOK) paradigm. In this task, participants are asked to estimate the likelihood with which they will recognize an item which they have failed to recall [27-30]. A FOK state thus occurs when one believes that one knows a piece of information, and given that the information is not forthcoming, believes that they would be able to identify it if it were shown at a later point in time. Prediction accuracy is obtained by comparing predictions to subsequent recognition of targets [31]; healthy participants make reliably non-chance judgements while patients are unable to accurately gauge whether they would be able to retrieve information accurately or not.

### Table 1. A Contemporary Overview of Memory: Recollection and Familiarity Processes

<table>
<thead>
<tr>
<th>Brain Region</th>
<th>Subjective State</th>
<th>Mental Resources</th>
<th>Conscious State</th>
<th>Contextual or Source Information</th>
<th>Status in Alzheimer’s Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recollection</td>
<td>Hippocampus; Frontal lobes</td>
<td>‘remembering’</td>
<td>Effortful, Slow</td>
<td>Autonoetic</td>
<td>Some</td>
</tr>
<tr>
<td>Familiarity</td>
<td>Peri-Hippocampal Regions</td>
<td>‘knowing’ or finding familiar</td>
<td>Relatively automatic, Quick</td>
<td>Noetic</td>
<td>None</td>
</tr>
</tbody>
</table>

In everyday life, the ability to know, or to be aware, that one will be able or not to retrieve information is very well described by the tip-of-the-tongue phenomenon (TOT). The TOT is a striking state of awareness – a common and dramatic word-finding failure where a person is temporarily unable to produce a well-known word, despite feeling certain that one knows the word [24]. This phenomenon has not been widely explored in Alzheimer’s disease and the studies have found contradictory results; one study shows that Alzheimer’s disease patients have more TOT states [25] and the other shows that Alzheimer’s patients do not produce more [26]. This issue is one which should be a priority for future research: people who have TOT experiences can be worried that they are a sign of dementia.

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The FOK can be measured on newly learned information (Episodic FOK, [29, 30, 32, 33] or for general knowledge (Semantic FOK [34, 35]). Researchers have found that Alzheimer’s disease patients do not present a uniform profile of performance across tasks and materials. Souchay et al. [33] found striking deficits in episodic FOK. Alzheimer’s disease patients were unable to accurately gauge whether they would be able to recognise recently learned but currently non-retrievable items. In contrast, Bäckman and Lipinska [34, 35] gave patients a test using general knowledge questions. Pronounced deficits in fact retrieval among the Alzheimer’s disease patients were observed but no reliable group differences in semantic FOK accuracy were found: patients were able to accurately predict which non recallable general
Table 2. Memory Awareness: A Summary of the Literature

<table>
<thead>
<tr>
<th>Study</th>
<th>Method/Material</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tip-of-the-tongue states (TOT)</strong></td>
<td></td>
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<tr>
<td>Delazer et al. (2003) [26]</td>
<td>Famous people</td>
<td>No differences between AD patients and older adult control</td>
</tr>
<tr>
<td><strong>Feeling-of-knowing judgments (FOK)</strong></td>
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<td></td>
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<tr>
<td>Backman et al. (1993) [34]</td>
<td>Semantic FOK (general knowledge)</td>
<td>Accurate FOK in AD</td>
</tr>
<tr>
<td>Lipinska et al. (1996) [35]</td>
<td>Semantic FOK (dated Versus contemporary knowledge)</td>
<td>AD Gammas*: .31 (dated information); .55 (contemporary information) / Control Gammas: .40 (dated information); .45 (contemporary information)</td>
</tr>
<tr>
<td>Pappas et al. (1993) [36]</td>
<td>Semantic FOK (general knowledge)</td>
<td>Non accurate FOK in AD</td>
</tr>
<tr>
<td>Souchay et al. (2002) [33]</td>
<td>Episodic FOK (word pairs)</td>
<td>Non accurate FOK in AD</td>
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<tr>
<td><strong>Judgment-of-Learning (JOL)</strong></td>
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<tr>
<td>Moulin et al. (2000) [38]</td>
<td>JOL on list of words</td>
<td>AD Gammas: .14 Gamma accuracy scores for patients not different from zero suggesting a difficulty to predict memory performance Control Gammas: .54</td>
</tr>
</tbody>
</table>

* Gamma scores are presented when available. Gamma scores are used to calculate prediction accuracy and are a measure of association that allows the comparison of performance for high and low predictions. This index ranges from –1 to +1, with large positive values corresponding to a strong association between memory performance and predictions, while negative values show an inverse relationship.

knowledge items they would be able to recognise. Overall, these findings show that AD patients have accurate FOKs for semantic material but not for episodic tests. Given that the FOK measures a form of conscious awareness of memory processing, it might be suggested that awareness of episodic processes is impaired in Alzheimer’s Disease, whereas the ability to make inferences about general knowledge is unimpaired (at least early in the disease, [36]).

Finally, another measure called either the judgment-of-knowing or judgment-of-learning refers to predictions made during or immediately after the learning phase [37]. A few studies have examined Alzheimer’s Disease patients’ ability to predict their memory performance on an episodic memory task using these judgements [38]. Finding that patients have some difficulty predicting their likelihood of future memory performance. For example, Moulin et al. [38] demonstrated that whereas memory performance increased over several repetitions of a learning event, the people with Alzheimer’s Disease, unlike controls, did not demonstrate a corresponding shift in their predictions. Whereas memory performance was improved by repetition, the patients lacked the reflective abilities to consciously report this in their predictions.

Thus far, it seems that people with Alzheimer’s disease are unable to reflect upon their performance during an episodic task [e.g., 38]. Furthermore, people with Alzheimer’s disease have a particular deficit in predicting the recognition of a non-recallable item in an episodic memory task [33]. These empirical findings suggest that one feature of the episodic deficit is a lack of awareness of the processing of this form of memory. No studies on the neural correlates of episodic metacognitive judgements have been carried out in Alzheimer’s disease; this remains a priority for future research.

3.2. Recollection

Another concept related to consciousness is sentience, in this case, what memory functioning feels like. This concept links to the notion of recollection, and the examination of mental contents during an act of remembering. Different theories have been proposed describing the nature of the information processed within the episodic system, and what constitutes ‘remembering’ [2]. For example, according to the fuzzy-trace theory [39], episodic memory, involves both detail information such as characteristics of the material presented, contextual or source information, and gist information defined as the general meaning conveyed by the information. Similarly, one can distinguish between item memory and source memory, source memory pertaining to the contextual information associated to the item (such as a spatial location or timing of a prior event). As shown in Table 1, episodic memory has also been associated with the process of recollection in opposition to familiarity [40, 41]. Familiarity is the sense that an item has been encountered earlier but
without the recall of any contextual detail about this item, while recollection involves the recall of specific details about the event. Thus it is possible to complete some memory tasks when recollection is impaired or unavailable, merely on a sense of whether material is a familiar or not. The terms recollection and familiarity are used differently by different researchers and in different paradigms. However, there is consensus that recollection and familiarity differ in terms of the type of information they provide. Familiarity is described as an index of memory strength whereas recollection reflects the retrieval of specific traces, contextual details or source information linked to the study event [42, 43].

The final view is that remembering does not only involve recalling information with its context but also involves feelings. Recently, Conway [44] suggested that remembering was ‘a process and a state’. The process refers to the construction of a mental representation while the state is ‘a state of conscious awareness distinguished by a specific type of mental content as a particular cognitive feeling’. According to Conway [44] these feelings can be conceptualised as *autonoetic consciousness or recollective experience*. Recollective experience, or ‘remembering’ occurs when a remembered has a sense or feeling of the self in the past. Images (often visual), feelings, thoughts and verbal statements directly related to the recalled episode also often come to mind during recollective remembering.

These frameworks are all somewhat different with some emphasising subjective feelings, and others, the nature of a retrieved memory by the nature of the material. For instance, the process of recollection is inferred if someone is able to state not only that the word ‘garage’ was presented to them in a memory test, but also that it was presented in blue ink, or with a female voice, etc. For others, the process of recollection is a direct statement about the quality of the experience of remembering. Authors often cite the different frameworks interchangeably, and whilst the field would clearly benefit from some precision [2], for the purposes of this review, we might think of recollection as any form of rich, evocative retrieval based on a subjective state and containing contextual information. One reason that we adopt this view is that, as will be shown, people with Alzheimer’s disease have deficits in this form of rich, evocative retrieval but not such the weaker, less self-knowing form of retrieval. The studies reviewed below clearly point to a recollection deficit, but they do not discriminate between theoretical positions.

### 3.3. Measuring Recollection in Alzheimer’s Disease

Specific paradigms have been developed to explore recollection and familiarity directly and some of these methods have been used in Alzheimer’s disease. These measures can be classified into three categories. The first category refers to the procedures used to estimate recollection and measures one of the main functions of recollection – the ability to minimize memory errors and avoid ‘illusions of familiarity’ [45]. For instance, if you had experienced a crime, and had seen two faces, one of a bystander and one the perpetrator, you would want to be able to recall the information about who was who in order to not be ‘seduced’ by the overwhelming sensation of familiarity of the bystander. This ability has been termed *recollection rejection* [46] and consists in correctly rejecting errors on the basis of recollection, e.g. remembering that the man with glasses was the man who was sat opposite you on the bus, and not the one who ran off with the handbag. Recollection is also involved in reducing susceptibility to memory distortions such as misattribution (i.e. the act of attributing a recollection or idea to an incorrect source). The second category refers to the subjective states associated with memory retrieval by directly asking the participants to say whether or not the information is familiar or if they can remember it. Finally, the last category refers to paradigms assessing participants’ abilities to retrieve specific information linked to the target event and measure another function of recollection: *source monitoring* (i.e. attributing the correct source to a particular item) [47]. Results from each type of category are reviewed in turn and the main findings summarized in Table 3.

### 3.3.1. Estimation Methods

Several paradigms have been proposed in which recollection is essential to minimize memory errors. With these paradigms the correct use of recollection is necessary to select or retrieve the correct answer. In the paradigm proposed by Deese-Roediger and McDermott [48], recollection is used to reduce familiarity-based false recognition. Several studies have used this paradigm to estimate memory for gist and memory for details. In this paradigm, participants are presented with lists of words related to a non-presented critical lure [49]. For example, participants study different categorised lists, e.g. *thread, haystack, pin, cotton*. Then in the recognition phase, participants are presented with studied items (targets, *thread, pin*) and non-studied items (critical lures, such as *needle* and non-related lures, such as other categorised items, like *red, blue*). At test, critical lures are likely to be falsely recognized because they match the gist information formed at study about related concepts [50]. Detail information is measured as the ability to distinguish between studied items and non-presented critical lures, requiring conscious awareness of the specifics of encoding [51].

Memory for both gist and detail information decreases in Alzheimer’s disease [51-54]. Budson et al. [51] suggest that Alzheimer’s disease patients demonstrate low levels of false recognition because they cannot create gist information. However, after repeated trials, gist memory is improved and patients’ sensitivity to false alarms increases as they fail to accumulate contextual recollection over repeated presentation of the list. These results thus suggest that Alzheimer’s patients have difficulties in suppressing false recognition of semantic associates using recollection. Pierce et al. [55] used a different paradigm, originally proposed by Smith et al. [56] in which recollection of source information is needed to avoid intruding presented exemplars from categorized lists. Alzheimer’s patients were unable to use recollection to avoid intrusions. Thus, people with Alzheimer’s disease have cognitions which are more likely to be on the basis of gist. In social situations, as one example, this might lead to inappropriate interpretations of events. The extension of this recollection deficit into real world behaviours remains an interesting priority for future research.

Another procedure used to estimate recollection is the process dissociation procedure [57]. In this paradigm partici-
Table 3. Recollection: A Summary of the Literature

<table>
<thead>
<tr>
<th>Study</th>
<th>Paradigm</th>
<th>Findings</th>
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<tbody>
<tr>
<td><strong>Estimation methods</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Budson et al. 2000, 2001, 2001 [51,52,53]</td>
<td>DRM* paradigm</td>
<td>Decreased memory for gist and detail in AD</td>
</tr>
<tr>
<td>Hudon et al. 2006 [54]</td>
<td>DRM paradigm and text memory task</td>
<td>Decreased memory for gist and detail in AD</td>
</tr>
<tr>
<td>Adam et al., 2005; Hudson and Robertson, 2007; Knight, 1998; Koivisto et al., 1998. [58,59,60,61]</td>
<td>PDP* paradigm</td>
<td>Impaired controlled processes (recollection) in AD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced automatic processes (familiarity) in AD</td>
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<tr>
<td><strong>Subjective states</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Della Barba (1997) [63]</td>
<td>R/K* paradigm</td>
<td>Fewer R (recollection) responses in AD</td>
</tr>
<tr>
<td>Rauchs et al. (2007) [64]</td>
<td>R/K paradigm with justification for R responses</td>
<td>Fewer R responses in AD and fewer justification (contextual details)</td>
</tr>
<tr>
<td>Piolino et al. (2003) [65]</td>
<td>R/K paradigm on an autobiographical memory task</td>
<td>Fewer R responses</td>
</tr>
<tr>
<td><strong>Source memory</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gallo et al. (2004) [68]</td>
<td>Discrimination between intact word pairs and rearranged word pairs</td>
<td>More false alarms to rearranged pairs in AD</td>
</tr>
<tr>
<td>Mitchell et al. (1986) [71]</td>
<td>Discrimination between words read versus generated</td>
<td>Impaired source discrimination in AD</td>
</tr>
<tr>
<td>Dick et al. (1989) [70]</td>
<td>Discrimination between words acted and words non-acted</td>
<td>Impaired discrimination in AD</td>
</tr>
<tr>
<td>Dalla Barba et al. (1999) [69]</td>
<td>Discrimination between seen from imagined objects</td>
<td>Impaired discrimination in AD</td>
</tr>
<tr>
<td>Multhaup et al. (1997)[72]</td>
<td>Discrimination between read versus self of experimenter generated words</td>
<td>Impaired discrimination in AD</td>
</tr>
<tr>
<td>Tendolkar et al. (1999) [73]</td>
<td>Words presented in different colours</td>
<td>AD patients unable to recall the correct colours</td>
</tr>
</tbody>
</table>

DRM= Deese-Roediger and McDermott procedure [48]
PDP= Process dissociation procedure [57]
R/K= Remember/Know procedure [12]

Participants complete two different memory tasks, one where they merely have to identify whether or not they studied the item before, and one where, additionally, they have to specifically declare where or when the item was studied. By comparing performance on the test assessing specifics (which requires recollection) and the test asking for a simple old/new distinction (which merely requires familiarity) it is possible to estimate the separate contributions of familiarity and recollection. Several studies using different variations of this procedure have showed that Alzheimer’s patients’ memory difficulties are attributable to a deficiency in effortful memory processes (i.e. recollection requiring specifics) but also had some reduced automatic processing (i.e. familiarity) [58-61]. Recently, this paradigm has been applied to Mild Cognitive Impairment, demonstrating that whereas familiarity is not impaired relative to controls, recollection is [62]. This procedure, therefore, might be suitable for early diagnosis of memory impairment in dementia.

3.3.2. Subjective States

The second category regards reports of subjective experience. With the remember/know procedure, participants are asked to report directly whether or not they recognize items on the basis of remembering or knowing, having been given definitions of the concepts, and/or examples. This method therefore asks for conscious self-evaluations of memory ‘feelings’. So far, only three studies have used the remember/known paradigm in Alzheimer’s disease. Della Barba [63] showed that patients produced fewer remember and the same amount of know responses compared to control participants. More recently, Rauchs, Piolino, Mezenge et al. [64] showed that Alzheimer’s disease patients give fewer remember but more know responses than controls. Rauchs et al. also asked participants to justify their responses. For each remember response, the participants were invited to give contextual details related to the target. Alzheimer’s disease patients were less able to justify their remember responses and they reported fewer details about the learning context. Finally, the
fact that Alzheimer’s disease patients report fewer remember responses has also been observed using an autobiographical memory task, where participants retrieve memories from their own past life [65].

These results clearly suggest that the subjective feelings associated with recollection are impaired in Alzheimer’s disease. Alzheimer’s patients report being in a state of remembering less often than controls and this is the case for newly learned information (episodic memory) or more remote personal information (autobiographical memory). In short, it appears that people with Alzheimer’s disease are less likely to experience the sensation of remembering: they are impaired in terms of consciousness in that they do not re-experience pervious events with the same quality as healthy older adults.

3.3.3. Source Memory: Contextual Details

The final category considers the specific information that can be produced during a memory test. Item versus associative recognition methods have been used to explore the retrieval of contextual information associated with recollection. In this approach, pairs are given at study, such as apple-table, monkey-tennis, radio-head. Participants are later asked to discriminate intact pairs (words studied in the same pair, apple-table) from rearranged pairs (words studied but in different pairs, monkey-head). The ability to correctly reject the rearranged pairs depends on recollection [41, 66, 67], because both of the items will feel familiar – they have both been encountered recently, but only recollection can produce information specific enough to correctly judge which item was presented with which other item. Gallo et al. [68] used such a task and showed that Alzheimer’s disease patients recognized fewer intact pairs and made more false alarms to rearranged pairs compared to control participants.

In other versions of recognition tasks, with a similar rationale, participants are asked to decide whether the word was spoken by a male or female voice or where the item was presented. With this type of task participants are thus asked to retrieve the context, or the source in which they learnt the information. Several studies with slightly different procedures have demonstrated that source memory is impaired in Alzheimer’s disease [69-73]. Mitchell et al. [69] asked Alzheimer’s patients to identify words from a sentence they had read or from a sentence for which they had generated the ending; Dick et al. [70] asked whether participants had performed an act or whether the experimenter did it; Dalla Barba et al. [71] asked participants to discriminate seen from imagined objects; Multhaup and Balota [72] asked participants to discriminate words they had read from words they had generated and words they had generated from words generated by the experimenter. Finally, Tendolkar et al. [73] asked participants to recall the colour in which words were printed when presented at study.

This research points to deficits in the specificity of recall: people with Alzheimer’s disease may be able to retrieve one piece of information, but arguably due to a failure of other aspects of the study phase to reach consciousness, they are unable to make sophisticated judgements about its source, or the specifics of encoding. Thus, in our view, the pattern of deficits in memory in Alzheimer’s disease are explained by the relative difficulty with recollection compared to familiarity. It is important to note that familiarity is probably impaired in Alzheimer’s disease but to a lesser extent than recollection [58-61]. Clearly there will be cases where both fail: and complete forgetting occurs.

4. ON THE RELATIONSHIP BETWEEN RECOLLECTION, FAMILIARITY AND METACOGNITION

Both familiarity and recollection are involved in successful retrieval, and some authors suggest that they may act sequentially [74] (See Fig. 1). The idea is that a fast familiarity response guides retrieval processes until recollection provides a subjective feeling of remembering, and additional contextual information [75]. The experient acts metacognitively upon these sensations of familiarity and recollection in order to reflect upon their mental operations. Thus, familiarity is used at a ‘pre-retrieval stage’ (cue-familiarity [73]) to trigger a rapid preliminary feeling which helps in the selection of the retrieval strategy. At a subsequent stage, the process underlying memory predictions may become more analytic, influenced by explicit consideration of the content of the cues (partial information, or contextual detail) that come to mind during the search of the target. This post-retrieval stage is based on both familiarity and recollection. We now turn to how such subjective sensations of memory drive more concrete concepts such as the feeling of knowing. We hypothesize that without recollection, someone with Alzheimer’s disease will not be able to reflect upon their memory function.

In a recent study on young adults, Hicks and Marsh [76] showed that high FOK predictions (i.e. when participants are confident that they will recognize the target) were associated with making more remember judgments in a recognition task. This suggests that the feeling of ‘knowing’ experienced during a failed recall attempt leads to items being later recognized on the basis of remembering (and not familiarity). Souchay et al. [22] showed that FOK accuracy was significantly correlated to remember responses but not to know responses, confirming this link between FOK and recollection (demonstrated in Fig. 1).

Research examining the basis of the FOK states also draws on concepts described above. According to Koriat [76], when healthy participants fail to retrieve a target they use some partial information related to this target to guide their predictions. This partial information induces the subjective feeling that the target will be recognized or recalled in the future. Our novel suggestion is that the partial information used to make metacognitive judgments depends on the type of states of consciousness associated to memory retrieval: noetic or autonoetic [12]. The use of noetic partial information would lead to a judgment based on familiarity whilst the use of autonoetic partial information would lead to a judgment based on recollection.

So far, two types of partial information have been proposed in the literature: structural-phonological and semantic. This has been supported by the studies showing that the tip of the tongue [77] and FOK states were associated with the retrieval of various types of information such as the initial letter of the missing word [32, 78] or the connotative meaning of this missing word [78-80]. We suggest that these cues...
are noetic cues. Our novel hypothesis is to suggest that, in particular for an episodic memory task, a third type of partial information needs to be added. This partial information is akin to the contextual information, feelings and self-awareness captured in Tulving’s concept of autonoetic consciousness and the state of ‘remembering’ [16]. Thus, partial information can be of three types: structural-phonological (noetic), semantic (noetic) or episodic (autonoetic). This is similar to the different types of source information proposed by Johnson et al. [47]. Source memory information can be of different types: sensory/perceptual information (noetic), spatial and temporal information (autonoetic), semantic detail (noetic) and affect (autonoetic) [47]. We argue that people with Alzheimer’s cannot reflect on their memory abilities when needing autonoetic consciousness to do so, the inability to correctly gauge performance in an FOK task is a consequence of a failure of recollection.

The disruption of recollection in Alzheimer’s disease explains why there is impaired awareness of memory in some circumstances but not others. According to Kioriat’s model [74], recollection is involved at a post-retrieval stage, when patients are actively searching the target. Souchay et al. [16] suggest that the type of partial information used to estimate future retrieval differs according to the type of task and what autonoetic partial information (or contextual details) are specific to the memory task. In an episodic task, the sensation of recollection, which indicates the presence of contextual information in memory, is a powerful cue by which a one can gauge how well something is learnt, and how likely it is that one will retrieve it again later; such cues are absent in Alzheimer’s disease. In contrast, familiarity is relatively intact and this may actually lead to inappropriate evaluations of memory performance. Metcalfe et al. [75] suggest that familiarity leads people to ‘approximate the uncertain quantity indirectly, rather than measuring the quantity itself’, resulting in biases and errors. The fact that Alzheimer’s patients have to rely more on familiarity than on recollection explains their difficulties in predicting future retrieval, but also the variability and lack of precision in their recall. In a general knowledge task, autonoetic partial information is not necessary to evaluate the state of memory and future performance – on such semantic tasks people with Alzheimer’s disease are unimpaired.

5. MEMORY, CONSCIOUSNESS AND THE BRAIN IN ALZHEIMER’S DISEASE

We now turn our attention to the neural substrates of this recollection deficit. A few studies have explored the neural correlates of recollective experience in Alzheimer’s disease. The cortical and neurochemical changes that characterize Alzheimer’s disease could support impaired recollection in two ways [68]. As outlined above, damage to the medial-temporal lobe explains the deficits in recollection observed in Alzheimer’s patients [81]. Consistent with this hypothesis, Tendolkar et al. [73] showed that Alzheimer’s patients who had smaller hippocampi showed more difficulties in recalling the study context (source memory). In a more recent study, Sperling et al. [82] found a decreased encoding activation in the hippocampal formation in a face name association task, suggesting a role of these regions in binding together contextual details.

Damage to the frontal lobes also explains Alzheimer’s patients’ difficulties in recollection. Neuropsychological studies suggest that damage to the frontal lobes disrupts recollection but leaves familiarity relatively intact. Frontal lobe patients have deficits in source memory [83], give fewer Remember responses [84, 85] and often present a very high rate of false alarms in recognition [86]. Recent neuroimaging studies on normal population have confirmed the involvement of the frontal lobes in recollection [41]. Direct support for the role played by the frontal lobes in explaining the recollection deficits in Alzheimer’s disease comes from a recent study published by Rauchs et al. [64]. Using correlations between memory performance and resting-state cerebral metabolism measured by positron emission tomography, these authors showed that the lack of remember responses in AD patients was supported by a dysfunction of frontal areas.

Despite the fact that no study has yet explored the neural correlates of the feeling of knowing in Alzheimer’s disease, we suggest here that as with recollection, the cortical changes observed in the frontal lobes and in the medial-temporal lobe regions produce the feeling of knowing defi-
cit. Patient and neuroimaging investigations suggest the existence of a network of brain regions implicated in awareness of memory including the mediotemporal lobe and the prefrontal regions [87]; a memory network that Conway [88] termed the fronto-temporal route (see [14] for a case showing impairment to this network, and disruption of memory awareness). Patients with frontal lobe damage are less accurate than control participants at predicting their memory performance when using FOK predictions, but as with Alzheimer’s patients this was only on episodic and not semantic material [83, 87, 89, 90]. Neuroimaging studies on healthy groups have clearly confirmed the role of the frontal lobes in FOK judgments, by showing frontal lobe activation for FOK accuracy in both episodic and semantic memory tasks [91-94]. Functional magnetic resonance imaging studies also showed activation of the temporal lobes in FOK accuracy [91, 94] suggesting that FOK was related to a left hemisphere network of frontal and temporal cortical regions. The neural substrates of tip of the tongue states in healthy adults have also been investigated using functional magnetic resonance imaging revealing that this state was associated to the activation of the prefrontal cortex [93]. Some studies also suggest that the frontal lobes would be involved in judgments of learning made during study [90, 95-97].

Our novel suggestion is that, in Alzheimer’s disease, the deficit in conscious awareness of memory elucidated here could be due to a disconnection syndrome [22]. Several neuroimaging studies show a structural disconnection between the prefrontal and the hippocampus [98, 99] in Alzheimer’s disease. This would lead to two types of impairment underlying recollection and awareness. First, the network of regions involving the medial temporal lobe and the frontal lobes would be involved in the retrieval of partial, contextual or source information. Indeed, in healthy populations, retrieval of partial information related to the target is linked to the activity of the medial temporal lobe [100] and the ventral medial prefrontal cortex [97]. Thus, a disconnection of these brain regions would result in a decrease of partial information retrieved, lead to recollection deficits and difficulties in predicting future performance. Second, a disconnection of the mediotemporal regions and frontal regions could contribute to Alzheimer’s patients’ inaccuracy through the involvement of these brain regions in monitoring retrieval. This resonates with the studies showing that the ventral medial prefrontal cortex is involved in the assessment of ‘felt-rightness’ of a memory [101] and that the frontal lobes are involved in strategic control of memory outputs [14].

6. CONCLUDING REMARKS

This review has described a pattern of deficits in Alzheimer’s patients involving the relationship between awareness of memory and a state of consciousness, recollection. There is the possibility that further investigations into this disease can illuminate current hot topics in psychology; the complex interaction between self and memory [88] and more subjective disorders of memory awareness, such as déjà vécu [14]. Our view is that Alzheimer’s disease results in a disconnection between experience and process in the operation of memory. In giving an overview of recollection and familiarity processes in human memory there is a clear explanation of the differences in recall and recognition, and one based on emergent research in the neuroscience of memory; recall requires recollection processes, whereas recognition can be completed on the basis of familiarity alone.

From a clinical point of view, further studies should determine how to improve memory rehabilitation and differential diagnosis in this population. The role of awareness has been explored in relation to rehabilitation in Alzheimer’s [102]; however, studies have not yet explored how to use the relatively spared familiarity in Alzheimer’s patients to potentially improve awareness of memory abilities. Awareness of memory abilities is a crucial issue as it is linked to the correct use of memory strategies and that recent work showed that Alzheimer’s patients failed to use appropriate memory strategies [103]. Future research should also look at whether or not training recollection (which is possible in healthy older adults with memory difficulties; [104]) would also improve awareness of memory abilities.

One critical issue in Alzheimer’s disease is early diagnosis. Interestingly, Mild Cognitive Impairment (MCI), which represents a preclinical phase of this disease [105] has attracted little or no attention from researchers investigation awareness of memory abilities or recollection. One study suggests that measuring MCI patients abilities to predict their memory abilities might be a useful tool for the differential diagnosis [106] where another has shown that assessing recollection can help to differentiate Alzheimer’s patients from MCI patients [54]. As a consequence, knowing more about MCI in this regard is a research priority.

Finally, the more that is understand about the specifics of memory impairment in Alzheimer’s disease, and its underlying brain basis, the better our understanding of pharmacological interventions will be. In this regard, Winstin et al. [107] have researched the impact of donepezil on declarative and non-declarative memory in Alzheimer’s and showed that this medication had beneficial effects on both. Declarative memory can be further sub-divided into the separate recollection and familiarity processes discussed here. Following, Winstin et al.’s lead, the further fractionation of memory in Alzheimer’s disease and its treatment is a priority for current Alzheimer research.

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REFERENCES


