

Review

Awareness as the heart of working memory

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The assumption that attention and short-term memory combine to play a crucial role in cognition continues to influence cognitive modeling. We trace the development of the multicomponent model of working memory, initially consisting of a limited-capacity central executive controlling two domain-specific systems: the phonological loop and the visuospatial sketchpad. The later introduction of the episodic buffer addressed the need to explain how information from different sources is bound into unified episodes. Subsequent developments suggest that the buffer functions as a consciously accessible, multidimensional interface combining storage with executive manipulation and attentional control. These developments lead to a reformulation of the model in which the episodic buffer, renamed the ‘awareness buffer’, is placed at the focal point of working memory.

Working memory, attention, and awareness

Working memory (see [Glossary](#)) has long been viewed as a central hub in cognition, control, and conscious awareness. Our early attempts to conceptualize and test this [1] focused on exploring working memory’s role in complex cognition and the possible storage and processing components that might be involved. This approach proved fruitful for both theory and application over the subsequent years. Following Broadbent [2], one theme that emerged in the late 1980s was the importance of attention, with work on executive control [3] and the subsequent emergence of embedded processes models [4,5]. The issue of executive control gained traction in the 2000s, along with research exploring what is now seen as a close interactive relationship between working memory and attentional control, and how multifeature and multidomain representations might be bound together and retained as integrated objects or associations in working memory [6–9]. These developments have recently led us to further consider how attention and conscious awareness might be more usefully and explicitly placed within our own multicomponent model.

This review sets out our current views. We begin by summarizing our initial three-component model of working memory [1] and the later addition of a fourth component, the **episodic buffer** [10]. We then briefly review key literature that has emerged subsequently, exploring interactions between storage, processing, and attentional control. This leads to our current conceptualization of the multicomponent model, reflected in an updated visualization and, crucially, a better understanding of the episodic buffer, which we rename as the **awareness buffer** to emphasize what we see as its main function. We end by considering implications of these developments for working memory, attention, and awareness.

History of the multicomponent model

The multicomponent model began as an attempt to capture how certain forms of information are temporarily retained in memory and the role this plays in complex cognition. This has remained a central focus of the model during its subsequent development and refinement over time in response to theoretical and empirical challenges. However, research has increasingly emphasized the importance of considering how conscious awareness and attentional control might

Highlights

The multicomponent model of working memory originally included a central executive and two domain-specific stores. It was later expanded with the episodic buffer to integrate multimodal information and link to long-term memory.

We reconceptualize the episodic buffer as an awareness buffer: a multimodal, limited-capacity short-term store that binds information from internal and external sources for conscious access and manipulation and that serves as the focal point of awareness.

The contents of the awareness buffer correspond to the current focus of attention and are determined by top-down executive control and bottom-up influences, such as relevance and salience.

This reconceptualization aligns with a broader convergence in viewing working memory as a limited-capacity hub for conscious awareness and flexible, goal-directed behavior.

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be incorporated within working memory. The sections that follow review the origins of the multi-component framework, the challenges that prompted its subsequent development, and how more recent findings have influenced our views. Together, these sections chart the gradual expansion of the model from a memory-focused system to one that also encompasses attention and awareness.

Early development

The original multicomponent model consisted of three interconnected components with limited capacity: an attentional control system and two buffer stores (one phonological and one visuospatial). The attentional system, the **central executive**, was assumed to manage control processes in tasks such as reasoning, comprehension, and learning. The examples studied in Baddeley and Hitch [1] combined central executive control with information held in the phonological buffer, which is prone to rapid forgetting. To maintain this information, subvocal rehearsal could be used to refresh the buffer without heavily taxing the executive, forming the **phonological loop**. The second buffer, the **visuospatial sketchpad**, was originally based on research into nonverbal tasks involving imagery [11,12]. It was assumed to complement the phonological loop by temporarily storing visual and spatial information in a distinct code and was similarly prone to rapid forgetting.

Up to this point, our model focused on the memory components of a system designed to combine memory with attention. Most models of the time followed Broadbent's [2] focus on perceptually directed attention [13] and largely overlooked internally directed attention, which we considered central to working memory. One exception was proposed by Norman and Shallice [14] to explain everyday slips of action and clinical disorders of action control following damage to the frontal lobes. It distinguished between automatic control based on well-practiced habits and control involving active cognitive oversight and limited capacity resources, which they termed the supervisory attentional system. The latter was later adopted as a basis for the central executive in the multicomponent model [3], recognizing a key distinction between explicit attention, which involves conscious awareness, and automatic control, which may occur with or without awareness.

The episodic buffer

The simple three-component model was effective in capturing a body of existing evidence and generating new research questions, while also being accessible to a broader audience of practitioners in applied settings. One influential practical application was the development of complex span tasks as measures of working memory capacity, assessing the ability to keep track of recent information while carrying out processing operations. These tasks proved to correlate highly with performance on a range of cognitive tasks, including measures of general intelligence [15,16]. For example, reading span involved reading a series of unrelated sentences and then recalling the last word of each, and was typically limited to only three or four items [17].

However, although offering powerful support for the importance of working memory capacity, complex span was difficult to explain within the three-component model without a way of combining information from the subsystems and from long-term memory. Indeed, the influence of long-term memory in short-term memory tasks is long established, as seen in chunking [18] and the capacity to retain longer sequences of structured sentences [19,20]. The model's inability to account for complex span could be seen as related to its failure to address the 'binding problem' (e.g., [21,22]), whereby separately processed perceptual features of an object, such as color, shape, and location, are represented together in memory. In fact, our interest in binding was somewhat broader than this and incorporated questions of how information is integrated across multiple domains and modalities, and from long-term memory too.

Glossary

Awareness buffer: a new reconceptualization of the episodic buffer. It serves as a temporary and dynamically changing integration space for information accessible to conscious awareness, aggregating perceptual input, internally generated thoughts, and long-term memory into a unified internal model that supports higher-order cognitive processes.

Central executive: a set of limited-capacity attentional control resources that coordinate cognitive processes.

Embedded processes: a theoretical approach to working memory that conceptualizes working memory as a subset of activated long-term memory representations, combined with a limited-capacity focus of attention.

Episodic buffer: a component of the multicomponent model of working memory that was introduced to capture how information from multiple sources is bound into coherent, multifeature episodes.

Phonological loop: a specialized system responsible for storing and rehearsing verbal and auditory information. It consists of a phonological store and an articulatory rehearsal process.

Prioritization: strategic allocation of storage and attentional resources to important or goal-relevant information. This influences which items are actively maintained in the awareness buffer and remain accessible to conscious awareness. Prioritization can be driven by top-down factors and is harnessed through methods such as task instructions and forms of cueing, and it interacts with bottom-up influences like perceptual salience. It does not typically increase overall capacity but redistributes resources to favor high-priority items.

Visuospatial sketchpad: a specialized system for temporarily holding visual, spatial, and motoric information.

Working memory: a cognitive system responsible for temporarily holding and manipulating information to support complex tasks such as reasoning, learning, and comprehension.

The capacity to maintain bound, multimodal representations in working memory was highlighted in studies of mental imagery that investigated the rated vividness of visual and auditory memories under various dual-task conditions [23]. The initial expectation was that such experiences would depend principally on the visuospatial and phonological subsystems, respectively. While this proved to be the case for short-term retention of colored shapes and tones, there was less involvement of the two subsystems in images generated from long-term memory (e.g., a familiar scene or the sound of a telephone ringing), for which vividness appeared to depend more on the retrieval of detailed sensory features. This suggested the need to go beyond the three-component model to address conscious awareness.

The basic idea of a link between working memory and awareness was also developed through research on eye movement desensitization and reprocessing (EMDR), a clinical intervention that uses side-to-side eye movements to reduce the emotional intensity of disruptive memories in post-traumatic stress disorder [24]. The effectiveness of EMDR can be understood through evidence that saccadic eye movements disrupt the visuospatial sketchpad [25] and reduce the emotionality of distressing personal memories [26]. Andrade *et al.* went on to use the multi-component model in clinical contexts, combining it with existing behavioral control methods and applying it to areas including food cravings, smoking and alcohol reduction, and ‘choking’ in sport (e.g., [27,28]). Similar intervention methods have been applied to depression [29], anxiety [30], and post-traumatic stress disorder [31].

A major extension to the model was developed to address three key issues: its links with long-term memory, the binding problem, and its role in conscious awareness. This new version of the model (Figure 1) added an ‘episodic buffer’ and explicit links between working memory components and long-term memory [10]. The episodic buffer was proposed to bind information from visual and verbal working memory together with relevant information from perception and long-term memory into multifeature episodes. We further assumed that it had a limited capacity, which was made available to conscious awareness via the central executive.

Despite its increased scope, the multicomponent model remained simplistic, providing a high-level guide for asking further questions rather than a detailed account of the underlying processes. If the concept of an episodic buffer was to prove fruitful, however, it was necessary to use it to test specific hypotheses and to use the results to develop the overall model. The most immediate question concerned our assumption that the attentional capacity of the central

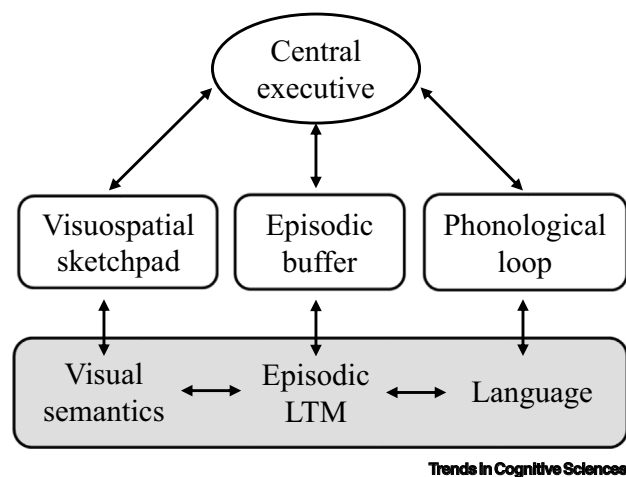


Figure 1. The multicomponent model of working memory. The version of the multicomponent model of working memory, adapted from Baddeley [10], illustrated the relationship between working memory storage, the central executive, and long-term memory. Baddeley suggested that information from the specialized subsystems (the visuospatial sketchpad and phonological loop) and from long-term memory was bound together in the episodic buffer. This was initially characterized as being dependent on central executive control, but the model was later amended to include direct links from the specialized subsystems to the episodic buffer [32]. LTM: Long-term memory.

executive is applied to the buffer, enabling it to bind information from several sources to form integrated episodic representations. A series of dual-task experiments on immediate memory for colored shapes showed that this was not the case for binding features within the visuospatial sketchpad [6,33,34], for cross-modal binding between visual and auditory features [35], or for binding information across the phonological loop and long-term memory in immediate memory for prose [32,36,37]. These experiments did, however, point to an important role for central executive resources in prolonging the maintenance of representations in the episodic buffer [7,38], possibly via ‘attentional refreshing’ [39].

Our findings suggested that information can be bound in a relatively automatic way, often via modality-specific subsystems or long-term semantic and episodic memory systems. Depending on the task context, such information can then be represented within the episodic buffer, with its initial registration in conscious awareness not requiring explicit and critical executive control. However, active continued maintenance in this state may still require the availability of such control resources.

Attentional selection and control

We started to view the episodic buffer as holding a limited amount of current information in continuous flux due to the combined effects of rapid forgetting and attentional refreshing [7]. Some of the evidence came from experiments on memory for feature bindings in a set of colored shapes, where participants were instructed that some items had more value than others and should be assigned higher priority. This **prioritization** boosted the recall of high-value items and reduced that for other items, with no change in overall performance (for a review, see [40]). These effects were reduced under dual-task conditions designed to load the central executive [41]. They have been explored extensively in the visuospatial domain across different materials and task contexts in young adults [42–52] and have also been shown in children, adults with attention deficit hyperactivity disorder (ADHD) symptomatology, and older adults [53–55]. The effects have also been extended to tests of verbal [55–58] and tactile information [59], as well as cross-modal associations between visual–auditory and visual–olfactory pairings [60,61].

Taken together, these findings suggest the strategic allocation of a limited set of storage and attentional resources to information according to its priority. These resources influence which information is more active and accessible in conscious awareness, in combination with the influence of recency, which does not appear to be resource limited in the same way. Thus, the recency effect seen in immediate memory for a sequence of items persists under dual-task conditions that load the central executive [38] and survives even when priority is given to an early item in the sequence [41,56]. We have assumed that items of greater priority are more likely to be maintained in the ‘privileged state’ of the episodic buffer via internally controlled attentional refreshing [7,44,50]. However, as in the example of recency, the contents of the episodic buffer are also partly determined by bottom–up influences, as when salient perceptual input is encountered [49,62,63]. Thus, the episodic buffer is driven by a combination of bottom–up automatic inputs and top–down control.

Evidence from value-directed remembering broadly aligns with other forms of prioritization, including expectations of task relevance [64,65], and predictive pre- and retro-cueing [66,67]. In the latter case, cues inform the participant of which stimulus is likely to be relevant at test. As with the effects of value, memory is enhanced for prioritized items, indicating that they are being pulled into the focus of attention. Value and predictive cueing are not interchangeable in their effects and underlying mechanisms though, and some methods of poststimulus attentional direction appear to be more effective than others [68,69]. Nevertheless, the effects of predictive

cueing provide a further line of evidence for the influence of selective attention in determining what information is accessible in working memory and conscious awareness.

We have been encouraged by the broad similarities between our ideas about the episodic buffer, the focus of attention in Cowan's **embedded processes** model [5], and attentional refreshing in the time-based resource-sharing (TBRS) model [70]. The TBRS model has also incorporated the concept of an episodic buffer alongside multiple specialized storage capacities as part of a structural multicomponent account of working memory. The extent to which these different theoretical frameworks, based on a wide range of paradigms, have converged over recent years is reassuring. These developments in the field have highlighted the importance of considering interactions between working memory, awareness, and attentional control [7,40,71,72]. They also broadly align with popular conceptualizations of consciousness, which from William James through to global workspace theory [73] have often emphasized the central role of working memory in underpinning our introspective sense of unitary, coherent experience.

Reformulation of the model

These developing themes have led us to a reformulation of the multicomponent model, which we set out below. We begin by outlining and characterizing this reformulation before discussing its implications for conscious awareness and attentional control within working memory. In doing so, we consider how these latest developments highlight a degree of convergence with other influential views of working memory and conscious awareness, and how these ideas might usefully inform future exploration of mind, brain, and behavior.

From the episodic buffer to the awareness buffer

Our initial ideas and explorations regarding the episodic buffer emphasized its multimodal storage functions, for which there was a clear need and compelling rationale. The link with conscious awareness [10] was more speculative and was based entirely on research examining mental imagery. However, as we have seen, our own and others' experimental investigations have strengthened the link with conscious awareness through the role of attentional control, as well as through continuing work on imagery in applied contexts. As a result, we have begun to conceptualize the episodic buffer in a different way—one in which awareness is placed at the heart of working memory.

We therefore set out a major adjustment to the multicomponent framework, with the episodic buffer renamed as the 'awareness buffer' to make its function explicit. Our current view of the multicomponent model incorporating the awareness buffer is illustrated in Figures 2 and 3. Figure 2 is adapted from Hitch *et al.* [74] and embeds working memory within the broader cognitive system, with links to long-term memory, perception, and action. Figure 3, adapted from Baddeley *et al.* [32,75], illustrates how different forms of information are captured in the multicomponent model.

The episodic buffer was initially identified with conscious experience [10], and we later referred to it as being equivalent to the 'focus of attention' [7,41]. However, Logie *et al.*'s [76] concept of a 'focus of awareness' does a better job of capturing the important distinction between the conscious experience of cognitive function and the locus of cognitive control. This renaming of a key subcomponent within the multicomponent model parallels earlier changes to the tripartite model. The phonological loop terminology was preferred over the original 'articulatory loop' because it better captured the broader scope of assumed function, conveying a store for auditory-verbal information that is supported by, but separable from, articulatory rehearsal [77]. Similarly, the visuospatial component was renamed as a sketchpad rather than the original

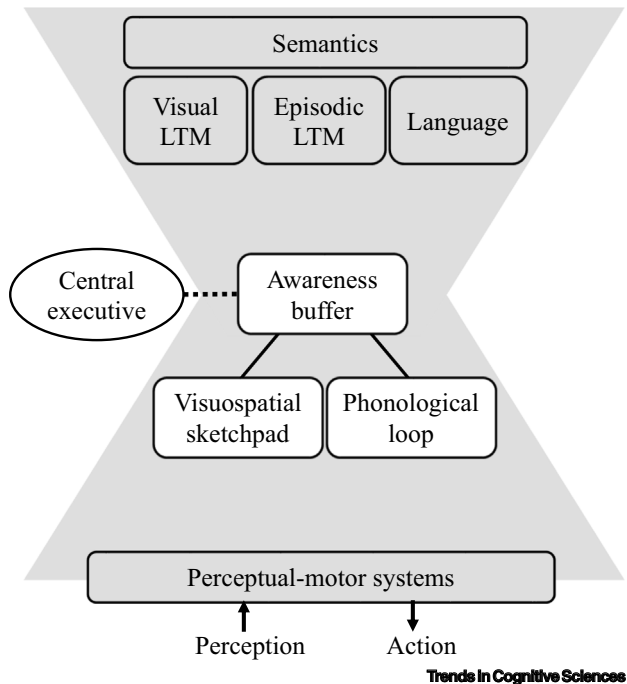


Figure 2. Current view of the multicomponent model and its connections to broader cognition.

This incorporates working memory storage; central executive control; and interactions with perception, action, and long-term memory. The hourglass shape is adapted from Hitch *et al.* [74] and emphasizes working memory as the limited capacity hub of the cognitive system with internal-facing connections to vast amounts of information stored in long-term memory and external-facing connections to systems for perception and action. The central executive is shown as being connected to but separable from the storage components of the system. LTM: Long-term memory.

‘scratchpad’ to more clearly convey its role in mental imagery, spatial orientation, and visual perception [3]. As with these earlier changes, we suggest the term awareness buffer with the same aim of ensuring greater transparency in communicating and applying the model.

Characterizing the awareness buffer

Despite the change in terminology, we still consider the awareness buffer to be ‘episodic’ in nature, representing integrated chunks of information that extend beyond the individual feature or item. We assume that the awareness buffer constitutes a central component of working memory, serving as a temporary integration space for information that is accessible to higher-order cognitive operations (Box 1). This includes reasoning, verbal reporting, and the guidance of

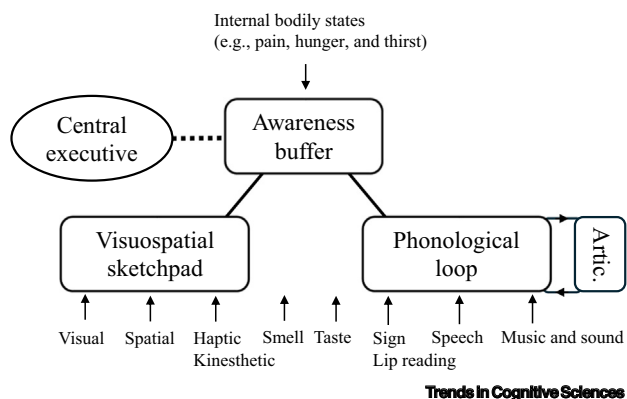


Figure 3. The multicomponent model and different forms of input.

This figure is an adaptation and update from Baddeley *et al.* [32,75]. Buffer storage is required in information processing systems when information needs to be combined across different times or sources. We see different forms of input as tributaries, with buffers placed at the confluence of these tributaries. In an information processing systems approach, explanations involve breaking down and examining interactions. It is important to constrain fractionation and only split off into distinct components when the rationale

or evidence is sufficiently convincing. Our model therefore ties the visuospatial sketchpad and phonological loop to multiple inputs. Input streams are illustrated as independent channels but may merge in some cases, for example, music and sound may combine with auditory speech input. Smell and taste must also combine and feed into the system, but we leave open the question of how such input should be handled.

Box 1. Main features of the two central subsystems

Property	Central executive	Awareness buffer
Capacity and core function	<ul style="list-style-type: none"> Limited capacity attentional resource. Performs internal goal-driven control processes. Processing operations are implicit. 	<ul style="list-style-type: none"> Limited capacity multimodal store subject to rapid forgetting. Holds information bound together across a variety of sources. Contents form a conscious model of external input, thoughts, and feelings that correspond to the current focus of attention.
Relation between components	<ul style="list-style-type: none"> Closely linked to but separate from the awareness buffer. The effects of its operations enter consciousness when they activate representations in the awareness buffer, as in procedures such as attentional refreshing, subvocal maintenance rehearsal, and creative mental imagery. 	<ul style="list-style-type: none"> Closely linked to but separate from the central executive. Binding processes are largely automatic but can sometimes depend on top-down control involving the central executive. Continuing maintenance in awareness over time may also draw on executive control.
Relation to other systems	<ul style="list-style-type: none"> Interacts extensively with other parts of the cognitive system via implicit, bottom-up connections that compete for resources with top-down control. 	<ul style="list-style-type: none"> Sits at the heart of cognition, with contents influenced by perceptual input, long-term memory, and bodily states, and through a combination of bottom-up and top-down control.
Temporal dynamics	<ul style="list-style-type: none"> Processing operations are in continuous dynamic flux. 	<ul style="list-style-type: none"> Contents are in continuous dynamic flux.

intentional action. The awareness buffer maintains representations that are interconnected with attentional control, semantic networks, and affective states. It aggregates content from multiple sources: perceptual input, internally generated thought, and long-term memory retrieval. In doing so, it provides a unified representational space upon which executive processes can operate. The access consciousness [78] provided by the buffer also enables the individual to metacognitively monitor and reflect on ongoing cognitive performance [79,80]. However, the subjective, qualitative aspects of conscious experience, often described as phenomenal awareness [78], are also likely to feed into and influence the awareness buffer.

A simple way of thinking about the buffer is as an internal model that is dynamically linked with other sources of information. Here, we note links to the suggestion of attentional ‘pointers’ in working memory [71,81], supported by behavioral and electroencephalography (EEG) evidence [82–85]. These are described as spatiotemporal and modality-general references that link to modality-specific featural signals and help bind item-based representations to the surrounding event context. This is a potentially useful concept that could eventually be integrated into our approach. However, it may prove to be limited if pointers are characterized as simple, unidirectional markers of information. We prefer to think of the content of conscious awareness as reflecting the outputs of multiple bidirectional links based on spreading activation or resonance within and across different specialized working memory subsystems and long-term memory, with the balance of emphasis changing depending on contextual factors such as emotional context and content [28,86].

As with the earlier conception of the episodic buffer, the awareness buffer provides a locus for the deliberate, top-down manipulation and maintenance of visual images and mental representations. This is limited in capacity [87] and is vulnerable to visuospatial manipulations, which can be positively utilized in therapeutic approaches as described earlier [28,31]. Similarly, for the mental construction of novel conceptual combinations (e.g., imagining an elephant playing

ice hockey [10]), the buffer would not itself do the creating but would serve as the space in which such creations are constructed. This type of active imagination is also involved in our ability to draw on and reconfigure memories of past experiences for the purposes of anticipating possible events still to come [88–91]. The awareness buffer would be the component within working memory where such representations and processes are consciously experienced and developed. Exploring how various components of working memory and control interact to support active maintenance and constructive processing remains an important and promising direction for future research (see [Outstanding questions](#)).

Awareness and attentional control

What appears and what stays within the awareness buffer is determined, in part, by the central executive, which is seen as a limited-capacity, goal-directed attentional system open to competing internal and external sources of information. For example, current goals may involve the executive inhibiting the present contents of the awareness buffer and activating other contents, as when prioritizing, refreshing, task switching, updating, or performing dual tasks. Information can be called into the awareness buffer for attentional refreshing while other information remains latent until it is refreshed again. Awareness, therefore, dynamically shifts as attention cycles between items for refreshing and between refreshing and processing associated with other tasks that are concurrently required [70].

Information can also enter the awareness buffer inadvertently, as shown in visual working memory experiments when a distracting stimulus from the same category as the memorized set appears as an intrusion in recall [47,49]. Much the same happens in some slips of action in everyday life [14]. Sources of information that are unrelated to the goals of current activity can also take over the awareness buffer, as when we experience an unexpected loud bang or a sudden pang of hunger. Indeed, in keeping with the concept of the predictive brain [92], dynamic updating of the internal model would not only track the immediate past but also orient us to the present and the immediate future, helping us become aware of these kinds of salient changes.

We view the awareness buffer as being where the outputs of attentional selection are represented and consciously experienced. Awareness fluctuates as attention shifts between competing demands. Ongoing conscious access to specific information hinges on prioritization and protection and can be disrupted when attention lapses or is captured by irrelevant stimuli. Individuals with better attentional control and higher working memory capacity are likely to be more able to hold goal-relevant information in awareness while resisting distraction [93]. The awareness buffer interacts with active control in that we can choose how to direct our attention and what to actively maintain in an integrated and accessible form. This relies on executive control and competes with other information we might encounter or are also holding in mind. In this way, the awareness buffer operates as a central hub or interface in cognition, determined through a dynamically changing combination of top-down and bottom-up influences (e.g., [94]).

Information that is not deemed relevant to the task is more likely to be displaced from the awareness buffer with changes in environmental or task context. Effects of value, relevance, and predictive cueing [40,67,95] indicate that we are more likely to retain in the awareness buffer what we expect to be useful for the immediate task at hand, while information that is less relevant is likely to be immediately discarded. This may also relate to the phenomenon of ‘attribute amnesia’. Here, a feature of an item that had just been used to make a response is often not recalled in a surprise memory test [96,97]. This shows how attended features do not always enter or remain in working memory for subsequent conscious report.

Our view broadly aligns with Cowan *et al.*'s [71] conceptualization of consciousness and the focus of attention within the embedded processes perspective, in which consciousness is described as a limited-capacity working memory system optimized for flexible, goal-directed behavior (Box 2). Under this approach, information in activated long-term memory is consciously

Box 2. Convergence and divergence between multicomponent and embedded processes frameworks

Points of convergence

- Levels of explanation

Both approaches offer broad, high-level frameworks describing the overall working memory system and its relationship with perceptual input, long-term memory, and attention. They are intended to provide simple ways of capturing working memory function across a range of different materials and tasks.

- Central executive control

In each case, central executive control resources serve to manage the system and determine the allocation of attention. This control is connected to but separable from the storage aspects of the system.

- A basis for conscious awareness and attention within working memory

The awareness buffer in the multicomponent model and the focus of attention within embedded processes are closely analogous in capturing limited-capacity multimodal consciousness within working memory. They both describe dynamically changing contents of awareness driven by different forms of input and attentional control.

- Contents of working memory

Both approaches assume that phonological and visuospatial representations are not the only kinds of information that can be held in working memory.

- Verbal rehearsal

The multicomponent and embedded processes approaches both acknowledge the special qualities of the verbal rehearsal process in helping support maintenance and relieve attentional load.

Points of divergence

- Starting motivation

The multicomponent model began as a theory of memory, whereas the embedded processes approach was initially developed as a way of conceptualizing attention.

- Basic theoretical approach

The multicomponent approach adopts a process of analysis by constrained fractionation (e.g., between temporary and long-term storage, semantic and acoustic, verbal and visuospatial, etc.). The embedded processes model attempts to apply general principles with assumptions mapping onto brain areas.

- Subsequent development

The initial incompleteness of the multicomponent model, along with evidence of fractionation, has led to development over time, whereas the embedded processes account has remained largely unchanged in its original comprehensive form.

- Relationship between working memory and long-term memory

Both approaches assume a close relationship. However, the multicomponent model assumes separate stores for short-term and long-term memory, whereas the embedded processes model assumes that short-term storage reflects the temporary activation of regions within long-term memory.

- Phonological and visuospatial information

The multicomponent model places greater emphasis on the importance of phonological and visuospatial information in working memory.

experienced within the focus of attention, while activated memory outside this focus remains unconscious. Although there continues to be disagreement between embedded processes and the multicomponent approach regarding the nature of short-term storage, we agree with Cowan's differentiation between the control and focus of attention (see also [76]), which in our case is captured by the central executive and the awareness buffer, respectively. We also agree that working memory is not entirely identical or synonymous with conscious awareness and that it can be engaged without awareness and can operate on nonconscious representations. Indeed, there is evidence demonstrating unconscious behavioral influences of storage and processing in (primarily visual) working memory tasks [98,99].

Working memory storage outside of direct conscious awareness can be captured within the structure of the multicomponent system by appealing to the domain-specific memory stores. The content of these stores is assumed to enter the awareness buffer when information is particularly meaningful or salient, or when current goals require it, as in some uses of subvocal rehearsal and visuospatial imagery. Thus, the phonological loop and visuospatial sketchpad are not themselves within conscious awareness, although their content may be accessible to awareness. Modality-specific information is temporarily held in these components and registered within or called into the awareness buffer when required, active, or salient. As set out earlier, whether this content reaches the awareness buffer is determined by a combination of intentional factors and automatic/implicit processes, consistent with our account of the awareness buffer holding a dynamic internal model fed from and feeding into other sources.

In emphasizing and characterizing conscious awareness within the model, our current view also highlights commonalities with global workspace theories of consciousness (e.g., [73]). As with those perspectives, we underline the central role of working memory in awareness and describe how bottom-up and top-down influences determine the dynamically changing content that forms limited-capacity consciousness at any given time. The awareness buffer would be analogous to workspace-level consciousness, providing a unified internal model upon which reasoning, metacognitive monitoring, and intentional action depend. However, the theoretical origins of the multicomponent model lie in working memory rather than in a general account of consciousness, with our approach offering a cognitively grounded framework that incorporates granularity and specificity across different components and systems. Furthermore, global workspace theories often equate the conscious workspace with the function of working memory itself, whereas in our model, the awareness buffer is only one component of a larger working memory system that includes nonconscious stores. By embedding awareness within a broader working memory system, the multicomponent model offers a unified framework for understanding how domain-specific processes, controlled attention, and conscious experience interact in real time to support flexible cognitive behavior.

Links to brain basis and atypical functioning

How might our cognitive model be linked to its neural basis, and what might we learn from considering atypical function in clinical groups? Throughout its development, evidence from neuropsychology has played a central role both in testing and elaborating the multicomponent model, beginning with the evidence for separate long- and short-term memory systems based on the classic amnesic syndrome [100,101], leading to the proposal that a condition previously termed 'conduction aphasia' was better seen as an impairment in verbal/acoustic short-term memory [102,103], while other single-case studies suggested separable and specific deficits in visuospatial short-term memory [104,105]. Similarly, deficits in central executive control associated with frontal lobe damage played a crucial role in the Norman and Shallice model of attentional control that formed the basis of the concept of a central executive [3,14]. We suggest that the

concept of an awareness buffer might prove useful in understanding the difficulties faced by a range of different clinical groups. This could include executive dysfunction patients who might struggle with inhibitory control and individuals whose condition involves disordered or intrusive occupation of awareness (e.g., schizophrenia, post-traumatic stress disorder, obsessive-compulsive disorder, depression, and anxiety).

With regard to neuroimaging, early studies were also consistent with separate cortical localization of phonological, visuospatial, and executive processing, with left hemisphere, right hemisphere, and frontal cortical areas, respectively [106,107], although subsequent fine-grained localization suggests a more complex pattern involving interaction between cortical regions and white matter tracts [108]. Given the breadth and complexity of working memory, it seems likely that further links will prove important, including those involving the hippocampus, the basal ganglia, and potentially the cerebellum [109–111]. Cowan *et al.* [71,112] have suggested the intraparietal sulcus as a possible candidate area for the focus of attention within the embedded processes framework; this might be considered in relation to our concept of the awareness buffer, given the functional similarities between these proposed components within each approach.

Concluding remarks

Working memory lies at the interface between memory and attention. Theoretical approaches such as that of Cowan *et al.* [4,5,71] originated in a direct attempt to explain the phenomenon of conscious awareness, while others, such as our own, emphasized the underlying memory structures, building on earlier developments in the cognitive psychology of memory while studying their interaction with an attentional control system of limited capacity. We aimed to model the working memory system using as few components as possible, ensuring it was consistent with data from a range of cognitive, neuropsychological, and applied paradigms and that it was readily applicable to practical problems. We resolved to add to our three-component system only when data demanded it, in due course resulting in the addition of a fourth component, the episodic buffer [10]. The present account describes the next stage of development, in which we bridge the gap between our memory-based foundations, elaborating the model's link to attention in general and, more specifically, to the role of conscious awareness. As such, our model retains the multicomponent framework that has already proved durable and practically applicable, while integrating it with more attentionally oriented approaches such as that of Cowan *et al.* [71]. We thus propose the revised model as offering a simple and coherent theoretical approach to the cognitive psychology of working memory, an approach that provides a broad account of existing evidence and will hopefully continue to be applicable to practical problems while suggesting further ways of testing and developing its structure.

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Declaration of interests

No interests have been declared.

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Outstanding questions

What determines whether information in the awareness buffer is stored in long-term memory for later access?

How might this approach encompass the concept of energy, as reflected in variables that drive the cognitive system, such as motivation, emotion, and arousal?

How might the application of the model to clinical problems such as depression, craving, and flashbacks address the question of how emotion impacts working memory? How might these be mapped and used therapeutically?

How might different priorities and goals be organized and handled within the multicomponent model, and how do different forms of top-down and bottom-up influence interact?

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