Where the magic breaks down: boundaries and the 'focus-of-attention' in schizophrenia.

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Commentary on Cowan
"The magical number 4 in short-term memory:
A reconsideration of mental storage capacity"

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Abstract:

The boundaries, the influences on and consequences of a short-term memory (STM) capacity of 4 lead us to consider global vs. local processing. We argue that in schizophrenia cognitive problems can lie partly in pre-conscious automatic selective attention and partly with the speed of processing in later controlled processes (including compound STM). The influence of automatic attentional mechanisms may be under-estimated in normal psychology and explain the loss of the magic 4 in schizophrenia.

Commentary:

Cowan's arguments for a store with a capacity limited to 4, or thereabouts are persuasive: these are most eloquent in tests of serial recall, using articulatory suppression and involving articulated responses. It is a sort of explicit, short-term memory (STM). To call it the focus-of-attention does an excellent service by emphasizing that the store (and by implication attention) are terms and concepts applicable not only for information of exogenous origin but also for information with endogenous sources (recall and inter-cortical monitoring activities). However, the need to define in and define out certain methodological (e.g. use of 0.5 sec presentation times in serial recall, p.28) and conceptual considerations (e.g. what makes up a chunk? cf. Shyns et al., 1998) points to some limits and consequences (see question 4 p.45) concerning the imprint of the arrow of information flow on the arrow of time.

The limit of 0.5 sec in tests of serial recall is remarkably convenient and reminiscent of Libet's 1964 report that a stimulus should last 500 ms to enter consciousness. Yet, Libet also reminds us that the information is there to be used when it reaches the cortex after less than 100 ms. Although processing at this early stage could literally be regarded as implicit, Cowan suggests that 'implicit memory' stores are also limited to about 4 items (p.41-42). So the sensory buffer or icon remains conceptually intact. This has been clear, at least since Sperling's (1960) account that cues at short intervals (<1 sec) can elicit correct recall of any of 4 rows of 4 letters. The buffer may contain up to 16, or even more items. Creation of this buffer also involves selective attention as it will only occur if the subject is not concentrating on the experimenter's tie or distracted by some fluff on the floor.

The separate influences of these 16+ and 4-item stores are a matter of daily experience. Faces (250 ms) can be recognized, holistically, by an automatic process up to 300 ms later. Only then can they be decomposed into the elements of eyes, mouth etc (ca. 4) by a controlled process (George et al., 2000). Global processing occurs faster than that for local information, with a peak of excitation in the range of 200+ ms, led by temporo-parietal areas on the right (Sugase et al., 1999; Yamaguchi et al., 2000). The efficiency of the early (automatic) selective process, in part, determines the performance of the "focus-of-attention".

But we need to look closer at the influences of efficiency and the speed of processing. Increases of the speed of processing improve the accuracy of recall and the number of items recalled (p.25). This applies, among controlled conscious processes, to the more superficial encoding of items in pure STM (as in the digit span) as well as deeper processing in compound STM (as in word lists). This holds also for patients with schizophrenia (Brebion et al., 2000), for whom there is abundant evidence of impaired STM, controlled processing and slowed information processing (Straube & Oades, 1992). However, it should not be overlooked that controlled selective attention mechanisms are also required, at the least to inhibit interfering associations (e.g. Stroop color-word interference). It is of interest, here, to note that Brebion and colleagues reported that Stroop indicators of selective attention would predict superficial but not the deeper (compound STM) performance. Yet, Stroop interference performance is *not* disproportionately impaired in schizophrenia (except those with predominantly disorganized symptoms), although compound (and pure) STM measures are reduced in size. This implies that one problem for patients with schizophrenia lies in making associations beyond the temporal and strategic bounds of pure STM and incurs the speed of processing.

But having emphasized the pure STM store and a selective attention mechanism at the level of controlled processing, we come to the sensory buffer and automatic processing of the through-put to pure STM. While latencies of later event-related potentials (ERPs) such as the P300 (around 400 ms) are usually delayed, the latencies of P50 (marking the thalamo-cortical arrival of information), N1 (excitatory cortical registration of sensory information) and mismatch negativity (sensory memory for deviance) are not consistently different between patients with schizophrenia and healthy subjects (e.g. Bender et al., 1999, Oades et al., 1996). It appears that the speed of automatic (e.g. MMN) as opposed to controlled processing (e.g. P300) is not delayed, even though the content marked by the amplitude of the ERPs recorded is often reduced in both cases.

Thus it would seem that at short latencies automatic selective mechanisms may make a larger contribution to impaired processing (exaggerated by the state of attention, Oades et al., 1997) than speeds of processing, but the opposite holds for controlled strategic processing. This idea is supported by the finding that the magnitude of sensory gating, a selective process, is impaired in schizophrenia around 100 ms post-stimulus (+/- 50 ms: Bender et al., 1999) and may contribute to the frequently reported phenomenon of sensory overload. In contrast local speeds of processing in different regions (frontal and temporal lobe latencies) may account for apparent deficits in the later 'negative-difference' marker of controlled selective attention (Oades et al., 1996).

Cowan suggests (p. 5) that the apparent pure-STM capacity can be increased by forming inter-chunk relations, perhaps by automatic processes (e.g. priming). This suggests to us the prediction that patients with schizophrenia, renowned for their 'loose associations' (see Spitzer, 1997) should average a larger capacity than normal: why is there ample evidence that this is not true (e.g. Brebion et al. 2000)? We return to global percepts. These activate the right temporo-parietal junction, as emphasized by Frith and Dolan (1997) in their imaging study, especially during sustained attention with few switches of attention. Granholm and colleagues (1999) found not only that processing of local stimuli was impaired in patients with schizophrenia but (perhaps because of this) under conditions of divided attention (requiring switches of attention between global and local conditions in the search for a target) were actually at an advantage compared to their controls when global processing was required. Switching requires inhibition of the alternative, selective attention the inhibition of the irrelevant: its under use resulted in the identification of fewer local items. It is this automatic mechanism of selective attention and its impoverished use that restricts the patients' STM capacity, not just to 'normal' but below normal levels.

We conclude that the automatic / pre-conscious application of selective attention is not only a source of schizophrenic cognitive problems, but has a determining influence on the normal appearance of 4 in Cowan's pure STM, that he has perhaps underestimated in his worthy review.

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Target article abstract:

The magical number 4 in short-term memory: A reconsideration of mental storage capacity

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Abstract

Miller (1956) summarized evidence that people can remember about seven chunks in short-term memory (STM) tasks. However, that number was meant more as a rough estimate and a rhetorical device than as a real capacity limit. Others have since suggested that there is a more precise capacity limit, but that it is only three to five chunks. The present target article brings together a wide variety of data on capacity limits suggesting that the smaller capacity limit is real. Capacity limits will be useful in analyses of information processing only if the *boundary conditions for observing them* can be carefully described. Four basic conditions in which chunks can be identified and capacity limits can accordingly be observed are: (1) when information overload limits chunks to individual stimulus items, (2) when other steps are taken specifically to block the recoding of stimulus items into larger chunks, (3) in performance discontinuities caused by the capacity limit, and (4) in various indirect effects of the capacity limit. Under these conditions, rehearsal and long-term memory cannot be used to combine stimulus items into chunks of an unknown size; nor can storage mechanisms that are not capacity-limited, such as sensory memory, allow the capacity-limited storage mechanism to be refilled during recall. A single, central capacity limit averaging about four chunks is implicated along with other, non-capacity-limited sources. The *pure STM capacity limit* expressed in chunks is distinguished from *compound STM limits* obtained when the number of separately held chunks is unclear. Reasons why pure capacity estimates fall within a narrow range are discussed and a capacity limit for the focus of attention is proposed.

Key Words: attention; enumeration; information chunks; memory capacity; processing capacity; processing channels; serial recall; short-term memory; storage capacity; verbal recall; working memory capacity.

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