WORKING MEMORY

Baddeley and Hitch (1974) and Baddeley (1986) replaced the concept of the short-term store with that of working memory. Baddeley (2001) described four components of working memory:

Central executive

- Key component
- Limited capacity
- Resembles attention
- Deals with cognitively demanding tasks.

Phonological loop

- Preserves the order in which words are presented
- Limited capacity.

Visuo-spatial sketchpad

- Storage and manipulation of spatial and visual information
- Limited capacity.

Episodic buffer

Assumptions from this theory:

- If two tasks use the same component, they cannot be performed successfully together.
- If two tasks use separate components, it should be possible to perform them as well together as separately. See Robbins et al.'s (1996) dual task studies.

PHONOLOGICAL LOOP

The **phonological similarity effect** is good evidence for the role of the phonological loop in short-term memory tasks. Larsen et al. (2000) found that serial recall was 25% worse if a list of words was phonologically similar.

The **word-length effect** (Baddeley et al., 1975) describes the ability to reproduce a sequence of words better with short than long words. This suggests that capacity of the phonological loop is determined by the

temporal duration and that memory span is determined by the rate of rehearsal. These findings have sometimes not been replicated. There is evidence that the word-length effect depends on the phonological loop (see Baddeley et al, 1975). Also see the evidence from Baddeley et al., 2002 (active reference link below).

According to Baddeley (1986, 1990) the phonological loop consists of:

- A passive phonological store concerned with speech perception.
- An articulatory process linked to speech production.

Baddeley suggests that auditory presentation of words has direct access to the phonological store, but visual presentation only has indirect access via subvocal articulation. Support from research with patients with brain damage (e.g., Shallice & Butterworth, 1977, Vallar & Baddeley, 1984).

Evaluation

Baddeley's theory accounts reasonably well for the word-length effect and the effects of **articulatory suppression**. Baddeley et al. (1998) and Papagno et al. (1991) suggest that the phonological loop may be more important in learning new words than familiar ones. Baddeley (1998) found evidence that subvocal rehearsal is not needed for vocabulary learning as young children (who do not use subvocal rehearsal) still show a link between phonological memory and vocabulary learning.

VISUO-SPATIAL SKETCHPAD

Used in the temporary storage and manipulation of spatial and visual information. See Baddeley et al. (1975) and Baddeley and Lieberman (1980) for studies which suggest that the processing of visualisable messages relies mainly on spatial coding.

Logie (1995) argues for two components of visuo-spatial working memory: The **visual cache** stores form and colour information; and the **inner scribe** deals with spatial and movement information and body movements; rehearses and transfers information in the visual cache to the central executive.

Evidence

Support for Logie's theory comes from

- Comparisons of learning techniques and interference tasks (Quinn & McConnell, 1996).
- Stroke patient data showing dissociation of task performance due to a specific functional deficit (Beschin et al., 1997;Farah et al., 1988).
- Smith and Jonides (1997; see E&K p. 200) conducted a PET study which showed differences in brain activation during different visual and spatial working memory tasks (also see Sala et al. (2003) review).
- Brandimonte et al. (1992) describe the link between the visuo-spatial sketchpad and Kosslyn's spatial medium.

Evaluation

Three main types of evidence support the theory of separate visual (visual cache) and spatial (inner scribe) components to the visuo-spatial sketchpad.

- Little interference between visual and spatial tasks (e.g., Baddeley & Lieberman, 1980).
- Brain damage to one, but not the other, component (e.g., Beschin et al., 1997).
- Brain-imaging data (e.g., Smith & Jonides, 1997).

  Many tasks require both components to be used in combination.

CENTRAL EXECUTIVE (CE)

The most important and versatile component of working memory. Resembles an attentional system. Baddeley (1996) argued that frontal lobe damage could cause impairment to the central executive (CE) and described **dysexecutive syndrome**. Baddeley (1996) identified the following functions:

- Switching of retrieval plans
- Timesharing in dual-task studies
- Selective attention
- Temporary activation of long-term memory.

- Smith and Jonides (1999) also produced a similar list (see E&K p. 201) including sub-task planning and coding representations.

Evidence

- Baddeley has used tasks with random generation of letters or digits to study the central executive (CE). Theory is that close attention is needed to avoid producing non-random sequences. Baddeley (1996) found that randomness decreases as digit memory load is increased. Randomness is also reduced by an alternation task suggesting that rapid switching of retrieval plans is a CE function.
- Towse (1998) argues that random generation is not a pure CE function.
- Baddeley (1996) studied patients with **Alzheimer's disease**, and thus reduced CE functioning, who show a marked reduction in performance when given two simultaneous tasks, compared with normal participants. This is taken as evidence for the CE function of distributing attention between two tasks.
- D'Esposito et al. (1995) used fMRI and found that the dorsolateral prefrontal cortex is activated during dual-task conditions.
- The **Stroop effect** requires CE functions of attention and inhibition.
- PET studies have found an area close to the dorsolateral prefrontal cortex (the anterior cingulate gyrus) which is active when the colour word conflicts with the print colour.
- However, Ahola et al. (1996) found that some patients with frontal cortex damage, and thus assumed CE deficits, have no problems on the Stroop test.
- Andres and van der Linden (2002) looked at patients with frontal lobe damage and concluded that not all CE processes are exclusively sustained by the frontal cortex. Evidence suggests that there are some common brain areas but there are also differences from task to task (see Collette & van der Linden's review, 2002).

Verbal vs. spatial working memory

Shah and Miyake (1996) disagreed with the idea of a single central executive serving various functions.They proposed separate verbal and spatial working memory systems. Supporting evidence showed that there was no significant

correlation between reading span and spatial span, which suggests that verbal and spatial working memory are rather separate.

EPISODIC BUFFER

Main characteristics (Baddeley & Wilson, 2002):

- Limited capacity.
- Integrates information from a range of sources into a single complex structure or episode.
- Acts as an intermediary between the subsystems, combining them into a unitary multi-dimensional representation.
- Active binding, which is highly demanding of the central executive.

The episodic buffer is designed to fill a gap in the model, because none of the three components (phonological loop, visuo-spatial sketchpad, or central executive) can be regarded as general storage that can combine several kinds of information.

Evidence

Various findings are hard to account for without the episodic buffer in the model. e.g., Chincotta et al. (1999). Immediate memory span for unrelated words is about 5 words; however immediate span for sentences is about 15 words (Baddeley et al., 1987). Baddeley and Wilson (2002) argued that high levels of immediate prose recall depend on:

- The capacity of the episodic buffer.
- An efficient central executive.
- As predicted by this model, patients with impaired long-term memory still have good immediate prose recall, and this recall is better if the amnesic patient has good executive functioning, compared to those with more severe executive deficits.

Baddeley (2001) believed that there is unlikely to be a single location of the episodic buffer in the brain. Prabhakaran et al. (2000) used fMRI and saw episodic buffer activation within the frontal lobes.

Evaluation

The episodic buffer is a valuable addition to the working memory model and increases its ability to predict behaviour in many situations. Future research will aim to clarify the processes involved.

OVERALL EVALUATION

There are several advantages of the working memory system over Atkinson and Shiffrin's short-term store.

Working memory:

- involves both active processing and transient storage of information.
- is involved in all complex tasks.
- explains the partial short-term memory deficits sometimes caused by brain damage.
- incorporates verbal rehearsal as an optional process which is more realistic that the enormous significance within the multi-store model.

However:

- the role of the central executive remains unclear.
- it is hard to measure limited capacity.
- precise constraints of central executive function are unknown.

It is probable that the central executive consists of several components, or that there are two or more central executives. More research is needed into the relationship between the episodic buffer, the other components of the system, and long-term memory.

So What Does This Mean?

Baddeley replaced the unitary short-term store with a working memory system consisting of three components: an attention-like central executive, a phonological loop holding speech-based information, and a visuo-spatial sketchpad specialised for spatial and visual coding.

This working memory system is of relevance to non-memory activities such as comprehension and verbal reasoning. The phonological loop and visuo-

spatial sketchpad have both been sub-divided into two-component systems, one component for storage and one for processing. The central executive fulfils several functions, some of which may be mainly located in the frontal cortex. Many of the characteristics of the central executive remain unclear.