Attention and Working Memory: Tools for Understanding Consciousness

Jill T. Shelton and Emily M. Elliott
Louisiana State University

Nelson Cowan
University of Missouri- Columbia

Submitted by Invitation to *Psyche*
June 16, 2008

Corresponding author:

Nelson Cowan
Department of Psychological Sciences
University of Missouri
18 McAlester Hall
Columbia, MO 65211 USA

Tel 573-882-4232
Email: CowanN@missouri.edu

Attention and Working Memory: Tools for Understanding Consciousness

Most would agree that attention and consciousness are related to one another; however, this is not to say that everything being attended to is available to consciousness, or vice versa. In fact, some researchers argue that information being attended to is not always under the control of top-down attentional processes, and attention can often be directed towards input that remains outside of consciousness (Koch & Tsuchiya, 2006). For example, the attentional system could become oriented to a familiar smell entering the environment. Attending to this sensory input could even bring on sadness without awareness of the culprit behind this sudden onset of emotion. Further examination could be facilitated by selecting the input being received by the olfactory system, leading to the conscious realization that the floral aroma filling the room reminds one of a recently-attended funeral.

The foregoing example raises several issues that speak to the connection between attention and consciousness. First, a person is not always consciously aware of what he or she is attending to, which suggests attention and consciousness are separate, albeit related, constructs. Attentional orienting is one example of how attention can be shifted in response to changing states in the environment, without the voluntary control of the organism (Cowan, 1995). Second, the contents of the unconscious mind can influence ongoing cognitive operations in a variety of ways that are not yet fully understood. Third, attention can be used to draw important information into conscious awareness, making the study of attentional processes useful as a tool to explore the nature of consciousness. The relationship between attention and consciousness, and the utility of this relationship for understanding these complex constructs, will be discussed, followed by a consideration of the remaining issues and the tools that may be used to address them.

What is the relationship between attention and consciousness?

One approach to investigating how attention and consciousness are connected is to identify a psychological theory that relies heavily on both constructs to explain cognitive functioning. Theories of working memory (WM) provide one good example of this, as attention and consciousness are inherent in some explanations of how the WM system operates. The processes that are believed to take place within this system include the active manipulation of items stored in memory, the binding of multi-sensory elements to produce novel representations, and the transfer of these representations to long-term storage. Clearly, a great deal of emphasis is placed on the controlled processing that occurs within conscious awareness. Additionally, an assumption that is present across theories of WM is that attention plays an important role in the memory process (Baddeley, 1986; Cowan, 1988). These attentional resources are deployed to a variety of information processing activities that influence memory function. However, only a subset of this information is believed to be available to conscious awareness at any given point. This suggests that, in addition to the consciously controlled portion of WM, there is a non-conscious portion that still influences ongoing cognitive activity

In the original WM model proposed by Baddeley and Hitch (1974) there were three components: the central executive, and two subsystems, the phonological loop and the visuo-spatial sketchpad. Baddeley and Logie (1999) acknowledged the central executive as an attentional control mechanism that allocates attentional resources to specific subsystems, and is responsible for transferring information into the long-term store. The phonological loop and visuo-spatial sketchpad are responsible for rehearsal and storage of verbal and visual information, respectively. Baddeley (2000) added a fourth component to his model, the episodic buffer, which was considered a limited capacity storage system that temporarily held activated

information from both of the subsystems, as well as information from long-term memory (LTM). Baddeley noted that two key features of the episodic buffer were the ability to integrate verbal and visual elements to create episodic representations, and to allow for brief storage of information that exceeded the capacity limits of the two subsystems. Recently, Baddeley (2007) wrote about the connection between WM and consciousness. He noted that consciousness is "…a legitimate and tractable scientific problem" (p. 301). He further stipulated that it is housed in the episodic buffer and works in combination with the central executive.

Cowan (1995; 1999) offered an embedded process view as a somewhat more general information processing framework. According to this model, the human memory system operates by way of rich interaction between attentional and memory mechanisms. Information in the memory system can be held in activated or non-activated states, and in its non-activated state these elements represent LTM. Attentional resources are used to stimulate information from LTM in order to meet current goals. In this model, activated units can arise from multi-modal sensory input, as well as semantic and episodic information from LTM. These representations may or may not be in conscious awareness, but they are readily accessible for use if necessary. A portion of these items can be further heightened to a highly active state that comprises the scope, or focus, of attention. Central executive resources are used to maintain information in the scope of attention. Cowan (1995) states, "The type of model I have proposed (Cowan, 1988) could, I hope, serve as a general framework for the conscious mind. Within that model, like many others, the focus of attention is assumed to be the same as the contents of conscious awareness." (p. 200)

A similar approach to conceptualizing the WM system has been taken by Oberauer (2002). In his concentric model of WM, Oberauer proposes three components of the memory system that are functionally distinct. Two of these components are comparable to the model proposed by Cowan, while the third segment is unique to Oberauer's model. First, there is an activated portion of LTM that contains items which were recently used or stimulated by other cognitive operations, but are not presently available to ongoing cognitive activity. The second component, the region of direct access, holds a limited set of items that are ready to be accessed and used for current processing demands. The final segment of this model, referred to as the focus of attention, represents the single item or chunk that is presently being used to perform the designated cognitive operation. According to the assumptions of this model, the primary limitation on the joint processing and storage of information is one of selection. The items present within the region of direct access are constantly competing for a spot in the focus of attention, as selection for this position results in further processing. In other words, the selection of specific items for conscious, controlled processing is a central goal of the WM system.

In each of these models of WM there is a separate region of the memory system that is devoted to temporarily holding information in a highly accessible state, making it available to conscious awareness. Furthermore, attention plays an integral role in stimulating and maintaining these representations for additional processing. Another facet within all of these models that is relevant to the present question is the presence of activated units within the memory system that are not in the realm of conscious awareness. For example, the models proposed by Cowan and Oberauer contain a portion of activated LTM, consisting of representations that are presumably being used for ongoing cognitive operations. These operations are not necessarily available to conscious awareness; they can result from some form of automatic, involuntary processing, such as accessing an entry in the mental lexicon. The same can be said about the processing taking place in the phonological and visuo-spatial subsystems of Baddeley's model. Finally, focal attention mechanisms appear to play a pivotal role in selecting the most relevant information for further controlled processing. The assumptions present within the framework of WM suggest

that the contents of conscious awareness are intrinsically linked to controlled attention processes.

Taken together, the assumptions present within formal models of WM raise some important questions about the nature of the relationship between attention and consciousness. First, how does the activated portion of LTM that resides in the unconscious mind influence the controlled processing that is taking place in the cognitive system? Second, how are items selected from these activated representations to be the focus of conscious awareness? These questions, and the tools that can be used to answer them, will be discussed further in the last section of the paper.

How can attention be used to better understand consciousness?

The study of consciousness has been an important endeavor for scientists and philosophers for many years. The popularity of this endeavor has fluctuated, particularly in the field of psychology. This is primarily due to the rise of experimental methods in psychological research that emphasized the importance of objective, rigorous measurement techniques. This movement brought on a general distrust of experimental techniques that utilized subjective reports of psychological phenomena, such as the method of introspection that served as the predominant approach to studying consciousness. The progression of experimental techniques through refinement and technological advances has led past behaviorism to renewed interest in cognitive research geared towards understanding consciousness.

An important step in conducting research on any psychological construct is to think about its function in human behavior. What is the purpose or utility of consciousness in humans? One way to answer this question is to go back to the assumptions laid out by WM theories. In Cowan's model the focus of attention serves as the seat of consciousness. The focus of attention is a dynamic mechanism that allows people to flexibly adapt to the situation being encountered in their environment. In certain situations it is optimal to hold the maximum amount of information in conscious awareness, while in other situations it is best to isolate a single chunk, minimizing interference from surrounding items. The flexible nature of the focus of attention allows an organism to make these necessary adjustments. Thus, consciousness may serve an adaptive function. This is similar to Baddeley's view of the process by which a limited set of representations are brought into consciousness (Baddeley, 2007). He states that it is "…a particular natural solution to one or perhaps a range of biological problems that has resulted from the process of evolution" (p. 301). The ability to select the most relevant items for further, more elaborate processing is quite useful from a resource conservation perspective, and this process is really an issue of attention.

In many ways, the global workspace theory proposed by Baars (1983) makes similar connections from attention and WM to consciousness. He recently evaluated the predictions that were made by this theory, and how research in the intervening twenty years had addressed these predictions (Baars, 2002). Several of the predictions that have received empirical support are relevant to the present arguments. The first point he makes is that conscious processing allows access to a variety of brain activities. This premise is consistent with the functional nature of the "seat of consciousness" in WM models (e.g., episodic buffer, focus of attention), in that these mechanisms are uniquely capable of holding an integrated set of representations drawn from a multitude of cognitive operations.

A second, related point is that consciousness allows people to process and understand novel information. Another function of the conscious portion of the WM system is to bind multiple sources of input together in order to create novel representations that are necessary for meeting the demands present within a given situation. Importantly, the functional aspects of these regions in the WM system are facilitated by attentional resources distributed by the central executive.

The third relevant prediction stemming from the global workspace theory (Baars, 2002) is that WM function primarily relies on conscious elements. It is true that the portion of the memory system that is most often referred to as "working memory' centers on controlled processes governed by the central executive; however, the other activated portion of the memory system is involved in ongoing cognitive activity that likely influences controlled processing taking place within the WM system. Finally, Baars highlighted an issue that is particularly intertwined with the foregoing discussion; selective attention provides access to the contents of the conscious mind. The focal attention mechanisms present within the WM system may play a pivotal role in drawing preferred cognitive elements into conscious awareness, and should be used as an agent for empirical inquiry into the relationship between attention and consciousness.

What are the unanswered questions pertaining to this issue and what are the tools that can be used to answer them?

1. *How does the activated portion of the memory system influence voluntary, controlled processing without being present within conscious awareness?*

The vast majority of studies that utilize WM paradigms focus on the conscious manipulation and retrieval of stored items. The outcome of this research, stemming from both behavioral and neuroimaging approaches, is typically taken as evidence for the claim that WM function reflects controlled, voluntary processes. Obviously, controlled cognitive operations greatly contribute to performance in traditional laboratory tasks used to measure WM, but reliance on this methodology may underestimate the influence of non-conscious activity.

Alternative approaches can be implemented into memory research to determine if the activated portion of the memory system, that is not available to conscious awareness, influences ongoing controlled operations. For example, Oberauer (2001) used a modified Sternberg paradigm that allowed the detection of multiple components within the memory system. In this experiment, two word lists were presented for memorization, followed by a cue that indicated which list was "relevant" and which could be forgotten. Participants had to make judgments about whether or not recognition probes matched items presented in the relevant list. The results revealed that response time for the recognition decision was a function of the length of both the relevant and irrelevant lists if the probe was presented immediately after the cue. If one second or more had elapsed in between the cue and probe, presentation response times were only affected by the length of the relevant list. Additionally, response times were longer for recognition probes that matched items from the irrelevant list relative to new items, even when a five second delay occurred in between the cue and the probe. The outcome of this research suggests that the activated portion of long-term memory, which is presumably outside of consciousness, can still influence controlled processing.

Neuroimaging techniques also offer a promising window into the potential influence of activated regions of the memory system on ongoing cognitive activity. A great deal of neuropsychological data already stands in support of the view that WM represents an activated portion of LTM (for review see Ruchkin, Grafman, Cameron, & Berndt, 2003), and these techniques could be useful in exploring exactly how the contents of the unconscious mind are used. For example, is there specific brain activity associated with the encoding of previously relevant information also observed during current cognitive activities? Could the content of the previously relevant information be useful in meeting current goals? Does the potential overlap between these representations prove to be a benefit or detriment to processing efficiency?

2. *How is attention used to select information for further conscious processing?*

The idea of consciousness as a "global workspace" that allows us to have access to regions

of neural processing that are otherwise occurring without our awareness has received empirical support (Baars, 2002). Also, the possible neural correlates of this global workspace have been examined (Dahaene & Naccache, 2001). Evidence suggests that connections between the thalamus and the cortex are critical for consciousness. Yet, more specific localization of the global workspace itself has proven to be more difficult, as potential candidate networks of neurons exist that do not explain the functional characteristics of consciousness (Churchland, 2002). Nonetheless, the close relationship between WM and consciousness has been substantiated by the identification of the brain regions subserving them (e.g., a connection between posterior and anterior components that could reflect the connection between the focus of attention in the parietal lobes and the connections to the frontal lobes for executive control; see Cowan, 1995; Baars, 2002). The overlap between neural correlates of attention and consciousness highlights the importance of attention in selecting items for conscious processing.

Although there are instances in which items are selectively drawn into consciousness, there are also situations in which elements of the unconscious mind will shift into consciousness without any voluntary effort. For example, selective attention research has demonstrated that people, especially those with relatively low working memory capacity, often cannot avoid shifting attention away from a selected channel to information they are supposed to ignore if that information is personally relevant (Conway, Cowan, & Bunting, 2001; Kane et al., 2007). Furthermore, there are clearly situations in which it is more plausible, and even advantageous, to allow the automatic processing of the cognitive system to function without interference from controlled operations. In a series of studies, Dijksterhuis (2004b) asked participants to choose among a series of alternatives, in which the features associated with each alternative (e.g., details about apartments) made certain options superior to others. Participants were asked to make their decision either directly after the options were presented, after contemplating the decision for a few minutes, or after completing an unrelated task that impeded the ability to consciously consider the options. The results revealed that participants who had engaged in another activity before making their decision consistently chose the best option relative to the other decision groups. Moreover, engaging in secondary activities after encoding the information relevant to the primary task led to more global, cohesive representations in memory than when time was spent consciously processing the task-relevant information (Experiments 3-5). These findings support the premise that unconscious processing can produce a more desired outcome in certain situations, and maintaining elements within consciousness can interfere with the natural progression of these cognitive operations.

There are a variety of potential reasons why certain disadvantages arise from controlled processing, not the least of which may be the capacity limits placed on the amount of information that can be held in conscious awareness, or the focus of attention (Cowan, 1995; Dijksterhuis & Nordgren, 2006). A discussion of these potential reasons is beyond the scope of this article but it is important to note that actively selecting information for further conscious processing may not always be the best route for achieving one's goals. Further research is needed to understand which situations are best suited for a deliberate selection process, as well as how attention is used to select and draw representations into consciousness.

Conclusion

It is apparent that attention and consciousness are intricately related, and by natural extension, are related to WM as well. The characteristics of our limited capacity system make it necessary for only a small amount of information to be attended to at any given time but the rich connections between the unconscious areas of the brain and that in conscious awareness make

daily activities appear as a connected and fluid experience. The questions of consciousness remain, but cognitive psychologists, philosophers, and neuroscientists are making significant progress towards unraveling these mysteries.

References

Baars, B. J. (1983). Conscious contents provide the nervous system with coherent, global information. In Davidson, R. J. et al., (Eds.) *Consciousness and Self-Regulation* (Vol. 3). New York: Plenum Press.

Baars, B. J. (2002). The conscious access hypothesis: Origins and recent evidence. *Trends in Cognitive Sciences, 6,* 47-52.

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Science, 4,* 417-423.

Baddeley, A. D. (2007). *Working memory: Thought and Action.* Oxford, England: Oxford University Press.

Baddeley, A. D. & Hitch, G. J. (1974). Working Memory. In G. A. Bower, (Ed.) *Recent Advances in Learning and Motivation,* (pp. 47-89). New York: Academic Press.

Baddeley A. D. & Logie, R. H. (1999). Working memory: The multiple component model. In A. Miyake and P. Shah (Eds.), *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control*, (pp. 28-61). Cambridge: Cambridge University Press.

Conway, A. R. A., Cowan, N., & Bunting, M. F. (2001). The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin and Review, 2,* 331-335.

Cowan, N. (1995). *Attention and memory*: *An integrated framework.* New York: Oxford University Press.

Cowan, N. (1999). An embedded process model of working memory. In A. Miyake & P. Shah, (Eds.), *Models of working memory: Mechanisms of Active Maintenance and Executive Control*, (pp. 62-101). Cambridge, UK: Cambridge University Press.

Churchland, P. S. (2002). *Brain-Wise: Studies in Neurophilosophy*. Cambridge: MIT Press.

Dehaene, S., & Naccache, L. (2001). Towards a cognitive neuroscience of consciousness: Basic evidence and a workspace framework. *Cognition, 79*, 1-37.

Dijksterhuis, A. (2004b). Think different: The merits of unconscious thought in preference development and decision making. *Journal of Personality and Social Psychology, 87,* 586-598.

Dijksterhuis, A. & Nordgren, L. F.(2006). A theory of unconscious thought. *Perspectives on Psychological Science, 1,* 95-109.

Kane, M.J., Brown, L.H., McVay, J.C., Silvia, P.J., Myin-Germeys, I., & Kwapil, T.R. (2007). For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. *Psychological Science*, *18*, 614-621.

Koch, C. & Tsuchiya, N. (2006). Attention and consciousness: Two distinct brain processes. *Trends in Cognitive Sciences, 11*, 16-22.

Oberauer, K. (2002). Access to information in working memory: Exploring the focus of attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 411-421.

Oberauer, K. (2001). Removing irrelevant information from working memory: A cognitive aging study with the modified Sternberg task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 978-957.

Ruchkin, D. S., Grafman, J., Cameron, K., & Berndt, R. S. (2003). Working memory retention systems: A state of activated LTM. *Behavioral and Brain Sciences, 26,*709-777.