Murdock free recall data: The initial recall search identifies the context by the location of the least remembered item and produces only better remembered items in proportion to the total recall difference. Memory activity level may be sensed by glial cells.

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Abstract:

The curious free recall data of Murdock (1962) shows an additional surprise that seems to have gone undetected until now: the probability of guessing an item in the initial recall is not identical to the overall free recall curve. Initial recall of an item is well correlated with the total recall of that item using a straight line but with an unexpected offset. The offset varies with the presentation rate and the total number of list items but in each case it is the same as the total recall probability of the least recalled item. Thus for the initial "freest" of recalls the location of the least remembered item is identified, in effect identifying the context, and from there the items recalled are those better remembered items, in proportion to the probability of total recall. Within the tagging/retagging model (Tarnow, 2008, 2009) the free recall starts by an identification of a discontinuity in the activity level and produces an item with a probability according to the relative activity level.

I speculate that the activation level and its discontinuity is detected by glial cells assisting in rebuilding post-activation empty presynaptic neurotransmitter vesicles.

Introduction

If the lag in free recall experiments between the item presentations and the initial recall is large enough, the initial recall can be thought of as the "freest." Subsequent recalls are cued. They tend to be more common in the forward than in the backward direction (in particular, if item N was recalled in the beginning then item N+1 is twice as likely to be recalled as item N-1, see Kahana, 1996 and Howard and Kahana, 2002). Subsequent recalls are also cued by the requirement of excluding the previously recalled items from further recall.

In this paper I study the initial recall. I will investigate the probability that an item is recalled in the data of Murdock (1962). In a recognition experiment where cue is varied through the items, the shape of the initial recall curve would likely be the same as the famous bowed total recall curves. In the initial free recall data, it is not the same.

To interpret the experimental results I will use the tagging/retagging model (Tarnow, 2008) which is an activation model. I will use "activation" and "tagging" synonymously throughout the paper.

The Murdock (1962) initial item recall data

The Murdock (1962) data can be downloaded from the Computational Memory Lab at University of Pennsylvania (http://memory.psych.upenn.edu/DataArchive).

The data consists of six experiments in which the presentation rate and list size was varied. The experiments are typically labeled M-N in which M is the number of list items and N is the number of seconds between item presentations. In Figure 1 is shown the 10-2 total recall data as well as the 10-2 initial recall data. Both curves show the famous bowing effect. Note that three of the lowest points in the initial recall curve have close to 0 recalls.

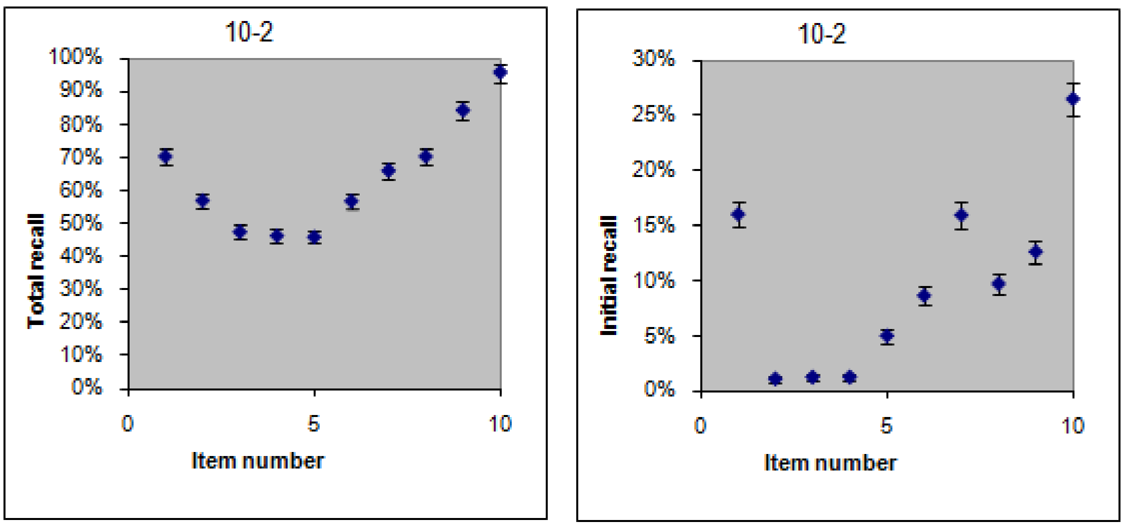

Fig. 1. The left panel shows the famous bowed curve of total recall versus item number. The right panel shows the bowed curve of initial recall versus item number. The error bars in each direction are the standard deviation of a Poisson distribution.

Figure 2 shows the number of initial recalls of each item as a function of the total number of item recalls. In a recognition experiment one would have expected the graph to be a straight proportionality. I find a straight line but with a curious offset. The offset is a result of low probability items almost never being recalled in the initial recall. In Figure 3 the offset varies with the six experiments but in each case it is the same as the total recall probability of the least recalled item. In other words, the brain knows at the initial recall how well it will recall the least remembered items but it chooses not to recall those in the initial recall.

Thus for the initial "freest" of recalls the location of the least remembered item is identified, and from there the items recalled are those better remembered items, in proportion to the probability of total recall.

That is a model independent statement.

Within the tagging/retagging model (Tarnow, 2008) the probability of total recall is the activation (tagging) level. The initial search that locates the least remembered item is then locating a discontinuity in activation level. This is true for any activation model. If the activation level is equivalent to the presynaptic neurotransmitter vesicles emptied (Tarnow, 2009), then the question occurs – how can a discontinuity in activation be detected? If the memory decay is the rebuilding of the presynaptic neurotransmitter vesicles (Tarnow, 2009) then the neurons are no longer firing. Without sending out new signals it is not clear how the neurons themselves would communicate that they previously were active without reactivating themselves. A more attractive explanation is that glial cells detect the activation level: The rebuilding of the synapses is a process involving glial cells. When the neurons stop firing the glial cells are active in proportion to the current or previous activation level and may be used for identification of short term memory activity. Indeed, it is the glial cells that provide the fMRI traces that are used to experimentally assess neuron activity.

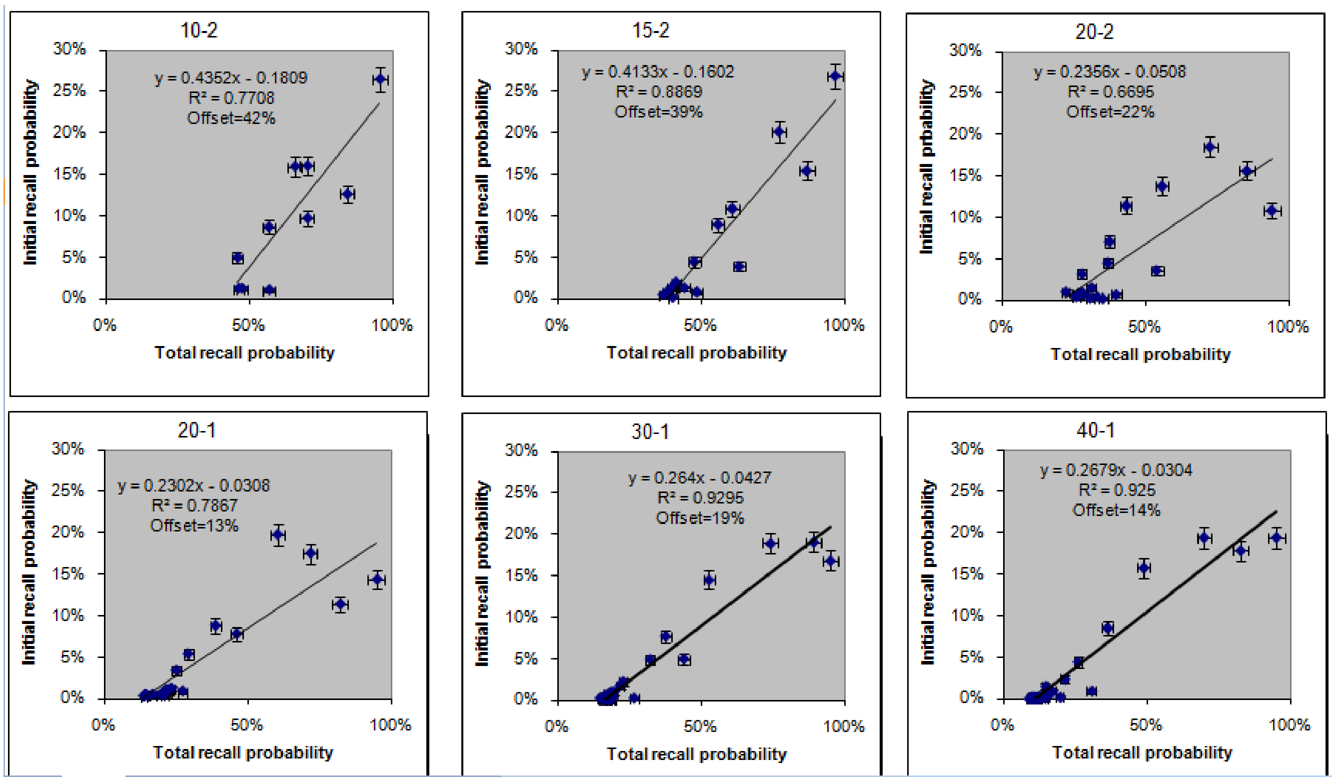

Figure 2. Number of initial guesses for each item versus the total number of guesses for that item. The six panels correspond to the six Murdock experiments labeled on top as M-N. M is the number of items in the list and N is the number of seconds between item presentations. Note the well defined intercepts. The error bars in each direction are the standard deviation of a Poisson distribution. The error bars are small compared to the typical distance from the points to the line - I am not sure why.

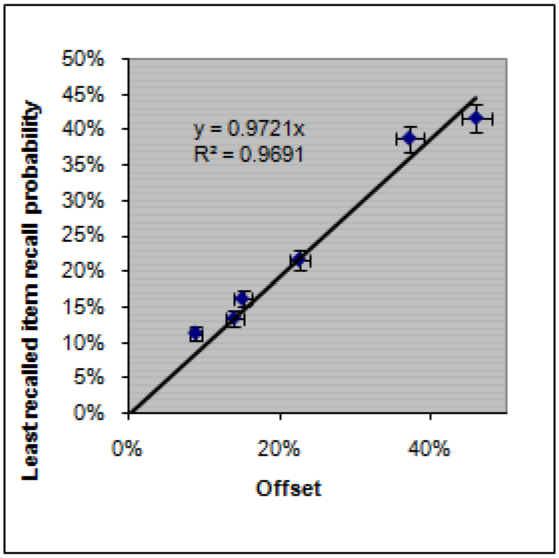

Figure 3. Recall probability of the least recalled item versus the offset in the curves in Figure 2. Note the relationship **offset=least recalled item recall probability.** The error bars in each direction are the standard deviation of a Poisson distribution. The error bars are appropriate compared to the typical distance from the points to the line.

Summary & Discussion

I find that the free recall data of Murdock (1962) contains well defined information about how a free recall search is accomplished: initially, the location of the least remembered item is identified, thus identifying the recall context, but the items recalled are the better remembered items. They are recalled in proportion to the difference in probability of total recall. After the initial recall, cued recalls proceeds (Kahana, 1996 and Howard and Kahana, 2002) and identifies remaining items including the neglected least remembered items.

There are at least three different classes of memory models, those based on decay, temporal distinctiveness and interference (Oberauer and Lewandowsky, 2008).

The current findings can be described within the tagging/retagging model (Tarnow, 2008) which is a decay type model: Word items are read in and tagged. As time progresses the tagging level decays. A free recall search identifies a discontinuity in tagging level (the contextual item that has decayed the most) and produces a word item that has a higher tagging level than the discontinuity. The word produced is selected in proportion to the difference in tagging level. If the tagging is the amount of absent presynaptic neurotransmitter vesicles (Tarnow, 2009), the tagging level might be detected by glial cells which assist in recreating the presynaptic neurotransmitter vesicles. In other words, when neurons stop firing, the information that they did fire recently is no longer in firing of neurons but in post-firing glial activity.

Interference models (see Oberauer and Lewandowsky, 2008) argue that items in short term memory do not decay but are probabilistically replaced by novel items. If the items were replaced in an all or nothing fashion, the current finding of an offset would argue against these theories: There would be no reason to identify, but not report, the least remembered item since all items remembered equally. The current finding does not rule out interference models that use encoding strength variables, nor does it rule out theories based on temporal distinctiveness.

Acknowledgement

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