An Overview of Attention, Memory, and Distractors: A Literature Review

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Abstract

The purpose of this review is to give an overview of the two main types of memory, working and long-term, how attention interacts with memory, what affects memory and attention, and what a distractor is. Working memory is defined and the drawbacks of limited resources are discussed as well as how the brain allocates those resources. Long-term memory is discussed in terms of how it interacts with working memory and allows for storage of a virtually unlimited amount of information. Attention is compared to working memory as they both have limited resources and affect what is stored in long-term memory. Several factors that affect memory and attention are discussed including the modality of presentation, the information being presented, and the characteristics of the presenter and the participant. Several studies on distractors are mentioned that show contradictory evidence for how distractors impact attention and memory. Finally, several gaps in the research are discussed and directions for future research are considered.

Keywords: memory, attention, distractors, remote instruction, COVID-19

An Overview of Attention, Memory, and Distractors: A Literature Review

Memory is an extremely complicated subject that continually defies scientists' attempts to put it in a box. Its definitions and parameters are constantly being updated and new forms and interactions are being discovered regularly. Even when scientists believe that they have nailed down what a specific kind of memory does, they learn that it interacts with another kind of memory and the lines between them blur. Then the word "attention" gets pulled in and a whole new subject is folded in and muddies the mix. Scientists attempt to ascertain the interaction between attention and working memory, the impact that attention has on encoding long-term memory, what things impact attention, the list goes on and on. Distractors are another element that can convolute the discussion, trying to figure out what acts as a distractor, whether all distractors are equal, and how distractors function. With all this overlap and interaction, it can be challenging to know exactly where to start learning about what memory, attention, and distraction really are. This literature review attempts to simplify the discussion, laying out the basic elements of two of the main types of memory, attention and what affects it, and what distractors are. Despite all of the research out there, there is still much more to be done to fill in the gaps. Hopefully, this review will provide a starting point to see where those gaps are and how researchers can go about filling them in the future.

Attention and Memory

Types of Memory

There are several types of memory (long-term memory, short-term memory, working memory, etc.) and, within those, even more categorized by the senses with which they correspond and the functions they serve (visual working memory, associative memory, central

executive memory, etc.). For the purpose of this review, the focus will be on working memory and long-term memory as these are the two overarching categories into which most of the other kinds of memory fall.

Working Memory

"Working memory is an information-processing architecture that consists of several modality-specific systems that encode, process, and maintain information," (Burnham et al., 2014, p. 391). This essentially means that working memory allows people to keep information in their consciousness and encode that information into long-term memory so that they can recall it at a later date. Working memory includes short-term memory and central executive processes that manipulate stored information (Cowan, 2008). There are several different types of working memory depending on the modality of the information that a person is trying to remember: visual working memory, spatial working memory, and phonological working memory to name a few (Burnham et al., 2014).

The key limitation of working memory is that it has a finite number of resources that are taken up by the items that a person is trying to remember. This has led to the development of what is called Load Theory: the idea that when perceptual load is high, a person will pay attention to a limited amount of information that is relevant to the task at hand; if perceptual load is low, a person is able to pay attention to much more information that is not necessarily relevant to the current task (Burnham et al, 2014). When the perceptual load is too high, a person's performance on a task will suffer and response competition is higher, but when perceptual load is too low, extraneous information will be more distracting and will result in lower performance (Burnham et al., 2014).

There are many ways that a person can keep information in working memory for longer amounts of time. The two primary ways are rehearsal and attentional refreshing. Rehearsal involves repeating the information either verbally or nonverbally, in an attempt to keep the information from fading. As this can really only be done with words or numbers (such as a phone number or remembering to buy a specific thing at the store), this is primarily effective for verbal information (Camos et al., 2018). Attentional refreshing involves refocusing on a memory trace of an item which allows that trace to be boosted, no matter the sensory modality, and increases the amount of time that that information is maintained in working memory (Camos et al., 2018). While attentional refreshing may sound similar to rehearsal, studies have shown that it is distinct both behaviorally and neurologically from rehearsal and other maintenance mechanisms (Loaiza & Halse, 2019). However, because attentional load is limited, neither attentional refreshing or rehearsal are effective when performing other attentionally demanding processes (Camos et al., 2018).

While many studies have shown that information only stays in working memory while the person is actively thinking about it, there have been some studies in the last 10 years that have shown that maintaining stimulus representation may not be necessary for working memory (Lewis-Peacock et al., 2012). Lewis-Peacock and colleagues (2012) showed that, even when attention was not directed toward it, information was remembered after a short period where attention was focused elsewhere. Using an fMRI, they found that refocusing attention towards an unattended memory can reactivate its neural signature, suggesting that a person may not need to continuously be thinking about information in order to utilize short-term memory (Lewis-Peacock et al., 2012). In light of this, some studies have suggested that

attentional refreshing could not only be a way to keep information in working memory, but it could also be a central process involved in the two-way information channel between long-term and working memory (Camos et al., 2018).

Long-Term Memory

When information is no longer held in working memory, it is encoded and stored in long-term memory so that it can be recalled at another time. Long-term memory acts as storage for information that is no longer available in working memory, and, as far as current research shows, is unlimited (Loaiza & Halse, 2019). However, the way that information is held in working memory can affect how it is encoded in long-term memory. Camos and Portrat (2015) showed that attentional refreshing affects both long-term and working memory. The act of attentional refreshing may benefit episodic long-term memory and these benefits are not affected by cognitive load or the amount of information that is being encoded (Loaiza & Halse, 2019). Research has shown that long-term memory and working memory are extremely interconnected and it is difficult to tell where one ends and another begins, which has led to the development of the embedded-component theory of information processing (Lewis-Peacock et al., 2012). This theory states that the interaction of long-term memory and attention results in short-term memory which is not found in either individually (Lewis-Peacock et al., 2012).

Attention

The brain has limited neural resources, so depending on how many of those resources are available, it must filter which information is important and which can be ignored (Fiebelkorn & Kastner, 2020). This filter results is called attention, when a person focuses on specific information while ignoring other pieces of information. Stimuli that are not in the focus of

attention do not take up neural resources, so there are more resources for the information that is relevant to the task being performed (Desimone & Duncan, 1995). Attention networks include both cortical and subcortical structures whose functional contributions can change from moment-to-moment, allowing for the necessary cognitive flexibility for paying attention in highly dynamic environments (Fiebelkorn & Kastner, 2020).

Similar to working memory, attentional resources are limited, so giving attention to one thing leaves less for another (Desimone & Duncan, 1995). This leads to competition between stimuli which is biased towards information that is relevant to the task at hand (Desimone & Duncan, 1995). More attentional resources are taken up when the stimuli are informative than if they are extraneous to the task being performed (Li et al., 2013). Due to the limited attentional resources, dividing attention between two objects decreases performance compared to when attention is focused on just one of the objects (Desimone & Duncan, 1995). This interference of adding another object to the focus of attention occurs independently of eye-movements and spatial separation between the objects (Desimone & Duncan, 1995; Lavie, 1995). Additionally, as with working memory, the difficulty of the task affects how much attentional load is left to attempt to filter out non-targeted objects. Both a high number of nontargeted objects and a high-load task decrease the ability to filter out distractors (Desimone & Duncan, 1995).

Eye-movements are important because attention can generally be ascertained by where a person's eyes are focused (Fiebelkorn & Kastner, 2020). However, studies have found that gaze direction is not always correlated with attention, such as in the case of covert attention (Fiebelkorn & Kastner, 2020; Hafed & Clark, 2002). Covert attention refers to a scenario where

attention is fixed somewhere other than where a person's gaze is. Recent studies discovered that microsaccades, while previously thought to be random eye-movements with no purpose, can actually be used to discern where covert attention is focused (Hafed & Clark, 2002). Hafed and Clark (2002) define microsaccades as eye-movements that are so small that they don't cause a change in focus to new visual targets. By observing the directions of microsaccades, they found that they moved toward where covert attention shifted, suggesting that microsaccades are not random and actually could occur because of the activation of the oculomotor system through a change in covert attention (Hafed & Clark, 2002). The majority of studies that look at eye-movement to measure attention use eye-tracking software or optical sensors (Cutmore & James, 2007). However, Müller and colleagues (2016) discovered that using an electrooculogram (EOG) was comparable to eye-tracking software for measuring the fixation of attention. In addition to eye-movements, Katidioti and colleagues (2014) not only discovered that a person's pupils dilate before shifting attention, but they also found that this pupil dilation occurred several seconds before the attention switch, indicating a decision to switch that takes a relatively large amount of time. They also made a distinction between self-interruption and external interruption that the majority of other studies failed to make, and found that both decrease performance even though one is a choice and the other is caused by an external force (Katidioti et al., 2014).

Things that Affect Attention and Memory

There are many, many things that affect a person's ability to focus attention on an object or information and remember it later. Several of these factors have already been mentioned (the difficulty of the task, the number of nontarget objects, dividing attention between multiple

target objects, etc.), however research has found several other factors that are less predictable than those based on theories of attentional load.

Modality of Presentation

The way that the information is presented has a substantial impact on how much a person is able to pay attention to and remember. Several studies have found that presenting information as videos actually resulted in increased memory and performance (Frieske & Park, 1999; Konstantinou et al., 2014; Meyerhoff & Huff, 2016). What all of these studies found were that videos resulted in much better memory performance than either audio or visual clips alone (Frieske & Park, 1999; Meyerhoff & Huff, 2016). Meyerhoff and Huff (2016) also found that adding motion to a visual scene improves memory performance and that, when comparing visual-only and audio-only clips, auditory clips resulted in poorer memory performance. Frieske and Park (1999) found that both younger and older adults were able to remember content from a video better than from audio only, which they hypothesized was due to an increase in the cognitive load by having to process two modalities rather than one. Konstantinou and colleagues (2014) agreed, claiming that adding visuals decreases the effect of distractors on memory as it increases the cognitive load. On a separate note, when comparing the impact of listening to a story and reading a story, Rickheit and colleagues (1987) found that, while the differences in processing either of these styles of communication depended on the previous experience of the subjects, people tend to focus more on the essential information when listening to a story, while they focus on all parts equally, including details, when reading a story.

Information Being Presented

In addition to the way that information is presented, studies have found that the information itself has an impact on how much a person is able to pay attention to and remember. Mohanty and colleagues (2016) found that items that are meaningfully related go beyond eliminating memory deficiencies in older adults and actually increase associative memory performance for adults of all ages. Additionally, when mental effort is low, a person's attention tends to be captured by high-salient parts of an image (Mathôt et al., 2015). But what several studies have found captures attention regardless of mental effort or the task being performed are faces (Devue & Brédart, 2008; Eitam et al., 2014; Riby et al., 2012).

Faces are processed regardless of whether they are relevant to the task being performed and whether the person is under high or low perceptual load (Eitam et al., 2014). In fact, Eitam and colleagues (2014) found that faces actually are highly effective at drawing attention away from the task being performed. A person's own face, and highly familiar faces, are very distracting at first, but become normalized over time (Devue & Brédart, 2008). However, Devue and Brédart (2008) found that this interference is only effective when the face is presented inside the focus of attention. Not only that, but they found that a person's face or name only are distracting in certain conditions and thus do not automatically attract the person's attention (Devue & Brédart, 2008). Interestingly, Riby and colleagues (2012) discovered that, while virtual faces are less physiologically arousing and thus draw less attention than live faces, they still act as potent distractors to task and memory performance.

Characteristics of Presenter and Participant

Finally, both the characteristics of the participant and those of the person presenting the information have an impact on attention and the amount of information that is remembered. The primary characteristic that affects both is gender. Men's implicit memory improves when information is spoken by a man's voice that has been artificially lowered whereas women's implicit memory improves when information is spoken by a man's voice that has been artificially raised (Albert et al., 2018). Additionally, information read by a man increases both visual object memory and working memory in women (Smith et al., 2012). However, Helfrich and Weidenbecher (2011) found that high- and low-pitched voices tend to lead to better retention of information than medium-pitched voices regardless of the gender of the participant, which seems to contradict the findings of the two previous studies.

Another characteristic of the participants that could impact attention and memory is their age. Cowan (2008) found that working memory differs substantially between individuals, developing in childhood and then declining in old age. More evidence for this difference is that young adults recalled more news content and performed better on source recognition tests than older adults (Frieske & Park, 1999). Frieske and Park (1999) believed these disparities were due to differences in sensory acuity and processing speed, meaning that older adults process information more slowly and remember less of the information that they encounter.

Distraction

Many of the external factors that affect attention could be described as distractors: objects that interfere with attention and working memory. There are as many different kinds of distractors as there are sensory modalities and each of them affect attention differently. As discussed earlier, faces act as very potent distractors (Devue & Brédart, 2008; Neumann et al.,

2011). But are all distractors equal and what makes them work? In relation to working memory, Burnham and colleagues (2014) found that distractors affect all but phonological working memory. As discussed earlier, the amount of load that working memory is under determines how much extraneous information (i.e., distractors) is able to be ignored (Neumann et al., 2011). Generally, high working memory load means that there are less resources able to be taken by extraneous information while with low load, distracting information will have more of an effect on performance (Lavie, 1995). However, Burnham and colleagues (2014) found that not just any working memory load will hinder distractor rejection, only those where both the task and the distractor require the same mode of working memory (i.e., spatial working memory, visual working memory, central executive, etc.).

However, some studies have shown that it is not so simple. Leiva and colleagues (2015) found that visual distractors only affect attention to auditory stimuli when the person's attention is voluntarily directed at the distractor while auditory distractors affect attention to auditory stimuli whether attention is directed at the distractor or not. This provides evidence that, while distractors in the same mode of memory do have an impact, distractors that are in different modes can also reduce performance when they cause attention to be split between them, as predicted by the limited attentional resources (Desimone & Duncan, 1995). Klauer and Zhao (2004) provide additional evidence that distractions in the same modality as the task produce more disruption, finding that spatial interference was more disrupting for a spatial short-term memory task than visual interference and the opposite was true for a visual short-term memory task.

Another study pushed against the evidence that the distractor had to be in the same modality as the task, finding that both visual and auditory distractors interfered with performance, but visual distractors were less distracting than auditory stimuli (Bendixen et al., 2010). Bendixen and colleagues (2010) attempted to explain this not through modality conflict or load theory, but by reasoning that this occurred because, while the auditory system is taking in all of the information in the environment, the visual system is naturally unable to see large sections, making it more difficult to tune out auditory distractors. They also found that changing how noticeable the stimulus is did not change the results and that any change in a sequence of repetitive stimuli was distracting (Bendixen et al., 2010).

Gaps and Future Directions

There are several gaps that are evident in the research that has been done specifically on attention and the effect of self-referential stimuli. For example, Devue and Brédart (2008) found that a person's face (and a highly familiar face) is very distracting when presented near where their attention is focused but becomes habituated over time. However, would the same effect be observed if the distractor was a recorded video of the person's face, or a live video of the person's face? Would the presence of the live video still not be distracting when it was presented in the periphery as images were found to be (Devue & Brédart, 2008)?

There is also a large gap in the research when it comes to determining the effect of distractors on covert attention. With the discovery that microsaccades can be used to determine where covert attention is focused, researchers could look at whether covert attention is distracted faster or more easily than overt attention (Hafed & Clark, 2002).

With the limited amount of research on attentional refreshing, there is much that could still be learned about the effect that it has on both working memory and long-term memory as well as potentially shedding some light on their interaction if it indeed acts as a part of the two-way information channel between them as Camos and colleagues suggest (2018). However, the largest gap in the research has to do with the effect of technology on memory and attention. While there have been some studies done on attention in a virtual environment (Doherty-Sneddon et al., 1997; Riby et al., 2012) there is still a huge range of topics within this area that are largely unexplored.

Remote Instruction

With the COVID-19 pandemic forcing more and more interactions to take place virtually, it is more important now than ever to look into the effect that communicating via computer screens has on attention and memory. One major area that has little-to-no research to date is the effect that remote instruction is having on children and their learning. In a survey of schools across the United States in the spring of 2020, 99% of teachers said they were facilitating remote instruction (Hamilton et al., 2020). Less than half of students in a Delaware Department of Education survey were satisfied with online learning and even fewer felt like they were learning new things after moving to remote instruction with the strengthening of COVID-19 restrictions (Resources/Remote Learning Survey Results, 2020). This is no surprise when research has found that live faces increased physiological arousal while video-mediated faces did not, meaning that video-mediated faces drew less attention (Riby et al., 2012). Doherty-Sneddon and colleagues (1997) also found that communication was much more formal when virtual and that people are less confident in mutual understanding when communicating

via video. In fact, task performance was reduced when communication was virtual rather than in-person (Doherty-Sneddon et al., 1997). A survey put out by the EdWeek Research Center found that 76% of teachers report that student engagement has declined in a two-week period after moving to remote instruction (Bushweller, 2020). More than three-quarters (77%) of students in a survey given by the University of Wisconsin Milwaukee during COVID-19 claim that they are not learning as much as they were before the COVID-19 crisis (Distance-Learning in the Time of COVID-19, 2020). It is clear that remote instruction appears to be having a negative impact on students' education, but what could be causing this decline in learning? Is it that teachers have no experience teaching remotely? Is it that students have a harder time paying attention when not in a classroom setting? Is it due to a lack of resources or support for parents and teachers? The problem cannot be remedied until it is identified, and it will take a significant amount of research to identify the myriad of problems impacting students' education.

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