

How Attention Networks Can Inform Research in Information Systems

Colin Conrad and Aaron Newman¹

¹ Dalhousie University, Halifax, Canada
{colin.conrad, aaron.newman}@dal.ca

Abstract. Attention is a construct that has been pursued throughout the information systems literature. It is also a topic that has been extensively studied in the cognitive neuroscience literature. To our knowledge there has not been any comprehensive work to bridge these two bodies of work. This idea paper introduces the Attention Networks model, which is one of the prominent models of attention in cognitive neuroscience. We also introduce the Attention Network Test, one of the prominent measures of attention networks. We explore two ways that the model can inform information systems research and conclude that there are many other potential ways that the study of attention networks can advance research in information systems.

Keywords: Attention · Attention Networks Test · NeuroIS research methods

1 Introduction

Information Systems researchers have identified a number of contexts where the study of attention is relevant. For example, attentional capacity has been identified as relevant to optimal virtual workplaces [1] or the sorts of ideas that are generated when brainstorming [2]. In the context of NeuroIS research, attentional processes have recently been investigated for the role they play in e-commerce decision making [3] its relationship with affective states in the context of user assistance systems [4], and has been identified as an area of interest among the NeuroIS community [5]. It is likely that attention will continue to be a relevant topic of interest to information systems in the future. However, despite the interest in attention, to the best of our knowledge there has not been comprehensive work describing the role of attention in IS research. Though there is a significant literature in cognitive neuroscience, key findings from this field have not been influential on information systems research to date. In this paper we discuss the Attention Networks model developed by Michael Posner and colleagues [6], one of the dominant attention models in cognitive psychology and cognitive neuroscience. We then propose some ways that this model can inform and extend the understanding of attention in information systems research.

2 The Study of Attention in Cognitive Sciences

Attention is among the most enduring subjects of inquiry in psychology and neuroscience. William James, one of the pioneers of psychology, investigated the phenomenology of attention and identified it as a process to focus on “one out of what seem several simultaneously possible objects or trains of thought.” [7]. Rather than a single mechanism as identified by James however, modern cognitive science identifies attention as a number of cognitive processes that work together to yield the attention phenomenon, and could even reflect different mechanisms for different domains (eg. auditory, visual) [8]. Though there are different models of attention, we will focus on the well-established Posner attention networks model in the context of visual attention [9,10].

2.1 Attention Networks

Attention networks describe the networks of neurons that govern the functions of attention. The original Posner attention model was imagined based on cognitive functions observed by psychologists in the 1970s and 1980s. These accounts distinguish three fundamental functions that are essential to the experience of attention: alerting, orienting and executive control. *Alerting* describes the function of maintaining a high degree of sensitivity to stimuli and is often distinguished from general arousal. *Orienting* describes the process of aligning with the source of sensory signals. *Executive control* describes the resolution of conflict among stimuli, including selecting some stimuli for attentional focus while inhibiting responses to other stimuli. Though each of these functions were envisioned based on research in cognitive psychology, they form the foundation for many ongoing research programs in neuroimaging and are foundational to much of the applied work on attention in clinical applications.

In the original attention networks model, the alerting network was originally identified by observing sustained vigilance in behavioral studies and was later correlated with brainstem activity and networks in the right hemisphere [8]. Knowledge of the alerting functions have significantly expanded since the publication of the original model but have largely corroborated alerting as a distinct network [10]. For instance, the effects of neuromodulator norepinephrine have been studied in monkeys and were observed influencing orienting functions, but not alerting, which supports this distinction [11]. However, in most real-world scenarios, the alerting function is observed in conjunction with orienting, leading some to question the independence of the networks [12]. Nevertheless, alerting is still commonly studied as a distinct phenomenon.

Orienting was originally distinguished by Posner in his works on attentional shifts [8]. In its original conception as a network, orienting functions were observed in association with the pulvinar and superior colliculus. However, more recent work suggests that orienting is more complex and involves multiple brain areas including the dorsal system [10,13,14]. Orienting continues to be a subject of considerable interest among cognitive neuroscientists not least because it governs the fundamental mechanism of feature selection, the process of recognizing visual patterns or relevant visual stimuli. Orienting is often further divided into *overt* and *covert* orienting, which rely on dif-

ferent observations. Where overt orienting is typically associated with eye movements or other overt behaviour in the direction of the attended stimulus/location, covert orienting does not necessarily evoke eye movements or other motor activity towards the attended stimulus/location but nonetheless engages similar neural networks [15-17]. Recent work on orienting networks have continued to explore this overt/covert distinction and its implications for attention networks research [18,19].

Executive control is a function that was originally conceptualized to describe target detection and explain the limited capacity of attention. Models have found this function to be associated with connections between the medial frontal and anterior cingulate cortex. Recent understandings of executive control have expanded on this original conception. The original conception of executive control considered it to associate with focal attention. Recent theories suggest two separate executive control networks, as evidenced by neuroimaging studies which reveal distinct frontoparietal and cingulo-opercular networks [10,20]. Other conceptions of executive control identify it with the same network as working memory or as a component of working memory [21,22] or recognize it as many distinct networks for different domains (ie. visual, auditory) [23]. Though the extension of executive control networks continues to be a live topic of inquiry, the original conception of executive control continues to play a significant role in attention research today. Though the Posner three systems model has been arguably the most historically influential model, there is significant ongoing work in attention networks to move beyond this model, especially in the space of the executive brain. Contemporary models have introduced other networks that have been observed since and have incorporated them into an extended attention networks model [24].

2.2 Measuring Attention Networks Using the Attention Networks Test

Attention networks performance are often measured through neurocognitive tests that are designed to separably tap each of the three independent networks. The Attention Network Test (ANT) is the most prominent example of such a test [25,26]. The ANT measures the three attention networks through a combination of flanker tests, which are tasks designed to test response inhibition, and reaction time from cuing tasks, which were designed to measure attentional shifts [27]. In the ANT, the participants' task is to respond as quickly and accurately as possible indicating the direction of an arrow (left or right). The attention networks are differentially engaged by, on different trials, preceding the target with either spatially informative (orienting) or uninformative (alerting) cues, and by arrows flanking the target that are either congruent (same direction) or incongruent (opposite direction) stimuli flanking the target when it appears (executive control). Differences in reaction time can be used to measure the efficiency of alerting and orienting, while executive control is examined by measuring successful responses to the cues.

Though the ANT is the dominant test to advance the study of attention and population research, it has limitations. In response, researchers have investigated expanded measures to explain functioning of attention networks. Studies of the ANT have found weaker associations between alerting and orienting network scores and other attention

measures such as those used in the Dalhousie Computerized Attention Battery (DalCAB) [24]. DalCAB is an example of a new attention battery, which uses eight reaction time tests to improve on the ANT by introducing additional measures such as vigilance [24]. As research in this field continues to advance, NeuroIS can benefit by observing the advances in neurocognitive tests and adapt them to IS contexts.

2.3 Measuring Attention Networks Using EEG and MEG

Much of attention networks theory has been validated using neuroimaging, notably electroencephalography (EEG), magnetoencephalography (MEG) and functional magnetic resonance imaging (fMRI). Many studies observe correlations between attention task performance, such as the ANT, and the neurophysiological indicators of attention [12,28]. While fMRI research and attention networks is an active area of inquiry and has been demonstrated in the context of attention networks and the ANT [12], there are also common EEG (and consequently MEG) correlates that are observed, particularly with event related potentials, which are short changes in electrical potential on the scalp triggered by neural activity. We introduce two EEG correlates because EEG has been identified as an accessible technology to IS researchers and is applicable to many IS contexts [29], while noting that considerable work has been done on identifying Attention Networks using fMRI and other neuroimaging tools.

The P1-N1-P2 complex is a mandatory response triggered by early attention control mechanisms in the occipital regions of the brain and is sensitive to both visual and auditory stimuli [30]. When a stimulus is detected by the auditory or visual system, this pattern of electrical potentials can be observed at 100-220 ms. Attended stimuli can be observed having higher electrical amplitudes from this response. Early negative electrical potential responses have been found to be associated with alerting and have been observed during the Attention Networks Test [10]. The P1-N1-P2 complex is thus a useful neurophysiological response that can be used to observe alerting and orienting networks in the context of human-computer interactions.

A second EEG component that is often studied in attention research is the P3 component. The P3 response occurs immediately following the P1-N1-P2 response, typically between 250-500 ms, but only in response to task-related, attended stimuli. The P3 is known to be driven by the activation of executive attention and contextual updating in working memory [28,31]. In the context of the ANT, the P3 is evoked during the cuing and can be observed having lower amplitudes depending on attention capacities [28]. Study of the P3 response can thus also be a useful neurophysiological indicator to observe executive functions or dysfunction in IS contexts.

3 Improving IS Measures with Attention Networks

Though there are many potential applications of this research [29], perhaps the most promising contribution of attention networks to the information systems field is in the improvement of IS measures. As mentioned, though alerting, orienting and executive control networks can be identified as separate phenomena, they are often examined in

conjunction. A number of research topics in information systems such as awareness displays [1], visual search in web/e-commerce [32-34], electronic brainstorming [35], and online wait times [36,37] have examined topics where the alerting and orienting networks may play a role in the phenomena observed. The methods used in these works included construct questionnaire measures [32,37], comprehension measures [33] or task success measures [34-37]. These represent constructs that could be examined using neuroimaging to determine the impact of attention networks on the tasks, particularly by observing EEG event related potentials such as the P1-N1-P2 response or the P3. By doing so, we can improve the attention-related IS constructs perhaps most noticeably by adding *specificity* and *temporality* to the measures.

Though we are not aware of any extant work in the information systems literature that leverages the neuroscience of alerting or orienting, some work considers the role of arousal, which has long been noted for having common psychophysiological correlates [8]. Electrodermal activity and EEG oscillatory activity has been employed to observe changes in users' cognitive states and to observe flow, which may have some similarities [38]. Considering orienting networks, notable recent work has been conducted by Léger et al., which [39] established the P3 ERP and eye fixation-related potentials as significant measures in information systems research. These methods reflect the state of the art in overt orienting research [40] and open a new area of inquiry for the field with applications to is research with a visual component. Covert orienting, by contrast, remains a potential topic of interest for IS research involving this type of attention without a visual component. Such questions might benefit by leveraging covert orienting measures such as auditory event related potentials [41].

We anticipate that this line of reasoning presents a larger research project on the topic of attention which has the potential to advance IS and human-computer interaction research. In this paper, we discussed the neuroscience of attention networks, an important concept in the neuroscience of attention that, to our knowledge, has not been addressed in the information systems or NeuroIS literature. We also propose a potential application where attention networks can advance research in information systems. However, we conclude that there are also many other potential applications of the attention literature that remain to be seen. For instance, attention networks could inform the creation of new IT artifacts or could inform the creation of brain-computer interfaces [29]. We anticipate that deeper understandings of attention will not only help advance the field but offers the potential to raise entirely new domains of inquiry into the interaction between humans and information technology.

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