Working Memory

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Synonyms
Active memory; Working memory capacity

Definition
A system for the temporary storage and manipulation of information

Introduction
Working memory can generally be defined as the cognitive capacity for the temporary storage and manipulation of information. It is a construct that encompasses elements of both memory and attention and over the last decade or two has become a topic of increasing interest to a diverse population of researchers. The rise in popularity in the study of working memory is largely attributable to its robust relationships with many cognitive abilities known to influence daily functioning. These related constructs include fluid intelligence (Kyllonen 1996; Shelton et al. 2010), short-term memory (Engle et al. 1999), long-term memory (Cantor and Engle 1993), and attention (Engle 2002), as well as academically relevant outcomes such as math (Passolunghi 2006) and reading achievement (Daneman and Carpenter 1980; Turner and Engle 1989).

Overview

In their seminal 1974 chapter, Baddeley and Hitch described a cognitive system for the temporary storage and manipulation of information, termed working memory. They described this working memory system as consisting of three distinct components that interacted. These were the phonological loop, the visuospatial sketchpad, and the central executive. The phonological loop stored verbal or semantic bits of information, while the visuospatial sketchpad was responsible for the temporary storage of spatial or visual information. In this way working memory was compartmentalized, having separate, domain-specific stores. Lastly, the central executive was believed to coordinate the organization and manipulation of information held in these two stores. The capacity then of this working memory system was concerned not with the volume of information that could be held within the phonological loop and the visuospatial sketchpad, but rather the critical concern was the capacity of the central executive for manipulating information held within the two slave systems. In this way it should be clear that...
while working memory and short-term memory are related, they are conceptually separable. Over time the specific model for the working memory system would undergo a variety of theoretical changes and overhauls, but the premise, that it is a system for the temporary storage and manipulation of information would endure.

Some have argued over the need for different domain-based subcomponents within working memory. One such example can be seen in a couple of experiments conducted by Turner and Engle (1989). Turner and Engle (1989) used tasks relying on either numbers and arithmetic problems or words and sentences. In both experiments they found that reading comprehension was positively related to a subject’s working memory, regardless of the domain of the working memory task itself. They reasoned that if the working memory system was truly divided between separate domain-specific subsystems, then the relationship between working memory and reading comprehension would be dependent on the means by which working memory was assessed. They observed that the opposite, working memory predicted individual differences in reading comprehension regardless of domain, implicating a more domain-general working memory system. Similarly, when Kane and colleagues (2004) explored the structure of working memory using factor analysis, they found that measures of verbal and spatial working memory were practically inseparable. Indeed, Baddeley (2000) updated his working memory model, adding a new component system known as the episodic buffer to account for the integration of information between the phonological loop and the visuospatial sketchpad.

One of the current areas of investigation within individual difference studies in working memory revolves around identifying the mental mechanisms that underlie working memory and attentional processes. It has been suggested that individual differences in working memory, and the degree to which those individual differences predict scores on other cognitive measures, can be accounted for by inhibition (Hasher et al. 1999; but see also Unsworth et al. 2004). In many tasks believed to measure attentional skills (e.g., Stroop, anti-saccade, etc.), subjects are tasked with avoiding or inhibiting a prepotent response. The rationale is that individuals high in working memory really just excel at generally inhibiting inappropriate responses. Kane and Engle (2002) observed that dorsolateral prefrontal cortex plays a uniquely important role in working memory processes. They took this to be evidence that individual differences in working memory can be best understood as a function of differences in executive attention. With that in mind, Engle and Kane (2004) suggested a two-factor theory of working memory, proposing that differences in working memory are driven by a goal maintenance component and an ability to resolve conflicting responses. According to this two-factor theory, individuals with low working memory are often unable to maintain their goal or intention, which leads to behavioral failures. At the same time, Engle and Kane (2004) also suggest that even when the appropriate goal is held within mind, it is still necessary for individuals to resolve conflict between competing potential responses. Low working memory individuals struggle to resolve this conflict between responses, particularly when a prepotent or habitual response is in conflict with the more appropriate, goal-oriented response. It is worth noting then that in order to have higher working memory, several mental mechanisms must be operating well, or conversely that it only takes one mechanism functioning suboptimally (e.g., poor goal maintenance) for an individual to have low working memory overall (Unsworth et al. 2014).

There are numerous methods of measuring individual differences in working memory, though perhaps the most commonly used are the complex span tasks. These complex span tasks are an adaptation of simple span tasks, which are used to assess short-term memory abilities. A classic example of simple span is forward digit span (Blankenship 1938), where subjects are presented with a list of digits to be recalled in the order that they were presented. The necessary cognitive processes in this case involve encoding and then quickly recalling the information. By contrast, a complex span task such as operation span adds an additional burden on cognitive systems. During
the complex span task, individuals are asked to encode items in the face of an additional attention-demanding task (Unsworth et al. 2005). In operation span subjects must process simple arithmetic problems in between the presentation of individual letters. At the end of each trial, the letters from a given trial must be recalled immediately. Ultimately, a subject’s score is based on the letters that they recall. In any complex span task there is a typical memory component and an additional attentional demand.

Recently a novel line of training experiments has emerged, wherein individuals receive some form of a working memory training intervention in the hopes that improving performance on computerized working memory tasks will translate into better cognitive functioning (i.e., increased fluid intelligence). Typically these working memory training interventions involved repeated practice on one or more complex span tasks (Harrison et al. 2013). Some of the initial results of these working memory training studies were promising (Klingberg et al. 2002), but more methodologically rigorous follow-ups revealed a disappointing lack of evidence that working memory training was beneficial in the way that had originally been hoped (Melby-Lervåg et al. 2016). Individuals taking part in these working memory training studies do often improve on the trained task, and sometimes there seems to be moderate improvements on similar tasks (i.e., near transfer). Unfortunately there is a growing accumulation of evidence that working memory training does not lead to gains in other untrained cognitive abilities, such as fluid intelligence or reading comprehension (i.e., far transfer).

Conclusion

With time the definition of working memory became more nuanced, as theories about it were adapted to fit with behavioral and neuropsychological data. Certainly other theories of working memory than what is presented here exist, and the exact nature of working memory and the critical mechanisms responsible for it are not universally agreed upon. However, the core tenants that Baddeley and Hitch (1974) proposed are still accepted as true, that working memory is a system for the temporary storage and manipulation of information.

Cross-References

► Attention
► Intelligence
► Short-Term Memory

References


