

resolves into an enduring feeling of contentment. Contentment from writing a song is a pretty good reward. But playing the song for band mates, and turning it into something that we perform, and then getting positive feedback from an audience is sublime.

I sometimes get asked how I find time to make music. I always answer the same way. I'm a better scientist, husband, father (and every other role I perform) because I find the time to make music. So whether you are just a couple of guys or gals with guitars, or in a full band that

plays original songs or covers, whether you are a scientist or a lay person, my advice is to rock on—crank up the amp and make some noise with others. Doesn't matter if it's good or bad, it's how it makes you feel that's important. Playing music makes me feel good. In fact, I can't imagine my life now without being in a band. Viva *The Amygdaloids*.

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## Letters

# Recollection, familiarity and memory strength: confusion about confounds

Rachel A. Diana and Charan Ranganath

Center for Neuroscience, University of California at Davis, 1544 Newton Ct., Davis, CA 95618, USA

In their recent article, Wixted and Squire (henceforth W&S) concluded that '[s]tudies that avoid confounding memory strength with recollection and familiarity almost always find that the hippocampus supports both recollection and familiarity' ([1], p. 210). Here, we argue that W&S's dismissal of the functional magnetic resonance imaging (fMRI) literature and their interpretation of their own fMRI data are based on fundamentally flawed assumptions.

Numerous fMRI studies have dissociated hippocampal and perirhinal cortex activation in relation to recollection and familiarity-based recognition [2]. W&S [1] dismiss these studies as irrelevant because they 'confound' memory strength with recollection and familiarity. W&S are correct that most studies linking hippocampal activity to recollection are based on the assumption that 'recollection yields strong memory' ([1], p. 211). Recollection leads to high confidence because retrieval of specific details is rarely spurious [3]. Thus, confidence is an emergent property of recollection, not a confound.

W&S state that their own fMRI studies [4,5] show that the hippocampus supports both recollection and familiarity. However, their studies show that hippocampal activation is specifically enhanced during encoding of items that are later recognized with high confidence. These findings are compatible with the idea that hippocampal activation is sensitive to recollection. Their studies do not reveal evidence for hippocampal involvement in familiarity unless one assumes that source memory is an exhaustive measure of recollection. By their logic, if one fails to remember a specific detail about a past event, then the recognition decision must have been based solely on familiarity. This is akin to saying that if you do not remember the color of the tablecloth on the dinner table, then you must not be able to recollect any details about dinner last night. In fact, W&S' assumption is untenable because one

can recollect details that do not pertain to the source question [6].

Consider Wais *et al.* [4] who reported that hippocampal activity was enhanced during encoding of items that were later recognized with high confidence irrespective of source memory accuracy (a finding that diverges from at least four previous fMRI studies [7–10]). Unlike most fMRI studies that have assessed familiarity-related activity, however, recognition in [4] was almost exclusively based on high confidence (two-thirds of items were rated at the highest confidence level). The behavioral results suggest that, for most studied items, participants were able to recollect some details about the study episode. The comparison of correct and incorrect source for these trials merely reflected whether participants were able to successfully retrieve a specific detail (which of two highly similar questions had been presented with the word during encoding). A reasonable interpretation of Wais *et al.*'s findings is that hippocampal activation was associated with confident recollection-based recognition, and that their study was ill suited to identify familiarity-related activity. To adopt W&S' interpretation, however, one must make the unrealistic assumption that recollection must always be accompanied by accurate source memory.

We agree with W&S that distinctions between medial temporal lobe subregions should reflect anatomical differences in the types of information received and therefore represented by these areas. However, there is a relation between the kind of information that is remembered and one's subjective experience [e.g. 11], and that is why activity in different medial temporal subregions is differentially sensitive to recollection and familiarity [12].

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Corresponding author: Ranganath, C. (cranganath@ucdavis.edu).

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## Letters Response

## Confusion abounds about confounds: response to Diana and Ranganath

John T. Wixted<sup>1</sup> and Larry R. Squire<sup>1,2,3,4</sup>

<sup>1</sup>Dept of Psychology, UCSD, San Diego, CA, 92093, USA

<sup>2</sup>Dept of Psychiatry, UCSD, San Diego, CA, 92093, USA

<sup>3</sup>Dept of Neurosciences, UCSD, San Diego, CA, 92093, USA

<sup>4</sup>VA Healthcare System, San Diego, CA, 92161, USA

We agree with Diana and Ranganath [1] that there is ‘confusion about confounds,’ so we begin with a brief explanation of what a confound is. The scientific method involves manipulating an independent variable across conditions while holding all other variables constant. If a dependent measure changes across conditions, then that change can be attributed to the independent variable. However, if the independent variable and a nuisance variable both differ across conditions, then a confound exists. In that case, change in a dependent measure cannot be attributed to the independent variable.

We claimed that when the independent variable involves memory processes (recollection vs familiarity), memory strength is often a nuisance variable (strong vs weak). In response, Diana and Ranganath state: ‘Recollection leads to high confidence because retrieval of specific details is rarely spurious... Thus, confidence is an emergent property of recollection, not a confound.’ However, even if one agrees that recollection implies high confidence (if P then Q), it does not follow that high confidence implies recollection (if Q then P). To assume otherwise is to commit a logical fallacy (affirming the consequent). The point is that familiarity (like recollection) can occur with high confidence. Indeed, all dual-process theories agree that high confidence is an emergent property of both recollection and familiarity (e.g. [2]). If

one proposes that recollection is associated particularly with hippocampal activity, then one must also show that equally strong familiarity is not associated with hippocampal activity. This is why it is essential to equate confidence (and accuracy, whenever possible) when comparing recollection and familiarity.

In studies of source memory using functional magnetic resonance imaging (fMRI), items recognized with low confidence followed by incorrect source recollection (decisions assumed to be based on familiarity) typically do not yield elevated hippocampal activity, whereas items recognized with high confidence followed by correct source recollection (decisions assumed to be based on recollection) typically do yield elevated hippocampal activity [3–5]. Wais *et al.* [6] eliminated the strength confound by comparing high-confidence responses for both source-correct and source-incorrect decisions and found that hippocampal activity was similarly elevated for both kinds of decisions (see also [7]). Diana and Ranganath [1] object that high-confidence recognition followed by incorrect source recollection might not reflect strong familiarity but could instead reflect strong task-irrelevant recollection. Under that interpretation, the results could still be consistent with the idea that hippocampal activity reflects recollection. However, the inability to measure task-irrelevant recollection is an inherent limitation of the source memory procedure that applies to low-confidence recognition as well as high-confidence recognition [3–5]. For example, low-confidence recognition followed

Corresponding author: Wixted, J.T. (jwixted@ucsd.edu).