Trends in
Cognitive Sciences

CellPress

Opinion

Attention with or without working memory: mnemonic reselection of attended information

Yingtao Fu,[1,3] Chenxiao Guan,[1,3] Joyce Tam,[2] Ryan E. O'Donnell,[2] Mowei Shen,[1,*] Brad Wyble,[2,*] and Hui Chen,[1,*]

Attention has been regarded as the 'gatekeeper' controlling what information gets selected into working memory. However, a new perspective has emerged with the discovery of attribute amnesia, a phenomenon revealing that people are frequently unable to report information they have just attended to moments ago. This report failure is thought to stem from a lack of consolidating the attended information into working memory, indicating a dissociation between attention and working memory. Building on these findings, a new concept called memory reselection is proposed to describe a secondary round of selection among the attended information. These discoveries challenge the conventional view of how attention and working memory are related and shed new light onto modeling attention and memory as dissociable processes.

Highlights

Attention has been regarded as the 'gatekeeper' of working memory. However, this conventional view is challenged by recent demonstrations of attribute amnesia.

Attribute amnesia is a counterintuitive phenomenon where participants fail to remember a simple piece of information that had just been attended to several seconds ago. This phenomenon is not due to perceptual failure or forgetting, but instead is related to adaptive filters that affect memory encoding.

We propose the theory of memory reselection to explain attribute amnesia. Reselection is a secondary round of selection among information that had initially been selected by attention. This mechanism allows attention and working memory to be dissociated.

Memory reselection is achieved through an adaptive tuning of memory encoding which might be due to active inhibition of the information, preventing it from being stored in memory.

Attention as the 'gatekeeper' of working memory?

One of the most fascinating aspects of our lived experience with the world is that information we have clearly experienced with our senses can fail to leave a trace in memory, thereby creating blind spots in our record of recent events. Traditionally, the most exciting demonstrations of this phenomenon involve the distraction of attention, such that a clearly visible and, one would think, highly noticeable stimulus – for example, a person in a gorilla suit – completely escapes our notice (i.e., inattentional blindness [1–3]). In these demonstrations, attention is occupied with a demanding task, preventing a highly visible stimulus from being detected or stored into memory. More recently, an entirely new phenomenon has been demonstrated in which attention is directed towards a stimulus, rather than away from it, and yet critical, task-relevant information about that stimulus will be unavailable to memory retrieval a few seconds later [4–6]. This occurs with a manipulation in which participants are given a series of trials inducing them to search for a target based on a particular attribute (e.g., identity or color), with the expectation that they will not be asked to report that attribute, but rather only its location. Then, on a later trial, when they are first unexpectedly asked to report that same attribute, their accuracy is extremely low, even though the target was clearly visible, and they had just attended to that attribute several seconds ago to locate it.

This finding is surprising considering the close link between attention and working memory. This connection has been the default view in cognitive science since at least the era of Baddeley's model, which linked the central executive's control of attention with the control and maintenance of working memory [7,8]. Previous studies have shown extensive evidence demonstrating the significant overlap between attention and working memory at both cognitive and neural levels [9–12]. Critically, abundant evidence has accumulated that links attention and working memory encoding, some of which even suggests that attention is sufficient for information entering working memory (summarized in Box 1). Based on these findings, the metaphor of attention as the

[1]Department of Psychology and Behavioral Sciences, Zhejiang University, Zhejiang, China
[2]Department of Psychology, The Pennsylvania State University, University Park, PA 16802, USA
[3]These authors contributed equally.

*Correspondence:
mwshen@zju.edu.cn (M. Shen),
bpw10@psu.edu (B. Wyble), and
chenhui@zju.edu.cn (H. Chen).

Box 1. The close link between attention and working memory encoding

One line of research focuses on the modulatory effect of attention on working memory encoding. These studies typically manipulate the allocation of attentional resources during working memory encoding phase, so that more attention is directed to a specific subset of information, leading to better memorization of that particular information compared to the rest [75–78]. For example, spatial cuing studies demonstrated that when attention was directed towards a subset of target locations before the stimuli appear, the cued stimuli were more likely to be encoded into working memory [75]. Similarly, using a reward cue, participants directed their attention toward high-rewarded items within the memory array, resulting in an improved memory performance for those items [78].

Another line of research demonstrates that attended information is automatically encoded into working memory, even without explicit requirement to memorize it. This type of research typically involves a dual-task design, in which participants are asked to attend to an object (such as making a saccade towards it) without being asked to memorize it, and the encoding of memory is inferred when there is a cost on a concurrent working memory task [79–81]. In another study, working memory precision for orientations was comparably impaired whether using an interpolated orientation memory task or an orientation-matching attentional task, indicating that attended items consumed working memory resources similarly to memorized items [82].

Although these studies suggest a close link between attention and working memory encoding, there are some caveats. First, the roles of attention and expectation are difficult to distinguish in many situations. For instance, when spatial cues are employed to direct attention during working memory encoding, subjects might form expectations about the likely location of the target, which could also improve information processing by reducing perceptual uncertainty [83]. Second, the measure of whether the attended information is encoded into working memory is frequently indirect. In dual-task studies, the working memory cost of attending to a piece of information has been interpreted as evidence supporting the obligatory encoding of attended information. However, working memory performance drop could also be due to other factors, such as difficulty in dividing central executive control resources across tasks, rather than the encoding of information.

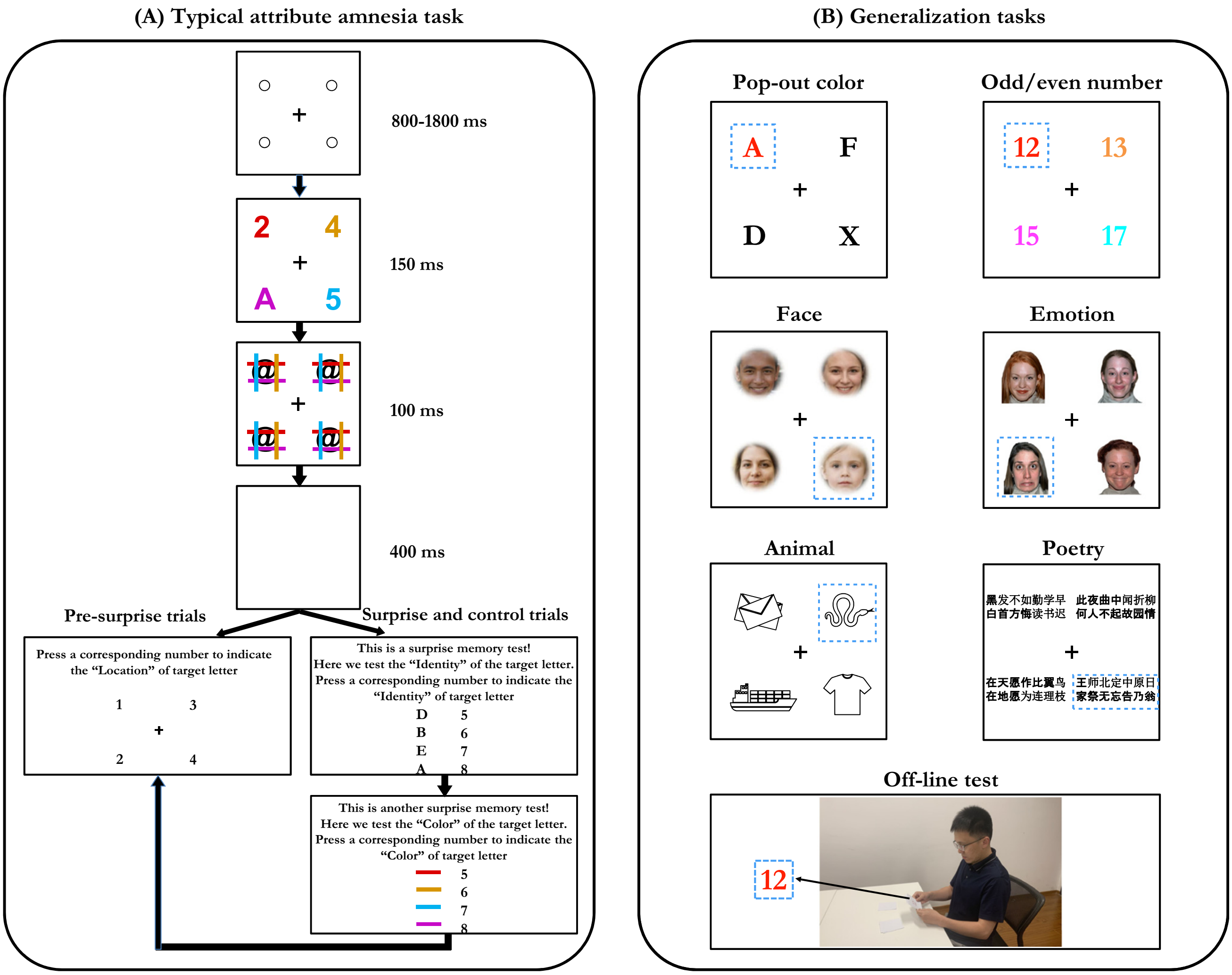
'gatekeeper' of working memory has been widely accepted in many theories of cognitive function [10,13–17]. For example, the assumption that attention will always produce encoding is a foundation of 'instance theory' explanations of automatization [13]. Some researchers even argue that attention and working memory are essentially the same mechanism [18–20].

Attribute amnesia: failing to report a piece of just attended information

Considering the obligatory role of attention in working memory encoding, it seems like a straightforward prediction (and one that is commonly held) that clearly visible information that has just received focused attention should be easily reportable from memory. However, a recently discovered phenomenon, named attribute amnesia [4], challenges this prevailing belief by demonstrating that people frequently fail to report information that they had specifically attended and used for a task just a few seconds earlier.

In a typical attribute amnesia task (Figure 1A), participants are instructed to find a target letter among three distractor numbers and then report its location. Following dozens of such trials, a surprise trial appears, in which participants are unexpectedly asked to report the identity of the target letter immediately after the stimulus array. Several control trials, with the same format as the surprise trial, are then carried out. Surprisingly, participants have difficulty correctly reporting the target identity on the surprise trial, though they can accurately report it in subsequent control trials once they have an expectation to do so. Notably, the identity information of the target letter is critical for distinguishing it from the distractor numbers, and is therefore necessary to be attended to and used to complete the localization task. This type of information, which needs to be attended to and used but does not have to be reported (thus decoupling the requirement of attending and memorizing), is termed a 'key feature', and the failure to report the key feature is known as attribute amnesia [4].

The phenomenon of attribute amnesia has been consistently observed across various types of stimuli (see Figure 1B for some demonstrations) ranging from simple forms – such as letters, digits, and pop-out colors [4,21–24] – to more complex and meaningful ones, such as animals,



Trends in Cognitive Sciences

Figure 1. Typical attribute amnesia task and the generalization tasks. (A) The typical attribute amnesia experiment [4]. In pre-surprise trials, participants are asked to find a target letter among other number distractors and then report its location. Following several such trials, a surprise trial appears, in which participants are unexpectedly asked to report the identity (i.e., key feature) and color of the target letter. Several control trials with the same format as the surprise trial are then carried out. (B) The generalization of attribute amnesia across different stimuli and tasks. The targets are enclosed within a blue dashed box (for illustrative purposes, not depicted in real tasks). Among these tasks, it is typically observed that participants have difficulty in correctly reporting the key feature in the surprise trial, whereas their performance shows a significant improvement in subsequent control trials.

scenes, human faces, real-world objects, words, names, and even Chinese poems [5,6,25,26]. For instance, participants were repeatedly tasked with finding a patriotic sentence within a set of poem sentences of other themes, but were unable to accurately report the exact sentence they had just identified in a surprise trial [5]. Attribute amnesia has also been observed outside of laboratory settings. In a real-world context, participants were asked to sort a set of cards into two groups based on whether the number written on each card was even or odd. When unexpectedly asked to recall the identity of the number on the last card, they were again unable to do so [24]. Note that a similar amnesia phenomenon is observed when participants are probed about an irrelevant feature of an attended object [27–32] or group of objects [33–35]. However, attribute amnesia is critically different from this irrelevance amnesia, because in attribute amnesia studies the attribute that participants cannot report (i.e., the key feature) is relevant to the search task that is being performed (see an extended discussion in the following section).

Undoubtedly, certain characteristics of stimuli can impact the accuracy of their reporting in a surprise test, such as novelty [5,36] (but see [6,26]), priority in memory [27], meaningfulness [37,38], or memorability [39]. Nevertheless, given the overwhelming evidence, attribute amnesia is a pervasive phenomenon that can be observed in diverse contexts.

Why is attribute amnesia interesting?

The attribute amnesia phenomenon stands out from similar demonstrations such as inattentional blindness or change blindness (Box 2) because the unreportable key feature is evidently within the attentional focus. Specifically, as an attribute of the search target, the key feature is under the focus of both space-oriented and object-oriented attention. Considering its task relevance (as discussed later), the key feature is attended to even to a feature-specific level. Moreover, the report failure cannot be attributed to a lack of conscious awareness for the attended stimulus (see Box 2 for demonstrations of attention without consciousness), as the stimulus is clearly visible and the task requires conscious access of the key feature. Additionally, there are several characteristics of the attribute amnesia phenomenon that make it particularly interesting and compelling from a theoretical perspective.

Attribute amnesia occurs despite task relevance. Complex objects have multiple features, and task-irrelevant features of an attended object are typically not remembered well [29,40] (see Box 2 for demonstrations such as irrelevance-induced blindness and short-term source amnesia). This might be due to the fact that these task-irrelevant features are not well attended since attentional selection can be specific to different features of visual objects depending on their task relevance [41,42]. However, it is commonly believed that a task-relevant attribute will be well remembered. In contrast to this assumption, attribute amnesia occurs prominently despite the fact that the unreportable key feature is the defining information of the target, necessary for distinguishing it from distractors. Thus, the information that cannot be remembered is task-relevant

Box 2. Other blindness/amnesia demonstrations

Inattentional blindness is a phenomenon in which individuals fail to notice obvious but unexpected objects or events in their visual field when their attention is engaged with another task [1–3]. Inattentional blindness happens even when the unexpected stimulus falls within the spatial focus of attention [84,85].

Change blindness is a phenomenon where individuals fail to detect obvious changes in visual scenes when their attention is not specifically directed towards the changing aspect [86,87]. The changes are typically obvious once the participant knows where to look for them.

Attention without consciousness is a phenomenon where observers can attend to an object/location without consciously experiencing that object (or objects at that location) [88,89]. For normal participants, the unconsciousness of attended stimuli is usually achieved through various psychophysical techniques (e.g., object-substitution masking [90], visual crowding [91]).

Irrelevance-induced blindness is a phenomenon in which participants fail to report a task-irrelevant attribute of the target of a particular task [33,34]. For example, participants are asked to concentrate on one color while ignoring the other color on the same object. When unexpectedly probed about both colors, participants' performance in reporting the irrelevant color is significantly worse than reporting the relevant color.

Short-term source amnesia is a phenomenon in which participants fail to recall the source format of a stimulus, even though they have just extracted its semantic meaning [92,93]. For instance, participants are asked to judge the semantic congruency between two color representations from distinct source formats (e.g., the color of a square and the identity of a color word). When unexpectedly asked to report the source format of one of the colors, many participants fail to report it correctly.

and must have been processed at sufficient levels to make decisions. It is worth noting that in some cases the key feature may even attract attention through a combination of both top-down and bottom-up mechanisms, such as a pop-out color that draws attention due to both its task relevance and physical salience [4] (Figure 1B).

Attribute amnesia occurs even with clear identification of key features. In attribute amnesia tasks, participants are typically instructed to locate target stimuli belonging to one category among distractors from a different category (e.g., locating letters among digits). Perhaps target localization is achieved through categorization without identification of the specific item (e.g., which letter it is). However, this possibility is ruled out in attribute amnesia tasks where participants cannot perform the task based solely on categorization. For instance, it is difficult to imagine that participants could locate a patriotic poem sentence based solely on categorization, as this task requires processing and extracting the abstract meaning of the sentence to determine its theme [5]. Furthermore, attribute amnesia effects were still observed when participants were tasked with finding an even number among odd numbers (or vice versa) [4], and it has been well established that judging the parity of a number necessitates the access of its specific identity [43,44]. In another study, participants were asked to locate a target number larger than five among distractor numbers smaller than five, and attribute amnesia was still observed [45]. In this case, the accessing of the target identity was directly evidenced by a distance effect [46,47], such that search became easier as the numerical difference between the target and the reference number (i.e., five) increased [45].

Attribute amnesia occurs with or without eye movements. Covert attention allows us to select information without moving the eyes. Such attention might be used in attribute amnesia tasks where stimuli are presented briefly (e.g., 150 ms) followed by rapid masks, where there is not sufficient time for the eyes to move to the target. However, attribute amnesia was also observed when the eyes were free to move to the target, for example when the stimulus duration was extended beyond 1 s with no subsequent masking [6,26,39], when clear eye movements were observed towards the target [45], or when the target was presented at the central fixation without masking until participants responded [24]. One study directly investigated whether saccadic selection could eliminate or weaken attribute amnesia by instructing participants to localize the target through a saccade, and found that attribute amnesia persisted even when the target was fixated for a short duration [23].

Is attribute amnesia due to forgetting?

In typical attribute amnesia experiments, the memory trace of key features is probed using a surprise recognition test, which inevitably induces an unexpected task switch that often involves reading and comprehending new instructions. Therefore, the critical and unavoidable question is whether the attended key feature is initially selected into working memory but its memory trace is disrupted by the need to read and interpret the surprise question.

One line of research attempts to address this question by measuring whether information that is definitely encoded into working memory can be reported in response to a surprise question. One study modified the attribute amnesia paradigm where participants had to hold a color in mind over a short delay in order to locate a target that had the same color [21]. On a surprise trial, participants were often able to report the color that they had just stored in memory. However, in a follow-up experiment, a different group of participants once again had to use a color to find a target, but no longer had to store the color in memory because it was presented simultaneously with the search array. Now memory was poor for the color in a surprise trial, consistent with attribute amnesia. Another study demonstrated that information stored in working memory could survive an unexpected change in the response question format, implying that the failures to report the key features in attribute amnesia experiments were not due to forgetting or overwriting induced by the surprise question [48].

One recent study directly tested the interference of an unexpected interruption on working memory performance using a similar surprise trial paradigm [49]. They asked participants to remember the identity of a target letter, but then added an unexpected event before the expected memory probe by asking participants to read a task-irrelevant passage. The introduction of this passage interfered with the memory trace, even for the feature that was instructed to be remembered. However, this cost was significantly reduced when a remember cue (e.g., 'remember the letter you just saw') was presented just before the reading prompt, suggesting that information already stored in working memory could be rapidly reinforced to resist interference. By contrast, the same remember cue failed to improve performance in the surprise test of the key feature in an attribute amnesia paradigm. These results indicate that there are significant differences between attended key features and explicitly formed working memory representations in resisting interruptive interference introduced by the surprise question. This finding further demonstrates that attribute amnesia is likely due to a failure of memory consolidation.

Instead of using surprise tests, alternate approaches have been employed by other studies to probe the memory trace of key features. One study tested whether the key feature could produce the working-memory-driven attentional bias effect [50], an effect showing automatic attentional bias to the items that match active working memory representations [51,52]. The results showed that the key feature produced a significant attentional bias effect, though the effect was much smaller than when the same information was intentionally encoded. This result seems to indicate that the key feature has been encoded into working memory. Nonetheless, this encoding might arise from the specific task setting, as holding the key feature in memory could facilitate a following search task. In recent studies using a similar paradigm wherein the key feature was unrelated to subsequent tasks, there was no working-memory-driven attentional bias effect observed for the key feature [53,54]. In addition to these behavioral findings, electroencephalographic (EEG) techniques can provide perhaps the most compelling evidence due to their high temporal resolution. One recent study utilized the contralateral delay activity (CDA), a well-established event-related potential component that tracks online storage of information in working memory [55,56]. The results demonstrated that the key feature did not produce any CDA component in pre-surprise trials, while the CDA was observed in post-surprise trials when the key feature was explicitly asked to be reported [54]. This finding provides neural evidence that key features fully attended to are not selected into working memory.

The aforementioned findings suggest that simply attending to a piece of information is insufficient to transform it into a durable working memory representation. However, this does not necessarily imply the absence of any memory trace for attended key features in all cases. One study found that the unreportable key feature produced an inter-trial priming effect, indicating that there was some memory trace of the key feature [57]. Moreover, in some studies finding positive evidence of attribute amnesia, response in the surprise trial was reliably better than chance, suggesting that at least some subjects were able to report the key feature. Indeed, in specific scenarios, such as when the key feature has strong physical salience or receives high activation, it could be encoded into working memory (yet subsequently actively removed [53]). In addition to working memory, there are other forms of short-term memory storage – such as iconic memory [58], or fragile visual short-term memory [59] – which have a larger storage capacity than working memory but are typically short-lived and susceptible to disturbance. Theoretically, key features could be stored in any of these memory forms, but more evidence is needed to make specific distinctions.

A novel aspect of cognitive selectivity: memory reselection of attended information

Attribute amnesia presents a counterintuitive case where participants fail to report a piece of information that was clearly visible and within the focus of their attention several seconds previously. This phenomenon suggests that even when we fully attend to and use a piece of information, it is not necessarily encoded into working memory. Based on these aforementioned demonstrations, we propose the existence of a memory-related selective mechanism that operates independently of traditional theories of attentional selection. We refer to this process as memory reselection, which enables a second round of selection among attended information to control which pieces of information are actually stored in working memory (Figure 2). In this view, the mind seeks to exploit pieces of information that are expected to be useful in the future. While attentional selection and memory reselection might often align in prioritizing the same pieces of information, they do not need to, and attribute amnesia paradigms create exactly this scenario. The role of attention is to foreground key pieces of information in the mind to facilitate a wide range of cognitive tasks, but when those tasks are completed, for example by finding a target in a search array, only a subset of the attended information needs to be stored in working memory.

It is also essential to make a conceptual distinction between the proposed memory reselection and other forms of selection within working memory. Previous studies have demonstrated that information stored in working memory could be selectively prioritized for optimally guiding behavior (i.e., internal selection [60]). For instance, while maintaining multiple working memory representations, participants may use retro-cues to prioritize specific contents that are most likely relevant for the upcoming task, while other contents are either removed [61] or transferred into an activity-silent state [52]. Both reselection and internal selection involve adaptive utilization of limited working memory resources for future goals; however, the former emphasizes how external information is transferred into internal representations, while the latter emphasizes how internal representations are modulated to guide external behavior.

The distinction of attention and working memory encoding provides new insights into understanding classical effects within various paradigms. For instance, many theories propose a close link between visual working memory and visual search; however, researchers have found that increasing visual working memory load does not affect search efficiency [62]. According to our reselection framework, such findings can be easily explained, as participants likely do not encode search items into working memory to determine whether they are targets or not. This proposal could also explain certain change-blindness demonstrations where observers fail to detect changes for the information they have just attended to and identified (e.g., for digits that they had just accessed their identities [63]). Recently, the idea of memory reselection has been proposed to explain some classical attentional effects. That is, the studies show that some spatial cuing effects (e.g., invalid costs and validity benefits) are largely determined by the extent of memory encoding of the attended cue information, which may be reduced by extensive experience in a given experiment [64,65]. Similarly, a lack of memory encoding for a target can play a role in alleviating the attentional blink [64].

The notion of memory reselection also carries implications for studies exploring the nature of human consciousness. For many researchers, the term ‘conscious access’ is essentially equated with working memory consolidation, and working memory tasks are usually used to investigate the characteristics of consciousness [66–68]. However, as most attribute amnesia studies demonstrate, the attended key features undoubtedly reach conscious access, yet they are not actually consolidated into working memory. This distinction further delves into a longstanding debate in consciousness research: whether consciousness is confined to the contents that

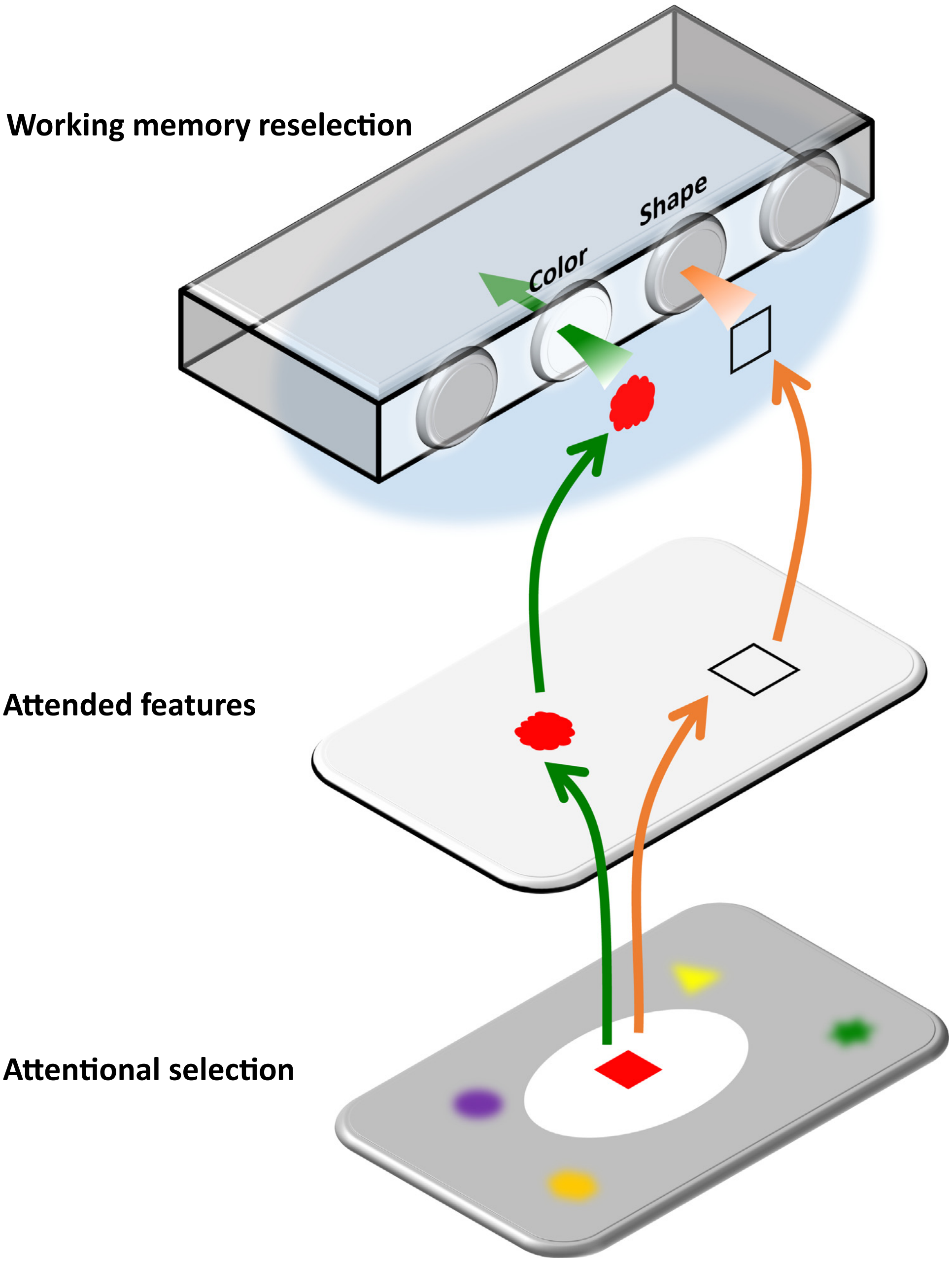


Figure 2. Memory reselection model. The bottom part indicates attentional selection in the external world. In the current illustration, the selected object stands out with a high resolution while unselected objects appear blurry. The middle part represents the specific features we are paying attention to, such as color and shape, on the selected object. The upper part shows how working memory reselects the attended features. For instance, one feature (such as color) is brought into working memory, while other features (such as shape) are blocked out.

can be explicitly reported, or whether it overflows what is reportable (i.e., the overflow debate [69]). The existence of memory reselection provides new theoretical support for the overflow view, as even consciously accessed information under attentional focus could overflow report due to a lack of memory consolidation (for a detailed discussion, see [70]).

Possible mechanism underlying memory reselection

One of the earliest explanations of how memory reselection works is due to an adaptive control of memory encoding [21]. The theory proposes that the even attended attributes of a stimulus can be filtered out of the memory consolidation process, suggesting that the connections between attention and memory can be selectively modulated in an attribute-specific manner. This idea is inherent in the 'memory for latent representations' model in which a given stimulus evokes multiple representations in different latent spaces that focus on different levels of abstraction or type (e.g., shape vs. color information) [71]. The memory-encoding mechanism can then select one or more of these latent spaces for encoding, which is akin to turning down the gain on the connections with the other attributes (i.e., decreasing precision of the unselected features).

Consistent with this adaptive control theory, memory reselection is greatly influenced by experience within a given task [72–74]. In one study, researchers manipulated the number of pre-surprise trials in attribute amnesia tasks, allowing the surprise trial to occur either early (e.g., the first trial) or later (e.g., the 50th trial) in the experiment [72]. The results demonstrated that the accuracy of reporting the key feature gradually declined as the number of pre-surprise trials increased. This suggests that when starting a new task, memory reselection operates via an exploratory mode, by encoding most of the attended information since it is not yet clear what information is required in the future. With additional experience, reselection is gradually shifted to a more exploitive mode, since expectations about what information is important become clearer. Additional studies have indicated that memory reselection can be significantly refined with sufficient experience, to a degree where even privileged features such as spatial locations are filtered out during working memory encoding [64]. Interestingly, one study explored dynamic changes of the memory reselection mode by employing a double-surprise-trial paradigm [73]. As typically found, participants performed poorly when unexpectedly asked to report the key feature (identity) or an irrelevant feature (color) in an attribute amnesia task. However, in the next trial or after a number of trials, when another unexpected question was presented to test the other feature (color or identity respectively), participants' performance was dramatically improved, indicating that the memory reselection shifted from a highly selective mode to a more exploratory mode that stored additional features of the object, even though they had not yet been probed.

Digging deeper into the mechanisms of memory reselection, it is important to consider the mechanism of how a task-relevant, attended piece of information is not necessarily consolidated. One possibility is that the attended key features are excluded from memory consolidation via active inhibition [45,53]. Considering that the key feature would become outdated following target selection, retaining such information would place a burden on the limited capacity of working memory. Therefore, actively inhibiting this type of information would improve the efficiency of cognitive processing. In support of this theory, one recent study compared memory traces of attended key features with completely irrelevant features that should be ignored throughout the experiment by measurement with a memory-driven attentional bias [53]. The results consistently showed that the memory trace of a feature produced less attentional bias when it served as a key feature compared with when it was an irrelevant feature. Since the key feature was essential for the task and participants had to attend to it, this result is paradoxical unless it had been inhibited immediately after it had been attended and used. This inhibition hypothesis was further supported by a developmental study which compared the memory trace for key features between young children and adults [45]. In a series of attribute amnesia experiments, the results demonstrated a 'developmental reversal'-like phenomenon in which children outperformed adults in reporting the key feature in the surprise test, consistent with the assumption that children's inhibitory abilities are not mature enough to inhibit extraneous information compared to adults. Therefore, the inhibition theory provides a mechanistic framework for understanding how key features could be omitted from consolidation.

Concluding remarks

The close link between attention and working memory encoding has long been emphasized; however, this conventional view has been challenged by recent attribute amnesia studies. Attribute amnesia research decouples the demands of attending to and memorizing information in a task, and provides converging evidence that the information selected by attention is not always selected by working memory and may even be actively inhibited. Based on these demonstrations, a memory reselection model is proposed which describes how working memory representations are formed by selectively storing attended information. Future research could delve deeper into the neural basis and computational mechanisms of this reselection process (see Outstanding questions).

Acknowledgments

This work was supported by grants from Science and Technology Innovation 2030-'Brain Science and Brain-like Research' Major Project (2022ZD0210800), Fundamental Research Funds for the Central Universities (2021FZZX001-06), National Natural Science Foundation of China (32171046, 32071044, 32200844), China Postdoctoral Science Foundation (2022M712789), a National Science Foundation award (1734220), and a Binational Science Foundation award (2015299). Emerging Enhancement Technology under Perspective of Humanistic Philosophy, supported by National Office for Philosophy and Social Science (No. 20&ZD045).

Declaration of interests

No interests are declared.

References

1. Neisser, U. and Becklen, R. (1975) Selective looking: attending to visually specified events. *Cogn. Psychol.* 7, 480–494
2. Mack, A. and Rock, I. (1998) *Inattentional Blindness*, MIT Press
3. Simons, D.J. and Chabris, C.F. (1999) Gorillas in our midst: sustained inattentional blindness for dynamic events. *Perception* 28, 1059–1074
4. Chen, H. and Wyble, B. (2015) Amnesia for object attributes: failure to report attended information that had just reached conscious awareness. *Psychol. Sci.* 26, 203–210
5. Chen, H. *et al.* (2019) Does attribute amnesia occur with the presentation of complex, meaningful stimuli? The answer is, 'it depends'. *Mem. Cogn.* 47, 1133–1144
6. Tam, J. *et al.* (2021) And like that, they were gone: a failure to remember recently attended unique faces. *Psychon. Bull. Rev.* 28, 2027–2034
7. Baddeley, A.D. and Hitch, G. (1974) Working memory. In *The Psychology of Learning and Motivation: Advances in Research and Theory* (Bower, G.A., ed.), pp. 47–89, Academic Press
8. Baddeley, A. (2012) Working memory: theories, models, and controversies. *Annu. Rev. Psychol.* 63, 1–29
9. Awh, E. and Jonides, J. (2001) Overlapping mechanisms of attention and spatial working memory. *Trends Cogn. Sci.* 5, 119–126
10. Awh, E. *et al.* (2006) Interactions between attention and working memory. *Neuroscience* 139, 201–208
11. Gazzaley, A. and Nobre, A.C. (2012) Top-down modulation: bridging selective attention and working memory. *Trends Cogn. Sci.* 16, 129–135
12. Panichello, M.F. and Buschman, T.J. (2021) Shared mechanisms underlie the control of working memory and attention. *Nature* 592, 601–605
13. Logan, G.D. (1988) Toward an instance theory of automatization. *Psychol. Rev.* 95, 492–527
14. Chun, M.M. and Turk-Browne, N.B. (2007) Interactions between attention and memory. *Curr. Opin. Neurobiol.* 17, 177–184
15. McNab, F. and Klingberg, T. (2008) Prefrontal cortex and basal ganglia control access to working memory. *Nat. Neurosci.* 11, 103–107
16. Schmicker, M. *et al.* (2016) Training of attentional filtering, but not of memory storage, enhances working memory efficiency by strengthening the neuronal gatekeeper network. *J. Cogn. Neurosci.* 28, 636–642
17. Kim, H. (2019) Neural activity during working memory encoding, maintenance, and retrieval: a network-based model and meta-analysis. *Hum. Brain Mapp.* 40, 4912–4933
18. Cowan, N. (1998) *Attention and Memory: an Integrated Framework*, Oxford University Press
19. Chun, M.M. (2011) Visual working memory as visual attention sustained internally over time. *Neuropsychologia* 49, 1407–1409
20. Kiyonaga, A. and Egner, T. (2013) Working memory as internal attention: toward an integrative account of internal and external selection processes. *Psychon. Bull. Rev.* 20, 228–242
21. Chen, H. and Wyble, B. (2016) Attribute amnesia reflects a lack of memory consolidation for attended information. *J. Exp. Psychol. -Hum. Percept. Perform.* 42, 225–234
22. McCormick-Huhn, J.M. *et al.* (2018) Using attribute amnesia to test the limits of hyper-binding and associative deficits in working memory. *Psychol. Aging* 33, 165–175
23. Born, S. *et al.* (2019) Saccadic selection does not eliminate attribute amnesia. *J. Exp. Psychol.-Learn. Mem. Cogn.* 45, 2165–2173
24. Wang, R. *et al.* (2021) Consciousness can overflow report: novel evidence from attribute amnesia of a single stimulus. *Conscious. Cogn.* 87, 103052
25. Liu, Y. *et al.* (2021) Using the attribute amnesia paradigm to test the automatic memory advantage of person names. *Psychon. Bull. Rev.* 28, 2019–2026
26. Cardenas-Miller, N. *et al.* (2023) Search without building memories: failure of visual recall for easy search tasks in natural scenes. *OSF Preprints* Published online January 30, 2023. http://doi.org/10.31219/osf.io/6c7qb
27. Chen, H. and Wyble, B. (2015) The location but not the attributes of visual cues are automatically encoded into working memory. *Vision Res.* 107, 76–85

Outstanding questions

What neural mechanisms enable the memory reselection of attended information? One possibility is that information is excluded from memory by inhibiting activations within sensory regions. Alternatively, memory reselection may operate through higher-level mechanisms that block information from being encoded into working memory.

Are there techniques that can encourage participants to deactivate memory reselection for long periods of time and thereby encode more into memory? If so, what are the consequences on the accuracy of autobiographical memories formed at the time?

What are the individual differences in the ability of memory reselection, and which other cognitive measures correlate with these differences?

What factors could influence the reselection efficiency (e.g., the associated value of the information, depth of processing, or the emotional state of the participants)?

How – and how quickly – does memory reselection change when participants' expectations of the environment are violated, such as with an abrupt interruption of the task course or with an unexpected change of the background?

What are the different characteristics between operations of memory reselection and attentional selection? How are they constrained by information structure such as objects or feature dimensions?

Does reselection of key features share a mechanism similar to the internal selection for information that has been stored in working memory?

28. Chen, H. *et al.* (2016) Prolonged focal attention without binding: tracking a ball for half a minute without remembering its color. *Cognition* 147, 144–148
29. Swan, G. *et al.* (2016) Memory for a single object has differently variable precisions for relevant and irrelevant features. *J. Vision* 16, 32
30. Born, S. *et al.* (2020) Attribute amnesia can be modulated by foveal presentation and the pre-allocation of endogenous spatial attention. *Atten. Percept. Psychophys.* 82, 2302–2314
31. Howe, P.D.L. and Lee, S.B.W. (2021) Attribute amnesia in the auditory domain. *Perception* 50, 664–671
32. Tam, J. and Wyble, B. (2022) Location has a privilege, but it is limited: evidence from probing task-irrelevant location. *J. Exp. Psychol.-Learn. Mem. Cogn.* 49, 1051–1067
33. Eitam, B. *et al.* (2013) Blinded by irrelevance: pure irrelevance induced 'blindness'. *J. Exp. Psychol. -Hum. Percept. Perform.* 39, 611–615
34. Eitam, B. *et al.* (2015) Seeing without knowing: task relevance dissociates between visual awareness and recognition. *Ann. N.Y. Acad. Sci.* 1339, 125–137
35. O'Donnell, R.E. *et al.* (2021) No explicit memory for individual trial display configurations in a visual search task. *Mem. Cogn.* 49, 1705–1721
36. Chen, W. and Howe, P.D. (2017) Attribute amnesia is greatly reduced with novel stimuli. *PeerJ* 5, e4016
37. Chung, Y.H. *et al.* (2023) Object meaningfulness increases incidental memory of shape but not location. *PsyArXiv* Published online February 27, 2023. http://dx.doi.org/10.31234/osf.io/th2rm
38. Sasin, E. *et al.* (2023) What allows a meaningful object to escape attribute amnesia? *PsyArXiv* Published online May 2, 2023. http://dx.doi.org/10.31234/osf.io/phqw5
39. Green, T. *et al.* (2023) Memorability effects emerge in incidental visual working memory. *PsyArXiv* Published online February 28, 2023. http://dx.doi.org/10.31234/osf.io/td5ub
40. Shin, H. and Ma, W.J. (2016) Crowdsourced single-trial probes of visual working memory for irrelevant features. *J. Vision* 16, 10
41. Chen, X. *et al.* (2012) Effect of feature-selective attention on neuronal responses in macaque area MT. *J. Neurophysiol.* 107, 1530–1543
42. Jackson, J. *et al.* (2017) Feature-selective attention in frontoparietal cortex: multivoxel codes adjust to prioritize task-relevant information. *J. Cogn. Neurosci.* 29, 310–321
43. Dehaene, S. *et al.* (1993) The mental representation of parity and number magnitude. *J. Exp. Psychol.-Gen.* 122, 371–396
44. Reynvoet, B. and Brysbaert, M. (1999) Single-digit and two-digit Arabic numerals address the same semantic number line. *Cognition* 72, 191–201
45. Fu, Y. *et al.* (2022) The development of memory selection: when children have better memory than adults. *PsyArXiv* Published online September 2, 2022. http://dx.doi.org/10.31234/osf.io/sn283
46. Moyer, R.S. and Landauer, T.K. (1967) Time required for judgements of numerical inequality. *Nature* 215, 1519–1520
47. Temple, E. and Posner, M.I. (1998) Brain mechanisms of quantity are similar in 5-year-old children and adults. *Proc. Natl. Acad. Sci. U. S. A.* 95, 7836–7841
48. Swan, G. *et al.* (2017) Working memory representations persist in the face of unexpected task alterations. *Atten. Percept. Psychophys.* 79, 1408–1414
49. O'Donnell, R.E. and Wyble, B. (2023) Slipping through the cracks: the peril of unexpected interruption on the contents of working memory. *J. Exp. Psychol.-Learn. Mem. Cogn.* 49, 990–1003
50. Harrison, G.W. *et al.* (2021) Remembering more than you can say: re-examining 'amnesia' of attended attributes. *Acta Psychol.* 214, 103265
51. Soto, D. *et al.* (2008) Automatic guidance of attention from working memory. *Trends Cogn. Sci.* 12, 342–348
52. Olivers, C.N. *et al.* (2011) Different states in visual working memory: when it guides attention and when it does not. *Trends Cogn. Sci.* 15, 327–334
53. Fu, Y. *et al.* (2021) More attention with less working memory: the active inhibition of attended but outdated information. *Sci. Adv.* 7, eabj4985
54. Zhu, P. *et al.* (2022) A new aspect of cognitive selectivity: working memory reselection for attended information. *PsyArXiv* Published online September 2, 2022. http://dx.doi.org/10.31234/osf.io/fzwp3
55. Vogel, E.K. and Machizawa, M.G. (2004) Neural activity predicts individual differences in visual working memory capacity. *Nature* 428, 748–751
56. Vogel, E.K. *et al.* (2005) Neural measures reveal individual differences in controlling access to working memory. *Nature* 438, 500–503
57. Jiang, Y.V. *et al.* (2016) Memory for recently accessed visual attributes. *J. Exp. Psychol.-Learn. Mem. Cogn.* 42, 1331–1337
58. Sperling, G. (1960) The information available in brief visual presentations. *Psychol. Monogr.* 74, 1–29
59. Sligte, I.G. *et al.* (2008) Are there multiple visual short-term memory stores? *PLoS ONE* 3, e1699
60. van Ede, F. and Nobre, A.C. (2023) Turning attention inside out: how working memory serves behavior. *Annu. Rev. Psychol.* 74, 137–165
61. Lewis-Peacock, J.A. *et al.* (2018) The removal of information from working memory. *Ann. N. Y. Acad. Sci.* 1424, 33–44
62. Woodman, G.F. *et al.* (2001) Visual search remains efficient when visual working memory is full. *Psychol. Sci.* 12, 219–224
63. Becker, M.W. and Pashler, H. (2002) Volatile visual representations: failing to detect changes in recently processed information. *Psychon. Bull. Rev.* 9, 744–750
64. Chen, H. and Wyble, B. (2018) The neglected contribution of memory encoding in spatial cueing: a new theory of costs and benefits. *Psychol. Rev.* 125, 936–968
65. Chen, L. *et al.* (2023) The modulation of expectation violation on attention: evidence from the spatial cueing effects. *Cognition* 238, 105488
66. Huang, L. and Pashler, H. (2007) A Boolean map theory of visual attention. *Psychol. Rev.* 114, 599–631
67. Huang, L. *et al.* (2007) Characterizing the limits of human visual awareness. *Science* 317, 823–825
68. Mance, I. *et al.* (2012) Parallel consolidation of simple features into visual short-term memory. *J. Exp. Psychol. -Hum. Percept. Perform.* 38, 429–438
69. Block, N. (2011) Perceptual consciousness overflows cognitive access. *Trends Cogn. Sci.* 15, 567–575
70. Fu, Y. *et al.* (2021) Does consciousness overflow cognitive access? Novel insights from the new phenomenon of attribute amnesia. *Sci. China-Life Sci.* 64, 847–860
71. Hedayati, S. *et al.* (2022) A model of working memory for latent representations. *Nat. Hum. Behav.* 6, 709–719
72. Wyble, B. *et al.* (2019) Learning how to exploit sources of information. *Mem. Cogn.* 47, 696–705
73. Chen, H. *et al.* (2019) Expecting the unexpected: violation of expectation shifts strategies toward information exploration. *J. Exp. Psychol. -Hum. Percept. Perform.* 45, 513–522
74. Yan, N. *et al.* (2023) Encoding history enhances working memory encoding: evidence from attribute amnesia. *J. Exp. Psychol. -Hum. Percept. Perform.* 49, 589–599
75. Schmidt, B.K. *et al.* (2002) Voluntary and automatic attentional control of visual working memory. *Percept. Psychophys.* 64, 754–763
76. Cowan, N. and Morey, C.C. (2006) Visual working memory depends on attentional filtering. *Trends Cogn. Sci.* 10, 139–141
77. Gazzaley, A. (2011) Influence of early attentional modulation on working memory. *Neuropsychologia* 49, 1410–1424
78. Allen, R.J. and Ueno, T. (2018) Multiple high-reward items can be prioritized in working memory but with greater vulnerability to interference. *Atten. Percept. Psychophys.* 80, 1731–1743
79. Shao, N. *et al.* (2010) Saccades elicit obligatory allocation of visual working memory. *Mem. Cogn.* 38, 629–640
80. Tas, A.C. *et al.* (2016) The relationship between visual attention and visual working memory encoding: a dissociation between covert and overt orienting. *J. Exp. Psychol. -Hum. Percept. Perform.* 42, 1121–1138
81. Schut, M.J. *et al.* (2017) The cost of making an eye movement: a direct link between visual working memory and saccade execution. *J. Vision* 17, 15
82. Marshall, L. and Bays, P.M. (2013) Obligatory encoding of task-irrelevant features depletes working memory resources. *J. Vision* 13, 21
83. Summerfield, C. and Egner, T. (2009) Expectation (and attention) in visual cognition. *Trends Cogn. Sci.* 13, 403–409

84. Most, S.B. *et al.* (2000) Sustained inattentional blindness: the role of location in the detection of unexpected dynamic events. *Psyche* 6, 10383060
85. Koivisto, M. *et al.* (2004) The effects of eye movements, spatial attention, and stimulus features on inattentional blindness. *Vision Res.* 44, 3211–3221
86. Simons, D.J. and Levin, D.T. (1997) Change blindness. *Trends Cogn. Sci.* 1, 261–267
87. Simons, D.J. and Rensink, R.A. (2005) Change blindness: past, present, and future. *Trends Cogn. Sci.* 9, 16–20
88. Koch, C. and Tsuchiya, N. (2007) Attention and consciousness: two distinct brain processes. *Trends Cogn. Sci.* 11, 16–22
89. Mulckhuyse, M. and Theeuwes, J. (2010) Unconscious attentional orienting to exogenous cues: a review of the literature. *Acta Psychol.* 134, 299–309
90. Woodman, G.F. and Luck, S.J. (2003) Dissociations among attention, perception, and awareness during object-substitution masking. *Psychol. Sci.* 14, 605–611
91. He, S. *et al.* (1996) Attentional resolution and the locus of visual awareness. *Nature* 383, 334–337
92. Chen, H. *et al.* (2018) Is source information automatically available in working memory? *Psychol. Sci.* 29, 645–655
93. Xu, M. *et al.* (2020) Source information is inherently linked to working memory representation for auditory but not for visual stimuli. *Cognition* 197, 104160