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The limited usefulness of models based on recollection and familiarity

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Wais PE. The limited usefulness of models based on recollection and familiarity. *J Neurophysiol* 109: 1687–1689, 2013. First published September 19, 2012; doi:10.1152/jn.00548.2012.—A recent report concluded that magnetoencephalographic signals of neural activity associated with memory based on the recollection process are independent from signals associated with memory based on the familiarity process. These data can be interpreted equally well, however, as indications of memory aggregated from both processes and showing that signals associated with high-confidence recognition are dissociable from signals associated with low-confidence recognition. The usefulness of interpreting neural data according to psychological models based on recollection and familiarity is discussed.

recollection; familiarity; discrimination; generalization

FOR MANY DECADES, PSYCHOLOGICAL SCIENCE has drawn qualitative distinctions in the awareness of prior experience that constitutes recognition memory. Behavioral results show that recognition based on contextual information associated with a specific event is more durable than context-free recognition (Mandler 1980). By comparison, awareness of previous experience that is context free is more rapid and less effortful (Atkinson and Juola 1973), which suggests that there are adaptive benefits of qualitatively different cognitive processes underlying the unified experience of recognition. Dual-process models of recognition refer to retrieval of long-term memory (LTM) that is based on recollection of contextual information and familiarity that is context free. However, there is substantial controversy over the interpretations from these models whether recognition decisions result from contributions of recollection and familiarity (Wixted 2007) or recollection or familiarity (Yonelinas 1994). This controversy gives rise, in turn, to divergent neural models of how recognition memory is supported in the brain. Recently, Evans and Wilding (2012) made an interesting and important contribution to this literature based on the novelty of their magnetoencephalographic (MEG) measures of neural activity. The authors reported data that support the conclusion that event-related field (ERF) signals associated with judgments based on recollection are independent (i.e., functionally dissociable) from signals associated with judgments based on familiarity.

Evans and Wilding (2012) collected neuroimaging data associated with participants' behavioral responses during a recognition memory task using the Remember/Know procedure. This procedure instructs the participant to respond Remember when they recognize a studied target as "old" on the basis of conscious retrieval of contextual information from the preceding encoding session, or to respond Know when recognition is not accompanied by memory of contextual details.

The behavioral results showed that participants were significantly more accurate in their judgments given to targets as Remember ($96 \pm 4\%$) than Know ($70 \pm 3\%$). Notably, accuracy is closely associated with the level of confidence experienced in recognition memory (Heathcote 2003; Slotnick and Dodson 2005). Mean latencies were faster for Remember than Know responses, which provided additional evidence that Remember were given with significantly greater confidence than Know responses. The authors adopted the High-Threshold Dual Process (HTDP) model (Yonelinas 1994) to infer that the high accuracy and confidence of Remember responses indicated recognition of the target words based on recollection. According to HTDP, the recollection process retrieves only memories that exceed a high threshold in confidence, with very few, if any, false alarms (i.e., recognizing a new word as old). HTDP also holds that less confident (i.e., subthreshold) recognition is based solely on familiarity, which is a less accurate and continuous process that retrieves a range of strength for memory free of contextual details from the encoding session.

In the analysis of the neural data, Evans and Wilding (2012) referred to the previous literature in event-related potential memory studies for guidance in selecting temporal windows of activity and cortical regions of interest (ROIs). The referenced studies were also guided by HTDP interpretations for recollection and familiarity. Notably, the test phase in the experimental paradigm did not include a probe of source memory (i.e., to determine objective recollection of whether target words were studied in the CONCRETE/ABSTRACT or ALPHABETIC study conditions). Functional ROIs were determined in a whole brain analysis of data that were selected from categories of trials associated with the highest rates of accuracy in the deep encoding condition. The critical analysis of the neural correlates of recollection and familiarity was then performed on the trials associated with the shallow encoding condition and revealed the dissociation between two ERF signals: an early signal above frontal regions (i.e., 300- to 500-ms poststimulus epoch) associated with Know, but not Remember, responses, and a later signal above posterior regions (i.e., 500- to 800-ms poststimulus epoch) associated with Remember, but not Know, responses. Evans and Wilding (2012) concluded that their results showed recollection and familiarity make independent contributions to recognition judgments, given 1) a behavioral dissociation between Remember responses based on recollection and Know responses based on familiarity, and 2) these two categories were correlated with different ERFs. They also concluded the data "do not support accounts where Remember and Know responses reflect different degrees of memory strength."

A major complication for these conclusions, however, is the limitation of the Remember/Know procedure for which Evans and Wilding (2012) did not account. Several studies find that Remember responses are diagnostic for a high level of confi-

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dence about memory retrieval, but not always for recollection of goal-relevant, or criterial, details (Brown and Bodner 2011; Wais et al. 2008). These same studies show that Know responses are accompanied by weaker, but accurate, recollection of criterial details more often than not. Other research shows that specifics of the instructions and terminology used during the test session influence the accuracy of Remember responses, both in terms of recognition and criterial recollection, but not the accuracy of Know responses (McCabe and Geraci 2009). The relevant literature has revealed, therefore, that even though Remember responses always indicate high confidence about recognition (i.e., high memory strength), accuracy for criterial details can be assured only through confirmatory evidence such as positive results from a probe of contextual or source memory. The literature also suggests that Know responses are accompanied by some contribution of objective recollection. Taking these findings from the broader literature into account, it is quite reasonable to interpret the results from Evans and Wilding (2012) as showing a later ERF signal over posterior cortical regions associated with very accurate, high-confidence recognition and an earlier ERF signal over frontal cortical regions associated with less accurate, lower-confidence recognition. This alternative interpretation assumes that the high-confidence (later) ERF signal is associated with strong memory based on recollection and familiarity, whereas the low-confidence (earlier) ERF signal is associated with weaker memory based on both processes. The patterns in accuracy and latency in the behavioral data support this interpretation of the results from the key analysis (Fig. 1). Critically, the report did not show results for source memory (i.e., the CONCRETE/ABSTRACT or ALPHABETIC study conditions) that accompanied Remember and Know responses and cannot confirm either the selective use of recollection underlying Remember or its absence underlying Know. Confirmation of both points would be necessary support for Evans and Wilding's (2012) interpretation about the dissociation in their neural results.

Equivocal conclusions about the results from Evans and Wilding (2012) could be avoided if there were a means in the analysis to equate relative confidence for responses indicating recollection with those indicating familiarity, as shown in other examinations of the neural correlates of recollection and familiarity (Duarte et al. 2008; Wais et al. 2010). Because recognition confidence is not equated between responses taken to indicate one or the other memory processes, the behavioral

results reported in Evans and Wilding (2012) confound dissociations between memory processes with differences between higher and lower memory strength. The reported pattern in neural results, therefore, cannot be associated more clearly with differences between memory retrieval processes than with differences in experiences of memory strength. The confound of memory strength and memory processes is a concern that applies to many studies that have examined recognition memory and the functional organization of the LTM system (Wais 2008). Notably, recent functional MRI (fMRI) results reveal that patterns in cortical activity that index the subjective sense of memory strength are distinct from those that support the amount of objective details that are subsequently remembered (Qin et al. 2011).

Yet, additional complications make it difficult for neuroimaging studies to avoid equivocal conclusions about underlying contributions of recollection and familiarity. An elusive problem is how to separate or classify memory judgments based on subjective recollection (i.e., recognition based on non-criterial details) from those based on familiarity (Duarte et al. 2008; Wais 2011; Yonelinas and Jacoby 1996). Another problem is that even when using a parametric measure of recognition memory confidence in parallel with a probe of contextual or source memory, it can be challenging to collect a sufficient distribution of observations to afford satisfactory statistical power for neuroimaging analysis that equates confidence between objectively confirmed recollection-based and familiarity-based responses. These two problems are important examples of the limited explanatory power that psychological models based on recollection and familiarity offer for the interpretation of neuroimaging data associated with LTM retrieval.

Beyond Recollection and Familiarity

The report by Evans and Wilding (2012) extends, rather than resolves, the debate surrounding divergent psychological models for recollection and familiarity, as well as interpretations about how recognition memory processes are supported in the brain. More generally, if additional research based on models of recollection and familiarity only extends this debate rather than resolving it, the broad usefulness of such models is subject to question. Perhaps superimposing psychological models that use experiential reports of recollection and familiarity onto associated patterns of neural activity has limited value to advance the cognitive neuroscience of recognition memory.

Alternatively, a new approach would be to objectively classify observable behavior as recognition based on discrimination of distinct contextual information relevant to retrieval goals, or as recognition based on generalization when memory for relevant context is absent. These behavioral classifications, discrimination and generalization, arise from the greater precision that a computational, neural network model can provide for the interpretation of qualitatively different recognition decisions (Norman and O'Reilly 2003). The Complementary Learning Systems (CLS) model proposes how distinct neural computations for pattern completion and pattern separation underlie recognition decisions, including predictions about associated patterns of activity in subregions of the medial temporal lobe (MTL). According to the CLS model, recognition based on pattern completion is experienced as a generalized match with some prior experience, whereas recognition

	accuracy / confidence	
	HIGH	LOW
Remember (S) HTDP recollection	0.94 %-correct	
Know (S) HTDP familiarity		0.73 %-correct

Fig. 1. Behavioral results associated with the critical event-related field analysis in Evans and Wilding (2012) are presented as the authors' interpretations of underlying recollection and familiarity (y-axis) compared with accuracy of those responses calculated as percent-correct (x-axis). Accuracy and confidence in recognition memory are closely associated. The empty quadrants (*top right* and *bottom left*) show that, according to the High-Threshold Dual Process (HTDP) model adopted by the authors, recollection responses are never below a high threshold in accuracy or confidence and familiarity responses are never above that threshold in accuracy or confidence.

accompanied by awareness of relevant contextual details is based on pattern separation. Because pattern separation depends on sparse coding of the particular features of an experience to make its memory trace unique, recognition based on underlying pattern separation is thought to engage different functional-neuroanatomic regions or networks than recognition based on pattern completion. Therefore, recognition responses based on generalization or discrimination can be interpreted from associated empirical evidence of the neural processes of pattern completion and pattern separation, respectively. Results from fMRI offer robust evidence that certain MTL subregions subserve pattern separation processes, while other subregions are biased toward pattern completion processes (Bakker et al. 2008). These neuroimaging results suggest that the neural processes of pattern separation and pattern completion could be associated with explicit recognition responses and that a new approach could examine how functional whole brain networks support discrimination and generalization underlying recognition decisions. Needless to say, given the reasons described above in relation to interpretation of the data from Evans and Wilding (2012), such a new approach would need to index memory strength associated with responses based on discrimination and generalization so that confidence could be equated in comparisons between the neural correlates of these categories.

In summary, the report from Evans and Wilding (2012) using MEG is interesting because its results offer additional and novel insight about the roles played by distinct brain regions in human memory operations. It is not clear whether these results support interpretations about a dissociation in neural activity underlying recollection and familiarity in addition to providing evidence that stronger and weaker recognition judgments are subserved by different ERFs. An alternative is to examine LTM retrieval from the perspectives of discrimination and generalization, which arise from a computational, neural network model. This approach compares neural activity correlated with pattern separation and pattern completion, and it would use a neural-based model to guide the interpretation of behavior, rather than characterizations of behavior to interpret neural data. If results from future research adopting this neural-based framework provide more specific information about how recognition is experienced, and supported in the brain, then we would have evidence in favor of an alternative approach with greater explanatory power than models based on recollection and familiarity.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

P.E.W. conception and design of research; P.E.W. analyzed data; P.E.W. interpreted results of experiments; P.E.W. prepared figures; P.E.W. drafted manuscript; P.E.W. edited and revised manuscript; P.E.W. approved final version of manuscript.

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