Understanding Attention as a Brain Process Using Biased Competition Model and Visual Psychophysics

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Abstract

No data was used for the manuscript. However, Structured Mind by Sebastian Watzl was notably used for the manuscript.

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Introduction

In "Structuring Mind", a book by Sebastian Watzl, Watzl claimed that attention is not a brain process, but rather attention is a mind process by which one's life comes to have a prioritization structure on several items that, together, constitute one's mental life. The first part of this paper will first define what the brain process view with respect to attention is according to Watzl followed by an elaborate discussion on Watzl arguments against why attention is not a brain process. The second part of this paper will briefly introduce visual psychophysics, address Watzl arguments against the claim that attention is not a brain process through using the Biased Competition Model to build an account and motivate the claim that attention is a brain process and use findings in visual psychophysics as evidence support to help motivate the claim, then conclude with a discussion on future directions of Biased Competition Models within understanding attention, action and consciousness.

Brain Process View

According to Watzl, the brain process view is a view that identifies, explains and understands behavioral, cognitive and mental processes through neuronal mechanisms, processes or properties (Watzl, 2011). For example, in attention, using the brain process view to identify, explain and understand attention would be achieved using at least one neuronal mechanism,

process or property. While Watzl states that it is highly plausible that attention can be explained in terms of neuronal processes, the concern he has with the brain process view is that the brain process view fails to identify attention via some brain process. He argues that given the current knowledge we have obtained through science (vision and spatial attention being the most studied form of attention), it is highly unlikely that there is a neuronal mechanism, process or property that coincides with vision-spatial attention and explains most of its central features (Watzl, 2017). Within Watzl's book of his, he presents both of his main arguments against the brain process view as two kinds of dilemmas. These dilemmas will be thoroughly explained in the next two sections.

Specific Mechanism Dilemma

The first dilemma that Watzl presents against the brain process view breaks down into two kinds of problems. The first kind of problem pertains to how given the current findings on attention, it still seems improbable that one specific mechanism is working in all scenarios in which attention is employed (Watzl, 2017). A potential counterargument that could be used to this was from Alan Allport's article that discussed about the concept of attention and information gate. From that article, information gate would be the mechanism that is working in all scenarios However, Watzl addresses that through stating in Structuring Mind that in the article by Allport, he mentioned how it is challenging to locate a specific information within the brain associated with vison attention and spatial attention. Thus, to see attention as an information gate inside the brain would be problematic as gate keeping is only one of the many mechanisms that underlie attention; in addition to information processing, attention modulates perceptual processing, and affects perceptual acuity, and spatial and temporal acuity.

The second kind of problem pertain to explanation, specifically how there isn't any one specific mechanism can explain most of the central features of attention (Watzl, 2017). To support

and strengthen this problem, Watzl used the article "Selection for Action" by Alan Allport. In that article, Allport points out that for the mechanistic explanations, given the large varieties of attention, it is highly unlikely that one neuronal mechanism can explain negative priming, temporal grouping, task switching, etc. (Watzl, 2011). Allport reaches a similar conclusion to that of Watzl by concluding that there is no one uniform mental operation or computational function to which all attentional phenomena can be attributed. The conclusion made by Allport was made after realizing that (selected) studies of the heterogeneity and functional separability of different components of spatial and non-spatial attentional control led to the idea that attention does not exist. While Watzl does not agree with the idea that attention does not exist, he does, however, agree that there is no one uniform mental operation or computational function to which all attentional phenomena can be attributed. Thus, in using the explanation provided by Allport, it allowed Watzl to reinforce problem of how there isn't any one specific mechanism can explain most of the central features of attention.

General Mechanism Dilemma

The second dilemma that Watzl presents against the brain process is that given our current data and evidence on the brain and neural activities, it is highly unlikely that there is a general type of mechanism (neuronal or computational mechanism) within the brain that can be used to identify attention. He elaborates by stating how what unifies neuronal or computational mechanisms involved in attention is that they are implicated in attention. To support this argument, he uses the argument pertaining to how there isn't any one specific mechanism can explain most of the central features of attention (Watzl, 2017). As there is no one specific mechanism that can explain most of the central features of attention, therefore there exist no general type of mechanism within the brain that can be used to identify attention.

To strengthen his arguments, he uses the case of feature binding mechanisms and biased competition mechanisms, two mechanisms that could be considered as two general type of mechanisms. For the case of feature binding mechanisms, he highlights how not in all cases attention is tied to the processes of feature binding. Thus, feature binding mechanisms cannot explain most of the central features of attention, and attention cannot be identified with feature binding mechanisms. Similarly, for the case of biased competition mechanisms, Watzl highlights how while there are biased competition mechanisms within the brain, that it is not unlikely that all of them have something to do with attention (Watzl, 2011). As numerous biased competition processes operate without attention, therefore biased competition mechanisms cannot explain most of the central features of attention, and attention cannot be identified with biased competition mechanisms.

Biased Competition Model

From the two-general type of mechanisms that Watzl discussed, Biased Competition Model was one of them. Biased Competition Model states that many brain processes compete for resources and for control (Watzl, 2011). According to this model, attention can be identified with a neural competition mechanism that is biased by high-level cognitive inputs: the strength of the competing sensory representations is influenced by feedback from higher brain components that represent a person's goals, interests, emotional state, motivation, etc. (Watzl, 2011). Competition in this context can be seen as incoming stimuli (internal and external) compete for representation in the network of interconnected neural populations that process sensory input to guide thought and action. To get a better understanding of whether attention can be identified with Biased Competition Model, we will further investigate the possibility of it.

Neuronal Competition

In the paper “Neural Mechanisms of Selective Visual Attention” by Robert Desimone and John Duncan, they argued for the neural basis for competition (Desimone & Duncan, 1995). Within the visual field in the nervous system, objects compete for processing within over multiple network cortical visual areas. While information about more than one object may be processed in parallel, information available about any given object will decline as more objects are added to receptive fields (Desimone & Duncan, 1995). This implies that objects must compete for processing in the ventral stream within the brain, and the visual system should use as information it has access to about relevant objects to bias the competition in their favor. This tells us that neuronal competition occurs within the brain, but also that attention can be identified as the (brain) process that determines which sets of available information about any given object will decline as more objects are added to receptive fields, and which will stay consistent as more objects are added to receptive fields.

In the paper “A System-Neuroscience View of Attention” by Christian Ruff, he mentions how neuronal competition may arise, and states that the resolution of neuronal competition is attention. Neuronal competition can arise from stimuli that elicit strong neuronal responses against background noises solely because of their sensory intensity; behavioral goals or expectancy of the observer leading to biases in the sensory competition in a way that favors certain aspects of the visual scene over others; a specialized processing (Mole, Smithies & Wu, 2011). The way winning the neuronal competition, would work would be different in each case. In the first case, a stimulus that elicit strong neuronal responses against background noises solely because of their sensory intensity may win the neuronal competition and dominate the nervous system in a bottom-up approach due to neural responses elicited by them being much stronger than that associated with any other object of the visual scene (Mole, Smithies & Wu, 2011). In the second case, behavioral

goals or expectancy of the observer may lead to biases in the sensory competition in a way that favors certain aspects of the visual scene over others. In the third case, a winning activity pattern from one of the specialized processing modules coming to dominate activity in all other of the network (Mole, Smithies & Wu, 2011). This tells us that neuronal competition occurs within the brain, but also how attention is the resolution to neuronal competition.

Ruff connects Biased Competition Model to winning the neuronal competition by stating that how the model along with the three cases can explain perceptual and attentional phenomena, specifically how neural information processing can favor a specific stimulus. For instance, in the case of psychological states, Biased Competition Model can explain the biasing effects of endogenous attention on the competition between the relevant stimuli. Biased Competition Model can also explain the biasing effects of endogenous attention on neural representation of the relevant stimuli. The role that attention plays on biased competition would be biasing effects on the competition between the relevant stimuli would be to make one stimulus be more focused to the point where the stimulus elicits strong neuronal responses where it wins the neuronal competition; have behavioral goals or expectancy of the observer focused enough to lead to biases in the sensory competition in a way that favors one stimulus over the other(s); focusing on having a winning activity pattern from one of the specialized processing modules coming to dominate activity in all other of the network. In addition, the role that attention would play on biased competition would be biasing effects on the competition between the relevant stimuli would be to make one stimulus be more focused to the point where the stimulus elicits strong neuronal representation where it wins the neuronal competition and becomes prioritized for perception.

What was observed earlier was that attention can be identified through the Biased Competition Model, which is a neural (or computational) mechanism. Here, we find that attention

is brain process working to resolve competition for visual processing and control of behavior. However, prior to immediately concluding that Biased Competition Model can be used to demonstrate that attention is brain process working to resolve competition for visual processing and control of behavior, we must investigate and evaluate research and evidence pertaining to the role of attention. To evaluate the role of attention in neuronal competition, I will investigate a specific research done on attention and the brain, evaluate the findings concluded from the research, then determine whether attention is a brain process that resolves neuronal competition for visual processing. Despite me stating that attention is brain process working to resolve competition for control of behavior, due to the complexity associated with analyzing research on attention, Biased Competition Model and control of behavior, I will not investigate research associated with attention and control of behavior, leaving it open to research and discussion.

Research on Vision and Attention

From basic observation, we know that while our brain is constantly bombarded by internal and external stimulation, at any given moment, we are only aware of a small fraction of this input. Attention is one factor that influences the focus and scope of our consciousness (Kandel et al., 2013). The reason for that was successfully identified by William James, which essentially, he noted that when the brain is confronted with at least two inputs, it does not process those inputs equally (Kandel et al., 2013). To better understand how and why such phenomena occurs, scientists that study the brain heavily conduct studies that involve the performance of subjects on a wide variety of perceptual discrimination and identification tasks. The performance within those studies are faster and more accurate when subjects attend to the right location at the right time. Using different imaging techniques such as nuclear medicine functional imaging techniques and neuroimaging techniques, combined with subjects' performing perceptual discrimination and

identification tasks, scientists were able to discover and get a better understanding of the connection between the brain (specifically neural activities) and attention. Early research on phenomena of visual attention identified two potential mechanisms. The first mechanism perceived attention as operating like a filter to eliminate noise or distractors in the visual field to allow focused processing on at least one location or object (Lu & Dosher, 2014). The second mechanism perceived attention as a process that improves the clarity or improves the representation of the attended object (Lu & Dosher, 2014). While these two mechanisms were only simply ideas that were proposed, researchers within visual psychophysics have further investigated and tested the ideas, which their findings leading to realizations associated with those ideas.

Visual Psychophysics

Visual psychophysics is an area in science that studies the relationship between physical stimulus and how those stimuluses are connected to human performance (Lu & Dosher, 2014). It has played a central role in the understanding of human visual capabilities and the brain, specifically with understanding the relationship between physical stimuli and mental phenomena. Zhong-Lin Lu and Barbara Dosher are two researchers that study visual psychophysics and have conducted experiments to test visual attention and quantify the two mechanisms of attention. From their studies, they proposed that a way to investigate them is through studying the changes in neural response in early visual cortical areas using blood oxygenation level-dependent (BOLD) changes in functional magnetic resonance imaging (fMRI), which through psychophysical mechanisms of attention to visual responses, fMRI can be used to measure the BOLD response to signal stimuli of different contrasts in several visual cortical areas: V1, V2, V3, V3A, and V4 (Lu & Dosher, 2014). Consequently, using fMRI to measure neural responses to signals of increasing contrast in

absence of visual noise can discriminate several different effects of attention in the absence of external noise.

As a result, fMRI investigation conducted by Lu and Dosher discovered that attention does two things (Lu & Dosher, 2014): (1) It increases the responses at all contrasts through a baseline shift in activity; (2) It simplifies the response to contrast, showing a contrast gain with increased responses for intermediate. Their study found an effect of attention on brain responses to visual stimulation that corresponds to stimulus enhancement within the Perceptual Template Model (PTM) framework. The PTM model, first introduced by Lu and Dosher is an observer model for detection and discrimination that defines the relationship between the physical stimulus, the internal representation and the response of the observer (Lu & Dosher, 2014). Their experiment demonstrated evidence for external noise filtering in early visual areas, corresponding to the external noise filtering previously reported in psychophysical treatment versus control (TvC) experiments. This provides a strong interconnected body of evidence in support of the two mechanisms of attention, which their fMRI results specify how these mechanisms are embodied in the internal responses to the contrast stimuli in different visual cortical areas (Lu & Dosher).

Central Features and Mechanisms of Attention

Given the strong interconnected body of evidence in support of the two mechanisms of attention, the first mechanism of attention as operating like a filter to eliminate noise or distractors in the visual field to allow focused processing on at least one location or object, and the second mechanism of attention as a process that improves the clarity or improves the representation of the attended object, the question that remains how the Biased Competition Model can explain the central features of attention. The answer to the question can be addressed into two separate parts, one addressing each mechanism of attention.

Within the first mechanism of attention, it perceives attention as operating like a filter to eliminate noise or distractors in the visual field to allow focused processing on at least one location or object, the main process that takes place is an *elimination process*. The Biased Competition Model works in all scenarios where the first mechanism takes place as it is involved in the elimination process; the model can specifically explain the biasing effects of endogenous attention on the competition between the relevant stimuli that occur during the elimination process. The explanation that the model can provide is that biased effects happen as the brain processes external stimuli with internal stimuli. The elimination process undergoes filtering that has been influenced by feedback from higher brain components that represent a person's goals, interests, emotional state, motivation, etc. Higher brain components that represent a person's goals, interests, emotional state, motivation, etc. are formulated through the subject's experiences, the development of the brain and neural plastic changes that took place throughout the subject's life. What results from the process is that filtering takes place, eliminating what the subject processes as noise or distractors in the visual field to allow focused processing on at least one location or object.

Within the second mechanism of attention, it perceives attention as a process that improves the clarity or improves the representation of the attended object, the main process that takes place is an *enhancement process*. The Biased Competition Model works in all scenarios where the second mechanism takes place as it is involved in the enhancement process; the model can specifically explain the biasing effects of endogenous attention on neural representation of the relevant stimuli that occur during the enhancement process. The explanation that the model can provide is that biased effects happen as the brain processes external stimuli with internal stimuli. The enhancement process undergoes enhancing that has been influenced by feedback from higher brain components that represent a person's goals, interests, emotional state, motivation, etc. What

results from the process is that enhancing takes place, refining what the subject's neuronal representation of the relevant stimuli through prioritizing it for perception.

From both mechanisms of attention, what can be deduced is that the Biased Competition Model can explain most of the central features of attention. To elaborate, we find that the model was able to explain the elimination feature and enhancement feature, two central features of attention. The elimination feature is a distinctive attribute in attention that's concerned with removing (external) noise, sorting, prioritizing and structuring the things that need to be focused, while the enhancement feature is a distinctive attribute in attention that's concerned with refining details on the person or thing that is being attended. Figure 1 is a diagram that shows how attention is processed with respect to the two central features of attention and the Biased Competition Model.

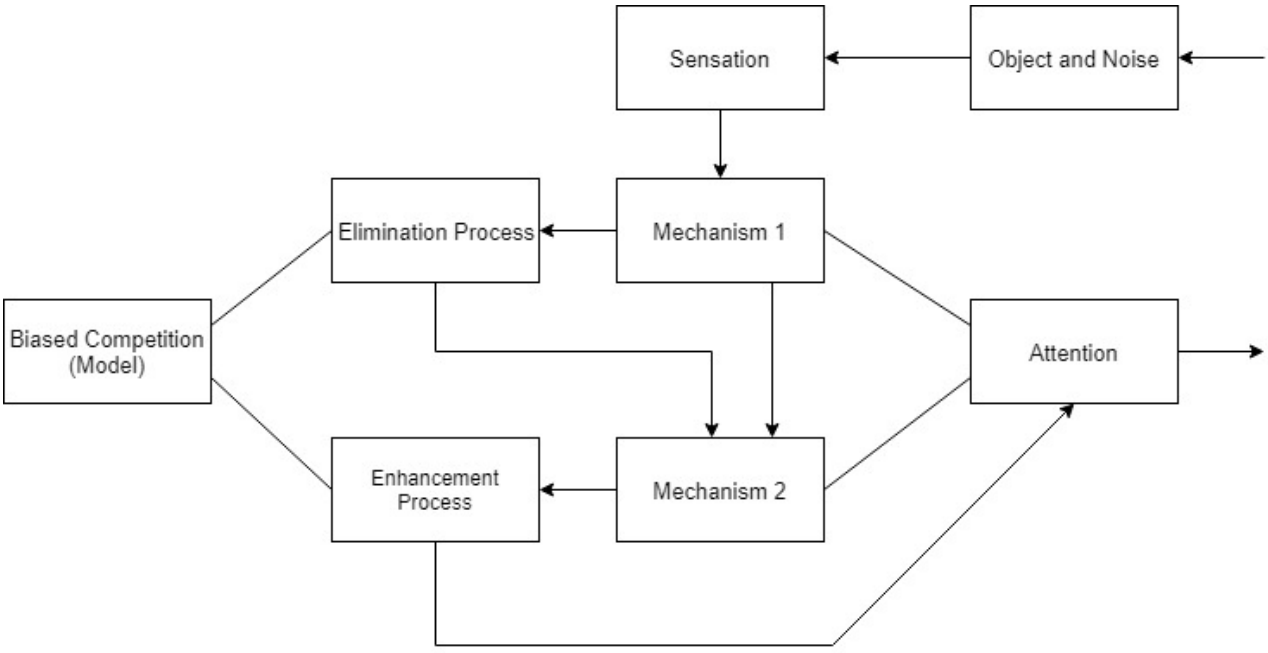

Figure 1: Diagram showing the connection between Biased Model Competition and attention. The input is some object (person or thing) and noise. Mechanism 1 and Mechanism 2 are two mechanisms of attention. Mechanism 1 is the process to filter to eliminate noise (i.e. external noise exclusion), and Mechanism 2 is the process to improve the representation of an attended object (i.e. stimulus enhancement). The output would be the subject's level or degree of attention, which that would be based on what was processed from Mechanism 1 and Mechanism 2.

Attention Scenarios

From the discussion on the Biased Competition Model and the mechanisms of attention, what can be additionally be deduced is that in addition to the fact that the Biased Competition Model can explain most of the central features of attention, another thing about the model is that it is working in all scenarios in which attention is employed. There are three scenarios for which attention is employed. It is employed when: (1) A subject wants to take notice of someone or something; (2) A subject wants to heed, observe or focus on someone or something; (3) A subjects wants to deal with someone or something.

For the case pertaining to attention being employed when a subject wants to take notice of someone or something, as mentioned in the beginning, knowing that it is physically impossible for a subject to attend to everything at once, this same notion can be transferred over to noticing things. That is, it is physically impossible for a subject to notice everything at once. Thus, a subject directly or indirectly selects what they want to notice. The subject can directly take notice of someone or something through voluntarily shift their attention to notice the person or thing. For instance, a person can directly take notice of a car that passes by them by acting voluntarily (or forcefully) to shift their attention to notice the car, the action being seeing. Similarly, the subject can indirectly take notice of someone or something through voluntarily or involuntarily shift their attention to notice the person or thing. The person can indirectly take notice of a car that passes by them by acting voluntarily or involuntarily to shift their attention to notice the car, the action being haphazard glancing. In directly taking notice, one attended to the car more than when they indirectly taking notice. In both cases, there is neuronal competition that occurs competing to decide how the subject will notice the car given that they want to notice the car. The brain process [attention] determines how the subject will take notice through the two mechanisms of attention.

Consequently, the two mechanisms of attention undergo an elimination and enhancement process, respectively, which is backed by Biased Competition Model (see Figure 1). Thus, Biased Competition Model is working in this case where attention is employed.

For the case pertaining to attention being employed when a subject wants to heed, observe or focus on someone or something, we first establish that the subject must first notice the person or thing. As mentioned before, the Biased Competition Model is working in the case where attention is being employed to notice the person or thing. Upon transitioning from noticing the person or thing to heeding, observing or focusing on them, the brain process [attention] determines how the subject will heed, observe or focus on the person or thing through the two mechanisms of attention. Consequently, the two mechanisms of attention undergo an elimination and enhancement process, respectively, which is backed by Biased Competition Model (see Figure 1). As noise gets eliminated or excluded, stimulus enhancement gets refined, leading to an increase in heed, observation or focus. Thus, Biased Competition Model is working in this case where attention is employed.

For the case pertaining to attention being employed when a subject wants to deal with someone or something, we first establish that the subject must first notice the person or thing, then focus (to some degree) on them. As mentioned before, the Biased Competition Model is working in the case where attention is being employed to notice, heed, observe and focus on the person or thing. Upon transitioning from noticing and focusing on the person or thing, the brain process [attention] determines how the subject will heed, observe or focus on the person or thing through the two mechanisms of attention. Consequently, the two mechanisms of attention undergo an elimination and enhancement process, respectively, which is backed by Biased Competition Model (see Figure 1). As noise is more or less completely eliminated or excluded, stimulus enhancement

gets maximized, resulting in an optimal level of focus needed to deal with the person or thing. Thus, Biased Competition Model is working in this case where attention is employed. As the Biased Competition Model is working in all three cases where attention is employed, therefore Biased Competition Model is working in all scenarios where attention is employed.

Results, Data and Evidence

Given our current data, evidence and findings on the brain and neural activities obtained through visual psychophysics, we find that Biased Competition Model is a general type of neuronal or computational mechanism within the brain that can be used to identify attention. The studies conducted by Lu and Dosher established that there is an effect of attention on brain responses to visual stimulation that corresponds to stimulus enhancement within the PTM framework, and evidence for external noise filtering in early visual areas, corresponding to the external noise filtering. Biased Competition Model can be used to identify attention through its effect on brain responses to visual stimulation that corresponds to stimulus enhancement, and through analyzing and evaluating the evidence for external noise filtering in early visual areas, corresponding to the external noise filtering.

Conclusion

As the evidence from visual psychophysics for external noise filtering in early visual areas, corresponding to the external noise filtering, attention cannot be based on a prioritization structuring process as suggested by Watzl. Prioritization does take place within attention; however, it is through the Biased Competition Model that prioritization occurs. This implies that in attention, for prioritization and structuring to happen, biased competition (model), which involves an

elimination process and an enhancement process, must be working. Prioritization cannot happen without competition, elimination, and refinement.

Through visual psychophysics, it was found that the Biased Competition Model can explain most of the central features of attention; the main two central features being (external) noise elimination and stimuli enhancement. There most likely is data and evidence on the brain and neural activities outside of visual psychophysics that can be used to argue that Biased Competition Model is a general type of neuronal or computational mechanism within the brain that can be used to identify attention. Research and studies in neuropsychology is one field that could be investigated for data and evidence to support the argument. While using evidence from visual psychophysics to argue for attention being a brain process working to resolve competition for visual processing, a potential next step can be to use visual psychophysics to gather evidence to argue for attention being a brain process working to resolve competition for control of behavior.

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