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Limitations of working memory capacity: The cognitive and social consequences

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A R T I C L E I N F O

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A B S T R A C T

This paper aimed to explore, from the perspective of cognitive psychology, the natural limitations of human cognition that determine our capabilities to deal with information overflow. These limitations are related mainly to the working memory system. This system is conceived to be composed of the storage components, which are responsible for active maintenance, and executive control that supervises the storage units. People differ in their working memory capacities, and because virtually every complex cognitive activity requires the temporal availability of a certain amount of cognitive representations, these differences are predictive of many outcomes. In the area of 'cold' cognition, these outcomes include intelligence and verbal reasoning, multitasking, language comprehension and verbal fluency, whereas in the area of 'hot' cognition, they include mentalising, stereotyping and self-control. Natural limitations in working memory capacity may be overcome (to some extent) through the training of working memory skills or the application of processing strategies (e.g. task simplification, using external environment as in situated or distributed cognition, changing a code of mental representation).

1. Introduction

In recent years, the concept of 'overflow' has occupied researchers in many fields: from economics to management, consulting and consumer studies, politics, education and so forth (Czarniawska & Löfgren,, 2012). However, when one specifically refers to overflow of information, the topic seems particularly relevant to cognitive psychology. Information overflow is defined as a situation in which 'an individual's efficiency in using information in their work is hampered by the amount of relevant, and potentially useful, information available to them' (Bawden & Robinson, 2008, p. 3). This concept is closely related to cognitive load, i.e. the state caused by excessive information supply and demand, continuous multitasking and interruptions, and inadequate workplace infrastructure (Kirsh, 2000). Among other conceptualisations, information overflow has been conceived specifically in relation to working memory (WM), a cognitive system that is responsible for maintaining access to goal-relevant information in support of ongoing cognitive tasks or behaviour (Baddeley, 1983, 2007). Accordingly, information overflow takes place when the amount of information exceeds the capacity of an individual's WM (Fournier, 1996). This constraint is seen as the primary impediment to knowledge construction (Sweller, 1994) and as a potential cause of everyday failures (Klingberg, 2009).

As Kirsh (2000) noted, studies on information overload were focused on its *consequences* (see: Bawden & Robinson, 2008), such as information anxiety, i.e. a state of uneasiness caused by the inability to access or process necessary information (Wurman, 1990), or information withdrawal, i.e. a state of avoidance of superfluous sources of information (Savolainen, 2007). It seems that not enough attention has been paid to the *sources* of this phenomenon. From the perspective of cognitive psychology, overflow may result from structural limitations of basic mental mechanisms that allow exertion and maintenance of control over informational demands.

This paper aimed to show that humans are structurally limited in their cognitive capacities and, consequently, that they are limited in their ability to deal with information overflow. We provide evidence that human cognitive limitations are rooted in the structure and functions of WM, which allows short-term storage and manipulation of task-relevant data. WM is severely limited in its capacity to deal with complex tasks and situations. Moreover, this capacity is not equally distributed among individuals and among task situations. In other words, WM capacity can be conceptualised

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in terms of both a stable trait and a transient state. We demonstrate that these inter- and intra-individual differences can account for a variety of phenomena, including the human (in)ability to deal with information overflow in the social context. First, we describe the concept of WM. Next, we address the issue of WM capacity. Finally, we discuss the significance of WM capacity for understanding some important psychological and social phenomena implicated with information overflow.

2. The concept of working memory

In a way, the human cognitive system has evolved as a mean to deal with information overflow. For example, humans see only a small fraction of electromagnetic spectrum and hear only a tiny portion of acoustic waves. Our momentary awareness of informational content is also very limited. These limitations are fundamental properties of the human mind and brain. The central issue in cognitive psychology amounts to the exploration of such limitations.

The early conceptualisations of the limits of human cognition were related to the concept of short-term memory (STM), a system responsible for moment-to-moment retention of information (Broadbent, 1958). Peterson and Peterson (1959) were among the first psychologists to investigate the time constraints of STM. In their experiment, participants were asked to remember and recall (with a delay of 3, 6, 9, 12, 15 or 18 s) meaningless three-consonant syllables (trigrams), while counting backwards to prevent rehearsal. Very fast decay of information occurred because participants could recall 80% of trigrams correctly after 3 s of delay, as compared to less than 10% of trigrams after 18 s (Peterson & Peterson, 1959). At the same time, George Miller (1956) summarised evidence that people can repeat back only about seven randomly ordered, meaningful items or chunks of information (i.e. letters, digits or words). This early research suggested that STM is very limited in both duration and capacity.

Nowadays, the concept of STM has been replaced by the notion of WM, first introduced by Miller, Galanter, and Pribram (1960) and then developed by Baddeley and Hitch (1974). WM is supposed to be an active, multicomponent system of information storage and processing. Initially, the model involved the supervisory 'central executive' system and two unimodal storage systems: the phonological loop and the visuospatial sketchpad (Baddeley & Hitch, 1974). The central executive system was envisioned as a control structure of limited attentional capacity, responsible for manipulating information in the WM and controlling the two subordinate subsystems. In contrast, both short-term storages, as domain specific, were responsible for maintaining verbal or visuospatial information, respectively. Several years later, Baddeley (2000) supplemented his model with the episodic buffer—a limited capacity multimodal store responsible for integrating information in various codes and, with regard to time axis, into unitary episodic representations. The three storage subsystems are controlled by the central executive system, which is additionally responsible for integrating information from various sources into coherent episodes. Importantly, all the systems proposed by Baddeley were of limited capacity, although in different ways. The central executive was conceived as a limited capacity pool of general processing resources, while the phonological loop, the visuospatial sketchpad and the episodic buffer were subjected to both time and span constraints.

In the model proposed by Nelson Cowan (1988, 2001), WM is conceived dynamically as a workspace that consists of temporarily active representations stored permanently in long-term memory. In other words, this model identifies WM with a process of maintaining access to information that is necessary to carry out current tasks. In Cowan's view, WM is subdivided into two basic elements: the central executive system and a homogeneous memory system. The central executive is responsible for directing attention and voluntary processing. The representations stored in the memory system vary in their level of activation, as determined by the current task. The focus of attention is composed of a subset of the activated representations and their associations. The focus can be directed both outward (to the external environment) and inward (to the existing memory traces). Importantly, Cowan abandoned the idea of separateness of memory storage systems, suggesting that the memory store has a domain-general character (Saults & Cowan, 2007).

Finally, Klaus Oberauer concluded that 'working memory (…) is not genuinely a memory. Rather, it is an attentional system that interacts equally with perception and with (long-term) memory' (Oberauer, 2009, p. 50). The author believes that WM consists of highly activated memory representations—a fairly dynamic maintenance component used for ongoing cognition. The information is actively maintained because of the process of allocation of attention. However, WM is also responsible for retrieval of task-relevant information through cue-dependent retrieval processes (see also, Unsworth & Engle, 2007). Furthermore, Oberauer (2009) distinguished between declarative WM and procedural WM. Both systems are conceptualised as largely analogous—as three embedded components that reflect three successive levels of selection of representations. The declarative WM includes the activated part of LTM, the region of direct access and the focus of attention. The procedural part of WM includes the activated procedural representations from LTM, the bridge (which holds the currently operative task set) and the response focus. The procedural WM includes both primary and executive processes. The primary processes produce manipulations of declarative representations or overt actions, while the executive processes can control primary processes.

In summary, although all theories of WM presented above point to slightly different research directions (Gruszka & Orzechowski, 2016), they emphasize the role of attentional mechanisms in the functioning of WM. Information overflow impairs WM processing by narrowing the scope of attention and restricting the range of cues that are encoded and processed. In concordance, limits of attention have also been recognised in the organisational literature as limits in 'span of control' (Stea, Linder, & Foss, 2015). Gifford (1992) discussed formal models of allocation of entrepreneurial attention and optimising techniques or rules that guide behaviour in this regard. Some of the discussed models recognise only limits in the ability to take in new information (that can be related to the attention component of WM), but others also recognise limits in the ability to recall previously obtained information (that can be related more to the mnemonic component of WM). Importantly, as Gifford (1992) pointed out, limited attention has a very important role in organisation as a whole because it constrains to the span of control of an individual. We believe that cognitive psychology can add to the understanding of this problem by helping specify the WM mechanisms. One factor overlooked in the organisational literature seems to be the issue of individual differences in WM abilities.

3. Working memory capacity

Although the term WM refers to a hypothetical cognitive system responsible for providing access to information required for ongoing cognitive processes, the term working memory capacity (WMC) is used to refer to individual differences that pertain to the personal level of WM efficiency (Wilhelm, Hildebrandt, & Oberauer, 2013). These authors distinguished between three theoretical views on WMC: the executive attention view (Engle, 2002), the

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