There is no capacity limited buffer in the Murdock (1962) free recall data

Eugen Tarnow

Received: 16 October 2009 / Revised: 6 February 2010 / Accepted: 12 February 2010 / Published online: 25 February 2010
© Springer Science+Business Media B.V. 2010

Abstract Theories of short term memory often include a limited capacity “buffer”. Such a buffer contains items which do not decay at all but are overwritten by new data. I show that one of the experiments that fueled the buffer concept, the free recall experiments by Murdock (J Exp Psychol 64(5):482–488, 1962), does not contain such a buffer.

Keywords Short term memory · Buffer · Capacity limit

The theoretical concept of a division of memory into short term memory and long term memory (apparently first mentioned by James 1890) explicitly expresses that short term memory is time-limited (“short term”). Since it is time limited it is effectively capacity limited, though the capacity could, in principle, be huge. At some point this distinction between time and capacity was forgotten and the idea of short term memory being capacity limited BUT NOT time-limited took shape.

In a very interesting paper, presumably quoted more than read, Miller (1956) wrote “everybody knows that there is a finite span of immediate memory and that for a lot of different kinds of test materials this span is about seven items in length”. He considered experimental data and continued: “Immediate memory is limited by the number of items. In order to capture this distinction in somewhat picturesque terms, I have fallen into the custom of distinguishing between bits of information and chunks of information. Then I can say that the number of bits of information is constant for absolute judgment and the

number of chunks of information is constant for immediate memory. The span of immediate memory seems to be almost independent of the number of bits per chunk, at least over the range that has been examined to date”. Thus he coined the “chunk” and stated that we remember about seven chunks (this concept actually goes back to Wundt (see Carpenter 2005)).

That computers used to have a small amount of RAM (now a huge amount of RAM) probably lead Atkinson and Shiffrin (1968) to propose the “rehearsal buffer” as a “control process” in which a small number of items could exist without decaying in time. When a new item was added, one of the old items would be kicked out of the buffer, just like in a computer old RAM entries are overwritten by new ones. The idea of a capacity-limited but time-unlimited buffer became prevalent (see, for example, Cowan 2000 and references therein discussing the “magic number” of items in the capacity limited buffer). A search on scholar.google.com of memory AND buffer (medicine, pharmacology and veterinary science) yields no less than 99,900 results and the yearly number is increasing sharply (see Fig. 1).

The rehearsal buffer is an interesting concept (and also helpful when one tries to fit experimental data to a theory but the data does not want to comply: “Any decay model can explain the absence of forgetting, should it arise in the data, by appealing to compensatory rehearsal, and at the same time, it can explain the presence of forgetting, should it occur, by suggesting that rehearsal was withheld or impossible” (Oberauer and Lewandowsky 2008)). In this contribution I will see what the data of one experiment in free recall say about the existence of such a buffer.

Note that I do not argue with Wundt (Carpenter 2005), Miller (1956) and Cowan (2000) that the capacity of short term memory is limited. Rather, I argue that we have to

E. Tarnow (✉)
18-11 Radburn Road, Fair Lawn, NJ 07410, USA
e-mail: etarnow@avabiz.com

Fig. 1 Number of memory buffer articles per year on scholar.google.com (using the search memory AND buffer limiting it to medicine, pharmacology and veterinary science) is increasing sharply

stick to the initial “short term” concept in which short term memory is explicitly limited by time (and only implicitly limited in capacity). The “in-or-out buffer” concept in which there is a small amount of memory not limited by time but by over writing, I will show is incorrect.

I use the data that inspired the Atkinson and Shiffrin paper, the free recall data of Murdock (1962). 1200 word lists were read to subjects who then tried to recall as many words as possible in each of six conditions—three with an item presentation rate of 1/sec and three with an item presentation rate of 0.5 per second (the experimenter was using a metronome to keep the pace). In this paper I limit myself to the condition with the lowest number of words, 10 list items in a list read at 0.5 words per second, which for our purposes has the best statistics (most responses per list item). The Murdock data shows the “bowing” effect in which items in the beginning and end of each list is remembered better than the items in the middle. This bowing effect was an inspiration to the Atkinson and Shiffrin (1968) rehearsal buffer.

The test for the existence of the buffer is a little complex so please stay with me: If there is a buffer, then the list item first remembered will either already exist in the buffer or will kick out an item in the buffer to make place for itself. In the former case, the remaining memory will be maximal since the memory content was not changed but in the latter case the remaining memory will be negatively affected by the displacement of an item. Whether an item is in the buffer or not is clearest for the last list item (item number 10, where the “item number” is the number of the item in the original list)—it should be in the buffer. As the list item number decreases from 10, the probability that the list item is in the buffer decreases. Thus we arrive at our test: *if there is a buffer, as the item list number of the first remembered item decreases, the total number of items remembered should decrease.*

Fig. 2 The total number of items recalled in Murdock's 10-2 experiment as a function of the first item recalled. The error bars are calculated as the standard deviation divided by the square root of the number of trials with the particular initial item

Fig. 3 The trend of total number of items recalled in Murdock's 10-2 experiment as a function of the first item recalled shows a negative slope for high numbered items

Alternatively, suppose there is no in-or-out buffer and the items in short term memory are not correlated with each other but simply decay independently. In this case, no matter which item is remembered, the subsequent memory content should not be affected. The total memory found should be higher if the initial recall was a low probability item (a lucky guess) and lower if the initial item was a high probability item according to the formula:

$$\begin{aligned} \text{Total memory given initial item } s \\ = \text{Average total memory} \\ + (1 - \text{average probability of recall of } s) \end{aligned} \quad (1)$$

In Fig. 2 is shown the total number of items remembered as a function of the initially recalled item number. The error bars show the standard deviations of the mean. (Items 2, 3 and 4 are picked only about 1% of the time so their error bars are substantially larger. We will disregard these three points in the remainder of the paper.) In Fig. 3 I fit the last six items to a straight line. We see that *as the item number decreases, the total number of items remembered increases.* This is the opposite what is predicted by an in-or-out buffer model and thus rules it out.

Fig. 4 The number of items recalled versus 1 minus the free recall probability of the first item. The data points are from Murdock (1962) and the dashed line is the theoretical prediction from Eq. 1

If there is no in-or-out buffer, does Eq. 1 fit the data? In Fig. 4 is shown the total memory content given item s , versus $(1 - \text{average probability of recall of } s)$ and the theoretical prediction from Eq. 1 (dashed line). A linear fit describes 94% of the variance in the experimental data. The slope is 0.79, not too different from the prediction of 1 and the offset is 6.25, not too different from the average total memory of 6.40.

The conclusion also disproves the more general case of a capacity limited buffer in which items decay more slowly than in a subsequent memory store.

Final note: While the buffer concept may be appealing from a theoretical point of view, it is difficult to think of a biochemical process that would accommodate it. Biochemical decay processes, on the other hand, are known to exist (see, for example, Tarnow 2009).

References

- Atkinson RC, Shiffrin RM (1968) Human memory: a proposed system and its control processes. In: Spence KW, Spence JT (eds) The psychology of learning and motivation: advances in research and theory, vol 2. Academic Press, New York, pp 89–195
- Carpenter SK (2005) Some neglected contributions of Wilhelm Wundt to the psychology of memory. *Psychol Rep* 97(1):63–73
- Cowan N (2000) The magical number 4 in short-term memory: a reconsideration of mental storage capacity. *Behav Brain Sci* 24(1):87–114
- James W (1890) The principles of psychology. Henry Holt
- Miller GA (1956) The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychol Rev* 63:81–97
- Murdock BB Jr (1962) The serial position effect of free recall. *J Exp Psychol* 64(5):482–488
- Oberauer K, Lewandowsky S (2008) Forgetting in immediate serial recall: decay, temporal distinctiveness, or interference? *Psychol Rev* 115(3):544–576
- Tarnow E (2009) Short term memory may be the depletion of the readily releasable pool of presynaptic neurotransmitter vesicles of a metastable long term memory trace pattern. *Cogn Neurodyn* 3(3):263–269