CORTEX 49 (2013) 1445–1451

Available online at www.sciencedirect.com

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Special issue: Editorial

The cognitive neuropsychology of recollection

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> My memory is extensive, yet hazy: it suffices to make me cautious by vaguely telling me that I have observed or read something as opposed to the conclusion which I am drawing, or on the other hand in favour of it; and after a time I can generally recollect where to search for my authority.
> Charles Darwin, (1887)

1. Being in two minds about recollection

The recognition of whether someone, something or somewhere has been experienced before rests on a decision making process. In human memory, information is not reproduced as it would be in a computer, but is a reflective, conscious process. This is more so the case when encountering the same scene, environment or idea for a second time. When we recognize something as having been encountered before we arguably make a comparison between what is represented in the cognitive system and what is currently perceived. Consider that somebody uses the word 'loquacious', a word which you have only just encountered recently, and up until then, you did not know its meaning, or even existence. When encountering the word a second time, a number of processes and sources of information bring to bear on your processing of the word: how fluently you can process it, its distinctiveness in the perceptual trace, the feelings generated when encountering it a second time, the effort involved in retrieving its meaning, and whether you can recall the specifics of your first encounter with the word. This information can be used to retrieve the meaning of the word, or to gauge the certainty with which you have encountered the word before, and so on.

Recent advances in human decision making suggest that complex tasks requiring problem solving and judgement rely on two categories of information, giving rise to dual process models of reasoning and judgement (Evans, 2008; Kahneman, 2011). The dual process account explains how people make decisions based on two separable streams of information: a fast, intuitive feeling and a slower, more deliberative evaluation, captured in the quote from Charles Darwin, above. These separable processes in cognition are arguably at play in memory decision making too (e.g., Arango-Muñoz, 2010; Hintzman and Curran, 1994; Koriat and Levy-Sadot, 2001) and map neatly onto the concepts of familiarity and recollection (for reviews see Mandler, 2008; Yonelinas, 2002), two key concepts which we describe below.

In fact, the neurosciences have long had dual process theorists who posit two separate processes in the mind, probably inspired by the division of the brain into two hemispheres. Many early scholars posited that the brain was a 'double organ' (e.g., Holland, 1840). Wigan's influential text (1844), *The Duality of the Mind* was an extreme position: that there were literally two separate brains which could work with each other or against each other. It was this kind of physiological view of the dual brain that Ribot drew upon in his early conceptions of human memory and its disorders (Taylor and Shuttleworth, 1998) and it undoubtedly influenced early theories of memory. In time, Stewart in the mid nineteenth century developed a distinction between recollection – the ability to consciously retrieve specific information – and memory more generally – a store of experiences and information which is not necessarily available for conscious report (Taylor and Shuttleworth, 1998). These dual process ideas of the mind have undoubtedly been influential in early neuroscientific works, but they have also helped shape the general public's thinking on this matter: we can talk about being 'in two minds' about an issue, and many lay people's conceptualization of déjà vu – an infrequent but striking memory error – is that it arises from a mismatch between separate

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0010-9452/$ – see front matter
http://dx.doi.org/10.1016/j.cortex.2013.04.006

streams of consciousness (often blamed upon two hemispheres working out of synchronization), something which Wigan himself proposed in 1844.

2. An overview of recollection and familiarity

A prominent contemporary view of memory is that there are two neurally distinct mechanisms of recollection and familiarity – nothing quite so mysterious as having a palimpsest of unconscious memories or as ridiculous as having two brains in one head, but contentious, nonetheless (for alternatives see Donaldson, 1996; Dunn, 2004; Squire et al., 2007). In the proposal for this Special Issue we invited articles using a broad, theory-neutral definition. We suggested that recollection refers to the retrieval of specific contextual information from the time of study, and this is often characterized as 'mental time travel' or as having the first person experience of remembering. A summary of the key concepts and the range of terms used in given in Table 1. We suggested that the neural basis of recollection is currently under debate; we attempt to summarize this debate here, but we knowingly err on the side of evidence *for* recollection, and point to some more critical issues in the final section.

Eichenbaum et al. (1994) and Aggleton and Brown (1999) put forward neuroscientific models of recollection, focussing on the hippocampus as critical for recollection, and the adjacent parahippocampal gyrus as responsible for familiarity (See Figs. 1–3 for a visual summary). Aggleton and Brown (1999) further suggested that due to the network connecting the hippocampus to the fornix, mammillary bodies, and anterior thalamic nuclei, these structures are also engaged during the encoding and retrieval stages of recollection. Moreover, they suggested that familiarity is supported specifically by the most anterior portion of the parahippocampal region.

These models predict that hippocampal damage should affect recollection but not familiarity, and parahippocampal damage should lead to impairments in familiarity, not

Table 1 – Some key concepts in recollection. Definitions of recollection, representative quotes and theoretical overviews of the main theories.

Article	Representative quote	Theoretical overview
Dunn, 2004	"During recognition, if the evidentiary or so-called trace strength of a test item exceeds the more stringent criterion, an R response is made…" p.524	Recollection and familiarity lie along a continuum; a single process captured in single detection theory measures.
Greve et al., 2010	"two distinct retrieval processes can operate on a single memory representation, yet still generate different retrieval outputs." p.246	Recollection and familiarity are not distinct representations, but different processes applied to one underlying trace.
Jacoby et al., 1993	"Although the opposition of consciously controlled processes with automatic processes does not provide a pure measure of recollection, it can be used as a methodological tool to identify factors which selectively influence the two forms of processing". p.140	Recollection is a controlled memory process, familiarity is automatic.
Klein, 2013	"What makes a memory experience episodic or semantic is not the nature of the content, or the hypothesized system in which content resides while in "storage," but rather an act of temporal (or atemporal) awareness that becomes associated with the content once it has been retrieved." p.3	Episodic memory is not a subsystem with distinct representations, but the act of recollection defines the reproduction of material with a definite past.
Mandler, 2008	"Recollection does involve a memory search … recollection/recall depends on the semantic (meaningful) organization in which the target item is embedded and that permits retrieval". (p.391)	Recollection is broadly synonymous with recall; it is a conceptual process.
Mickes et al., 2013	"[Recollection] reflects the consciously controlled retrieval of item-plus-source information from an episodic memory search set." p.345	Recollection and familiarity differ according to the information that can be retrieved: item-plus-source or item only information.
Montaldi and Mayes, 2010	"Recollection is recall of information that was experienced during the study episode that is cued by a recognition test stimulus" (p.1294)	Recollection and familiarity represent 'kinds' of memory with neuroanatomical correlates distributed throughout the MTL.
Rotello et al., 2004	"… both remember and know judgements depend on a combination of specific and global memory strength of the test probe. It is only the relative contributions of these two types of information that result in a decision that an item is remembered (if relatively more specific information can be retrieved)…" p.606	Remember responses are not merely high confidence 'old' decisions, but reflect a two-dimensional assessment of the strength of the memory trace according the previously encoded event more generally and the specific probe in memory.
Tulving, 1985b	"A normal healthy person who possesses autonoetic consciousness is capable of becoming aware of her own past as well as her own future; she is capable of mental time travel…" p.5	Recollection can be characterized as the conscious experience of 'remembering'; autonoetic consciousness.
Yonelinas, 2002	"Recollection reflects a threshold-like retrieval process that supports novel learning…" p.441	Recollection and familiarity are similar to (but not identical to) recall and perceptual implicit memory.

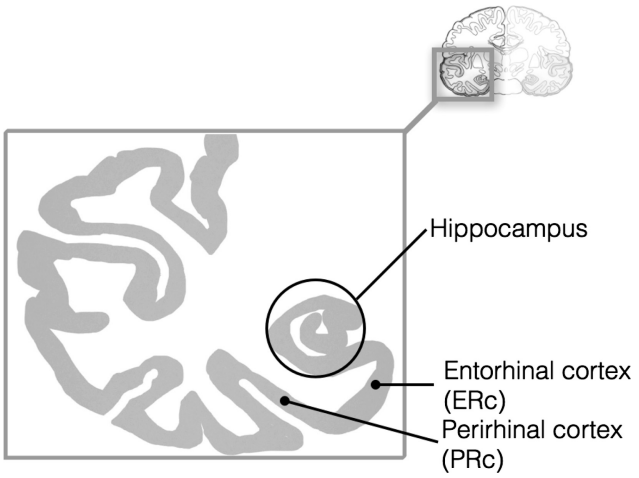

Fig. 1 – Schematic representation of the medial temporal lobe showing rudimentary locations of key structures, coronal section.

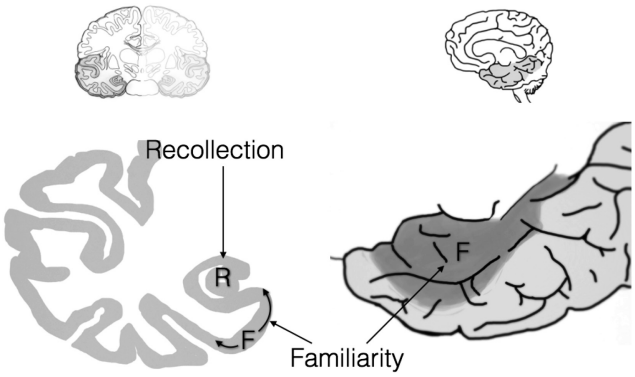

Fig. 3 – Schematic representation of the medial temporal lobe showing proposed locations of recollection and familiarity.

recollection. In support, patients with damage restricted to the hippocampus have displayed isolated impairments in recollection measured through a number of paradigms (Bowles et al., 2010; Holdstock et al., 2005). The pattern is made a little more complex by studies looking at laterality and modality specific effects, such as right sided deficits for non-verbal materials (e.g., Barbeau et al., 2011). Later models have elaborated on the specific roles of the Perirhinal (PRc), Entorhinal (EC) and parahippocampal cortices (PHc), due to the emergence of findings that extrahippocampal structures may be able to support associative memory when items are sufficiently unitized during encoding (e.g., Quamme et al., 2007). Such a departure, as Montaldi and Mayes (2010) describe, begins to view recollection and familiarity as 'kinds' of memory, because "each is a complex function, likely to depend on several different processes that are probably mediated by different structures that are functionally connected in a system" (p.1294).

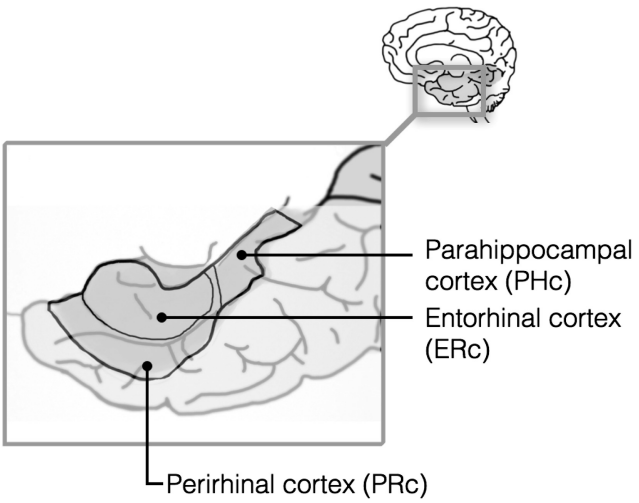

Fig. 2 – Schematic representation of the medial temporal lobe showing rudimentary locations of key structures, sagittal section.

In most definitions and descriptions of recollection, there is the idea of 'something more'. That is, alongside the assessment of a prior occurrence, extra information comes to bear on the recognition decision, or contextual information and thoughts from the time of encoding are retrieved. This idea places emphasis on the capacity to bind or associate information, and recollection might be thought of as the retrieval of information bound together during the original study episode. In their Convergence, Recollection and Familiarity Theory (CRAFT) model, Montaldi and Mayes (2010) argue that the PRc rapidly forms weakly pattern separated memories that support familiarity well. Intra-item associations can be supported by this area when bound (e.g., the words 'ice' and 'shaft' encoded as iceshaft), but inter-item representations may also be formed giving rise to a feeling that the two were presented before (e.g., face-word pairs). The ability of the PRc cortex to support such representations is dependent on the manner in which they are encoded; intra-item associations rely on a unifying conceptual link, inter-item associations rely on a linking of components. These representations are highly inflexible and if the linked components are altered, familiarity will diminish. In recognizing the similarities in cytoarchitecture between PRc and PHc, these authors further postulate that the parahippocampal cortex can also support associations, but for context–context relations. Such 'contexts', although difficult to define, can include visual, spatial or semantic information that is peripheral to the item that is the focus of attention (Diana et al., 2007). In contrast, recollection supports highly flexible associations and lies at the top of the MTL hierarchy, supporting between–domain associations (object-context links). Its cytoarchitecture allows rapid pattern separation (and completion), which supports recollection and not familiarity.

Cognitive single trace accounts both contest the assumptions of dual-process theories, and also tend to overlook the above neuroanatomical models, and neuropsychological data. Squire and colleagues however (Squire et al., 2007; Wixted and Squire, 2011; Zola-Morgan et al., 1994) argue that all structures within the MTL mediate recollection and familiarity equally.

Their MTL Unitary Trace Strength (MUST) account suggests that functional heterogeneity does exist within the MTL, but not for recollection and familiarity. Although their account does not question the existence of these two processes, it sees that examination of the components within the MTL cannot be illuminated by this distinction in psychological constructs. Wixted argues (e.g., Wixted, 2007; Wixted and Squire, 2011) that recollection is a continuous process just like familiarity. In order to provide evidence for this, they suggest methods must be used that do not confound recollection and familiarity with memory strength. For example, in a source memory experiment using fMRI, Wais, et al. (2010) measured hippocampal activity at retrieval after equating memory strength of recognition decisions on item-correct plus source-correct or item-correct plus source-incorrect trials. Their analysis focused only on Old/New trials where participants assigned high confidence ratings, regardless of whether the correct source was retrieved. They found that hippocampal activity was similarly elevated for both correct/incorrect source judgements, suggesting it is involved in both recollection and familiarity. This debate between the single and dual process theorists, whilst generating a rich body of experimental data is yet to be fully resolved.

3. An introduction to the special issue

Our motivation behind the special issue was to capture the progress made in the neuroscientific and neuropsychological understanding of recollection, and its importance in memory impairment. As a defensible starting point for the field we might take Tulving's paper of 1985. Tulving (1985a) asked memory researchers to consider that there were multiple systems of memory (and in doing so, he introduced the idea of autonoetic consciousness, the state of awareness typically associated with the process of recollection). Some of Tulving's argument was neuropsychological, based on research on blindsight:

> If 'seeing' things – something that phenomenal experience tell us is clearly unitary – is subserved by separable neural-cognitive systems, it is possible that learning and remembering, too, appear to be unitary only because of the absence of contrary evidence.
>
> (Tulving, 1985a, p.386).

There is no lack of contrary evidence now. Assuming that articles with 'recollection' in the title reflect this debate, there have been 2494 publications on the topic[1] to date, with 125 articles in the previous year (2012). Searching for recollection as a topic yields a domain which received 13,767 citations in 2012. For the special issue, we aimed to collect together some empirical work which investigates recollection but with populations and methods which elucidate the relationship between the nervous system and mental processes. In turn, two review articles (Morris & Mograbi, 2013; Markowitsch & Staniloiu, 2013) offer new insights driven by theories of recollection. A further paper (Palombo et al., 2013) offers a new tool for the assessment of memory function likely to be of value in the examination of recollection processes and memory abilities more generally.

The articles gathered here exemplify the broad range of methodological and theoretical approaches to the study of recollection, as well as a couple of applications. A number of different approaches which may be classified as either objective or subjective have been used to examine recollection and familiarity. Following on from the idea of the retrieval of 'something more', many studies examine the ability to retrieve specifics of the prior study episode as an index of recollection. This may include the recall of the source of an item once it has been correctly recognized (e.g., Souchay et al., 2013; DeMaster and Ghetti, 2013), or the capacity to retrieve contextual specifics to disentangle familiarity from recollection (Elward et al., 2013). The methods are objective insofar as it is possible to score as correct or incorrect the response on the basis of experimentally presented information at the study phase. A separate method places an emphasis on subjective report, and typically uses a judgement based on conscious experience. In a typical paradigm, participants report whether they can retrieve specifics from the study episode, or merely 'know' that they have encountered the item before (e.g., Taylor et al., 2013; Angel et al., 2013; Moulin, 2013). By a large margin, most studies on recollection use old/new recognition tasks, with subjective ratings or the R/K procedure which asks participants to differentiate between subjective states of remembering and knowing during a memory test phase. (For a brief critique of the over-reliance on these methods and just one alternative, see O'Connor et al., 2011; and for a single-trace account of the data generated from it see Dunn, 2004). Recently, Mickes et al. (2013) have applied the R/K procedure to free recall, with the finding that items recalled with high confidence without a feeling of remembering lack contextual information (i.e., are 'item-only' information).

The beauty of the R/K paradigm is that it can be used for both experimentally presented materials or autobiographical material in more naturalistic designs (e.g., Picard et al., 2013). In an autobiographical memory task, people can report the conscious experience of the retrieved information: we may *know* the church where our cousin was married and that we were there, but not be able to *remember* anything specific about the events of the wedding. In fact, such differences in autobiographical retrieval are critical in clinical and applied contexts. Palombo et al. (2013) report the development of a new measure which can capture the self-assessment of autobiographical retrieval, showing a significant relationship with a laboratory measure of recollection.

Unsurprisingly, one of the key developments in the recollection literature has been to examine memory in clinical populations, and this special issue covers work on recollection in Autistic Spectrum Disorder (Souchay et al., 2013); Developmental Amnesia (Picard et al., 2013); Alzheimer's disease and dementia (Genon et al., 2013; Morris & Mograbi, 2013; Moulin, 2013); and Functional Amnesia (Markowitsch & Staniloiu, 2013). It has also been used to examine lifespan development in memory in healthy populations, which is again covered in this volume with studies on healthy older

[1] ISI Web of Knowledge, 11 April 2013.

adults (Angel et al., 2013) and children between the age of 8 and 11 (DeMaster & Ghetti, 2013). Furthermore, Palombo et al. (2013) use relationships with depressive symptomatology to validate their new measure.

The majority of articles presented here report neural correlates of recollection, and the studies converge again on the medial temporal lobe, and the hippocampus (e.g., Picard et al., 2013). But the studies presented here also point to the activation of a wider network of regions. In this volume, Genon et al., show a functional connectivity between the hippocampus and the interior precuneus and posterior cingulate cortex, with deficient functional connectivity between these regions in a group of patients with Alzheimer's disease. Angel et al. (2013) describe a network of regions which also encompasses the frontal lobes, a network implicated also by Moulin (2013) in recollective confabulation, although the later presents no direct neuroimaging support. Angel et al. (2013) again suggest a wider network of regions may be implicated in recollection, also showing possible compensatory activation during recollection in healthy older adults in the right precuneus (cf. Genon et al., 2013). This network is also implicated in the research by DeMaster and Ghetti (2013), who indicate developmental changes in the activation of the hippocampus and surrounding cortices as a function of recollection.

The utility of the study of recollection is that it has offered new fine-scaled analyses of memory-related phenomena. Morris and Mograbi (2013), for instance, propose that a specific deficit in recollection-like mechanisms mean that people with Alzheimer's disease have degraded knowledge of self-ability. This leads to a 'semanticisation' of the self, and a lack of dynamic memory systems to represent changing memory abilities. In short, we might characterize the lack of awareness in Alzheimer's as a failure to update knowledge about self functioning based on a diminution of recollection processes, and a consequent over-reliance on over-general information about the personal past. This notion is also supported by Picard et al. (2013), who also highlight the relationship between the 'mental time travel' aspect of recollection and the self. They show that where specific recollection mechanisms are impaired, self relevant memories are still produced, but that these are conceptual, rather than based on the evocation of specific events from the personal past. Where we cannot remember events in detail, we can still know ourselves. But if there is a failure to update these self concepts, a 'petrified self' remains (Mograbi et al., 2009). Surely one of the priorities for future research is to further map out the relationship between recollection and the self in the past and future. Although early researchers posited a role of episodic memory – and in particular recollection – in the self, more recent research suggests that the self is a personal construct supported by a complex interaction of remembering and knowing (e.g., Rathbone et al., 2009). The very idea that recollection has been described as the capacity to see oneself in the past, requires that we continue to research the link between recollection and the self, especially in special populations, such as Autism (Souchay et al., 2013) and Functional Amnesia (Markowitsch & Staniloiu, 2013), where alterations in the self have been proposed.

The main contribution of recollection research has been to decompose recognition memory performance, and this is the defining feature of most of the articles in the special issue. For instance, Moulin describes how an interaction between the familiarity and recollection systems may be behind a type of chronic false recognition characterized by the confabulation of previous studied episodes in patients with dementia. Moulin proposes that erroneous familiarity signals may be behind a number of similar reduplicative delusions, and that such neuropsychiatric deficits may be better understood by the use of recognition memory measures which can decompose familiarity and recollection. There have been recent research findings which use recollection and familiarity to better understand the processes behind déjà vu in Temporal Lobe Epilepsy, for instance (Martin et al., 2012).

A more recent development is to consider the relationship between recollection and other cognitive systems. In the this volume, Elward et al. consider the relationship between working memory capacity and recollection, with the finding that there are competing cognitive resources for controlled recollection (the use of recollection to oppose familiarity) and working memory capacity. This idea has support from correlations in healthy older adults with a deficit in recollection as measured by the R/K paradigm, where there is a correlation between levels of Remembering and scores on executive test measures (Clarys et al., 2009). In a similar vein, using an experimental rather than individual differences approach, Taylor et al. (2013) show a relationship between classic implicit memory measures, and recollection. They show that conceptual priming of target words leads to increases in reports of recollection. The interpretation of this data is that the re-activation of semantic information at retrieval may prime the concepts generated previously during encoding, since the priming manipulation gives rise to activation in standard 'true' recollection networks of the brain. The data suggest that there is a complex interaction between processes at retrieval and encoding which gives rise to the conscious experience of remembering. This idea resonates with a recent conceptualization of recollection, not so much as retrieval from a separate store or system, but a feeling which arises according to operations occurring at retrieval (Klein, 2013). Klein argues that an act of temporal (or atemporal) awareness becomes associated with the content once it has been retrieved from long term memory.

Considering the patterns across the articles in this special issue, where we see impairment and dissociations between recollection and familiarity, there is scope for future research. Souchay et al. (2013) show that whereas source memory can be intact in autistic spectrum disorder (ASD), the phenomenology of 'remembering' is impaired. This may suggest, in line with Klein's view (2013) that it is possible to differentiate the feeling of remembering from the content which is retrieved. At the least, as the Elward et al. (2013) data propose, there may well be strategic and higher level processes at play in recollection which map onto working memory, and may be about regulatory processes in recognition memory rather than the act of recollection per se.

4. Concluding remarks

The contentious issue with recollection research is whether the qualitative characteristics of recollection represent a

separate memory system or not. A number of recent models offer a more nuanced view of the interaction between recollection and familiarity (e.g., Montaldi and Mayes, 2010; Wixted and Squire, 2011) and it seems unlikely that a strongly dichotomous model (in terms of experimental psychology, classic neuropsychology or neuroimaging) will ever be sustained. In this way, the debate over recollection and familiarity processes and their separable contribution to different tasks and different deficits may develop in the manner of the one-time-fashionable model of frontal dysfunction in memory in ageing (e.g., Perfect, 2007). Whereas a strong model of frontal involvement in memory in ageing (which equated memory deficit in ageing as one and the same as a frontal lobe deficit) was difficult to sustain and was rarely tested explicitly, it has become useful to think of disproportionate deficits on tasks which are *more frontal* even though the emergent view is that a network-based account of memory changes in ageing is more sustainable than a localizationalist view (e.g., Charlton et al., 2010; Greenwood, 2000). In a similar way, if we begin to see a continuum between familiarity and recollection contributions to recognition memory decisions, we can talk about tasks which are more familiarity-like and tasks which are more recollection-like. The blurring of the boundaries between familiarity and recollection processes (and even implicit and explicit memory) is clear in the Taylor et al. article in this volume (and see also mathematical modelling from Berry et al., 2012). But also the fact that recollection draws on other cognitive processes means that we might think that recollection depends partially on the control of memory processes, and their interpretation in a conscious, self aware system; as is suggested by Elward et al. (2013) and Genon et al. (2013). Indeed, the fact that different types of recollection measures may even dissociate (as suggested in ASD by Souchay et al., 2013) means that a priority for future research may be to further fractionate recollection into sub components which are more representative of awareness or strategic regulation. Perhaps people can retrieve specifics from a prior study episode but fail to act appropriately on this fact, for instance.

In sum, recollection will remain a concept which is useful for emphasizing the retrieval of specifics from a prior study episode, and this concept will have utility in explaining memory disorders and clinical features of people with memory impairment.[2] The neural basis of recollection and familiarity deficits remains a priority for research, and especially where it can describe the rich multitude of information sources and epistemic feelings used in a simple decision of whether we have previously experienced a person, idea, or place. We would echo the arguments of Montaldi and Mayes (2010) and Klein (2013) that recollection as a component of recognition memory may come to be seen as a type of retrieval process, a kind of memory experience, rather than a separable system or store. When there is a feeling of recollection, it suggests that a different type of experience can bring to bear on a recognition memory decision.

[2] To the best of our knowledge, no standardized clinical assessments of recollection and familiarity exist. Given the extensive use of recollection and familiarity in research contexts (and even in rehabilitation; e.g., Jennings and Jacoby, 2003) this is surely a priority for the field, including establishing reliability of measurement.

Acknowledgements

We are very grateful for the contributions of Dr Nathan Illman to the drafting of this manuscript; Dr Emmanuel Barbeau's and Laura Ferreri's comments on the figures; and editorial guidance from Prof. Sergio Della Sala. The Special Issue itself came from discussions at two meetings, Epilepsy and Memory: The State of the Art (4th–6th May 2009 Dartington, Devon, UK) and The 2nd Recollection Workshop (28th–30th May 2008, Tours, France). It is a direct output of the ESRC-CNRS collaborative workshops programme awarded to Chris Moulin and Michel Isingrini (Recollection, Remembering and the Complex Nature of the Self; RES-170-25-0008).

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