Response to: Gold et al. Reduced capacity but spared precision and maintenance of working memory representations in schizophrenia. *Arch Gen Psychiatry.* 2010; 67: 570-577

Precision versus capacity of working memory in schizophrenic and healthy individuals

16 July 2010

Gold et al[1] report that schizophrenic patients store fewer items in working memory (~2.4 versus 2.75 for controls), but have no impairment of memory precision. It's pleasing to see current cognitive neuroscience methods[2-4] being applied directly to psychiatry, but for correct interpretation it's crucial to be aware of all experimental details.

In this study, participants viewed a briefly-presented array of colored squares. After a delay, the location of one square was cued and participants clicked on a color wheel to indicate the color they recalled at that location. Responses were assumed to fall into two categories: (*a*) trials where the cued color was stored, so responses were distributed (with some variability) around the correct color, and (*b*) those where the cued color was not stored, so responses were scattered randomly around the color wheel[3].

However, to respond correctly on this task, one must remember not only the colors presented, but also *which color was where*. This introduces a third category of 'misreporting' responses: (*c*) where the cued color is stored but, because of errors in remembering its location, participants respond with one of the other (*uncued*) colors presented. We have shown that these errors make up the majority of supposedly 'random' responses[4], implying that the recall task probes limits on precision of memory[5] (for both color and location) rather than how many items are stored.

In our study, misreporting errors were evident as a peak in response frequency centered on each uncued color[4]. In contrast, Gold et al report this distribution was "essentially flat" in their data, leading them to discount misreporting as a significant source of error. However, this ignores a critical difference from some previous versions of the task[2,4]. In Gold et al, all colors to-be-remembered were separated

by a minimum angle (24°) rather than selected randomly from the color wheel. As a consequence, if subjects really were responding to only the cued item – uninfluenced by uncued items – their responses would rarely fall close to an uncued color. Therefore, the predicted frequency of responses centered on each uncued color should actually show a sharp *decrease*.

Indeed for this distribution to be uniform, as reported[1], for four-item arrays we calculate >25% responses would need to have been misreporting errors, i.e. responding to uncued colors. Taking into account this additional source of error might result in radically different conclusions regarding working memory in schizophrenia, as for normal performance[4].

Paul M Bays & Masud Husain
UCL Institute of Cognitive Neuroscience & Institute of Neurology, Queen Square, London, WC1N 3AR, UK

References

1. Gold JM et al. Reduced capacity but spared precision and maintenance of working memory representations in schizophrenia. *Arch Gen Psychiatry.* 2010; 67, 570-577.

2. Wilken P, Ma WJ. A detection theory account of change detection. *J Vis.* 2004; 4, 1120-1135.

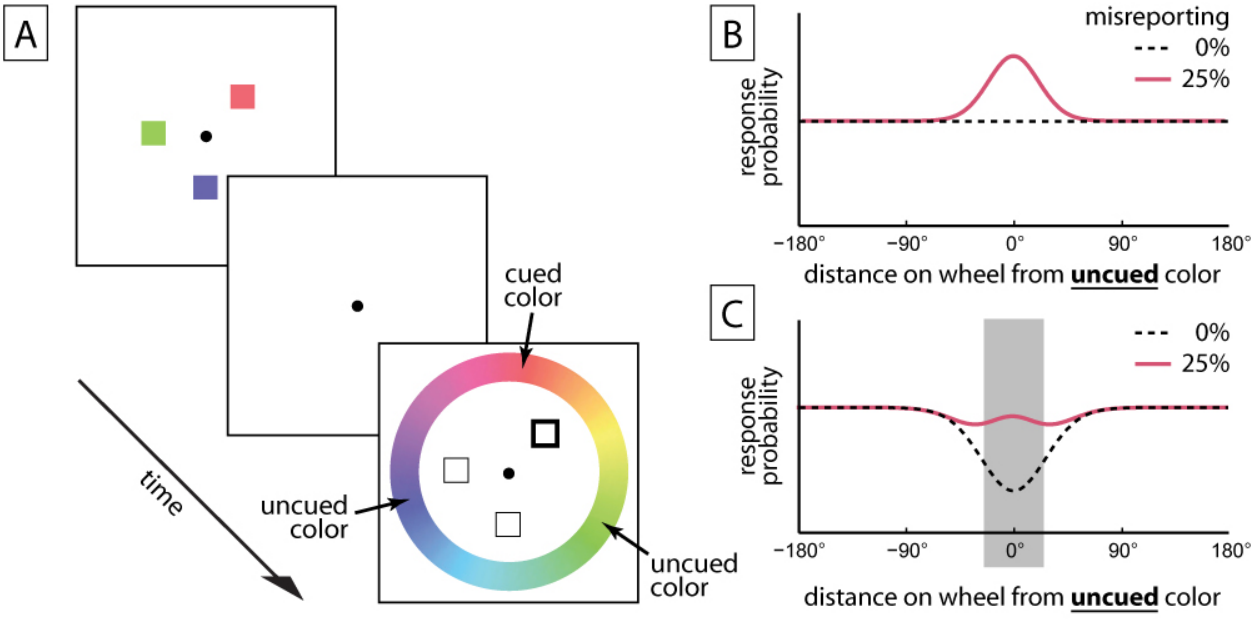
3. Zhang W, Luck SJ. Discrete fixed-resolution representations in visual working memory. *Nature*. 2008; 453, 233-235.

4. Bays PM, Catalao RFG, Husain M. The precision of visual working memory is set by allocation of a shared resource. *J Vis.* 2009; 9, 7.

5. Bays PM, Husain M. Dynamic shifts of limited working memory resources in human vision. *Science.* 2008; 321, 851-854.

Published as: Bays PM (2010) Precision versus capacity of working memory in schizophrenic and healthy individuals. *Archives of General Psychiatry Online*, 16 July. Available at: http://archpsyc.ama-assn.org/cgi/eletters/67/6/570#13801

Supplementary Figure



A, The color recall task. An array of colored squares which have to be remembered is briefly presented and then, after a short interval, one location is cued (solid outline). The participant must indicate the color they recall seeing at that location by clicking on a color wheel. While the majority of responses will be clustered around the correct point on the wheel (cued color: in this case, red), errors in remembering which color was at the cued location will mean some responses are centered on the other presented but *uncued* colors in the array (misreporting errors: in this case, green and purple)[4].

B, If the colors to-be-remembered in the memory array are chosen at random from the color wheel, misreporting errors are observed as a peak in the distribution of responses plotted relative to each uncued color (red line)[4]. If there are no misreporting errors this distribution will be uniform (dotted line).

C, In the study by Gold et al[1], cued and uncued colors were not chosen independently: a minimum distance (illustrated by the shaded region) was introduced between the colors of any two items in the array. As a result, responses in the region of uncued colors should in fact be much *less* frequent than elsewhere on the wheel and there should therefore be a dip in the observed responses around each uncued color (dotted line). But if the distribution is flat, as reported, a substantial number of misreporting errors must have occurred even to approach a uniform distribution (e.g. red line).