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Review Paper

Critical Review of Oscillatory Alpha-Band Mechanisms and the Deployment of Spatial Attention to Anticipated Auditory and Visual Target Locations: Supramodal or Sensory-Specific Control Mechanisms?

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ABSTRACT

This essay is a review of the article by Snigdha Banerjee, Adam C. Snyder, Sophie Molholm, and John J. Foxe, titled 'Oscillatory Alpha-Band Mechanisms and the Deployment of Spatial Attention to Anticipated Auditory and Visual Target Locations: Supramodal or Sensory-Specific Control Mechanisms?' The essay will look into the theory used, methods, results, and the conclusions drawn by the researchers respectively. In addition, the review will also present future research questions that can be tackled based on the findings of this study.

Keywords: *Oscillatory, Alpha-Band Mechanisms, Spatial Attention, Anticipated Auditory*

To begin with, the title of the study is long and difficult to understand in one read. So, in order to break it down, we need to understand the terms in the title separately, starting with 'Supramodal or sensory-specific control mechanisms.' Supramodal spatial attention system is a popular theory of attention which posets a singular control system deploys attention to space irrespective of the sensory system to be attended (Farah MJ, 1989). There are two other alternative accounts of the theory of attention. The first one suggests that spatial attention is deployed independently by the respective sensory-specific control system. This is the sensory-specific attention system (Snigdha Banerjee, 2011). However, several studies of participants with lesions in their right parietal lobe support the supramodal system. This evidence has come from Electroencephalography (EEG) (Eimer M, 2003) (Kerlin JR, 2010) (Stormer VS, 2009) and functional magnetic resonance imaging studies (Macaluso E, 2003) (Shomstein S, 2006) (Smith DV, 2010). The second alternative account suggests that a supramodal system interrelates with individual sensory-specific systems in order to deploy spatial attention. This approach is called 'the interactivity thesis.' (Eimer M V. J., 2002)

Next, we will look into the 'Oscillatory Alpha-Band Mechanisms.' Alpha-band power is the power which is related to the energy at the wavelengths (8-15 Hz) at which the oscillation of alpha waves occur in the brain (Rana KD, 2014). Alpha-band activity is mainly shown to be generated by specific systems in the right parietal lobe associated with the Supramodal

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theory (Eimer M, 2003) (Kerlin JR, 2010) (Stormer VS, 2009). Also, alpha-band activity has been strongly recognised as a source through which visual attention is engaged (Foxe JJ, 1998) (Dockree PM, 2007). However, in this study, the role of alpha-band activity is evaluated in the pre-emptive engagement of both auditory and visual spatial attention. This study was planned to arbitrate the three different accounts of the theory of attention. The aim of this study involves assessing the pattern of the invoking of alpha-band activity for both visual and auditory spatial attention to determine the theory of attention that is most likely to be true (Snigdha Banerjee, 2011).

If the alpha-band oscillatory mechanism is activated for the engagement of attention in the purely auditory spatial task, like the visual-spatial task, it would then provide considerable evidence for the Supramodal principle (Snigdha Banerjee, 2011). However, if the alpha-band mechanism is absent during attention engagement for an auditory spatial task unlike for the visual-spatial task then it would provide evidence for the sensory-specific attention system (Snigdha Banerjee, 2011). There is one more possibility where the alpha-band mechanism is activated for both auditory and visual-spatial tasks but in this case, the alpha-band mechanism would activate in different cortical regions in the brain. This would indicate that the supramodal system is individually coordinating with two different sensory systems. This evidence would support the interactive thesis (Snigdha Banerjee, 2011).

The methods and the materials used in the study will now be looked into. Twenty adults (12 female) were recruited for the study (Snigdha Banerjee, 2011). All the participants were from the psychology department at City College of New York. The data for two of the twenty participants were excluded due to excessive artefact rejection (Snigdha Banerjee, 2011). Their trials recorded a high number of eye blinks. Therefore, eighteen participants (11 female) remained in the study. All the participants had normal vision and hearing (Snigdha Banerjee, 2011).

The experiment was divided into two parts. The first task was a purely auditory spatial task (Fig 1A). The second task was a purely visuospatial task (Figure 1B). The task order is a vital aspect of the experiment (Snigdha Banerjee, 2011). As the primary question in the study is whether the alpha-band oscillations as seen in visual-spatial tasks can also be seen in auditory spatial tasks, it was important to conduct the auditory task first to prevent the participants to form any brain mapping from having the visual task performed first (Snigdha Banerjee, 2011). If the visual task is conducted first, then certain task strategies for handling stimuli in the visuospatial coordinates could be devised by the participants, and these strategies could carry over to the auditory task. This would skew the data for the auditory spatial task (Snigdha Banerjee, 2011).

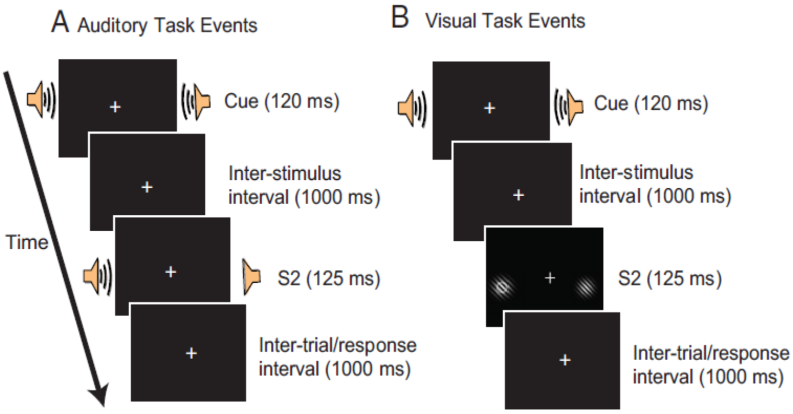

Figure 1

In addition, the manifestation of the alpha-band oscillations has already been established by many studies (Kelly SP, 2005) (Rihs TA, 2009). In this study, the secondary visual-spatial task was conducted to replicate the results of previous studies.

The participants sat in an unlit, sound-proof room. They were fixated on the centre of a cross-displayed computer monitor (Snigdha Banerjee, 2011). The stimulus was presented using the mode of presentation. The speakers were placed to the left and right of the monitor and were completely hidden from the participants via an impervious black curtain in order to prevent any kind of visual mapping from the participants of the speakers. Their eye movements and direction were tracked using an eye-tracker to assure that they were fixated on the monitor alone (Snigdha Banerjee, 2011). A classic system of S1-S2 attention task was used in the study. In such a system, first, each trial consists of a cue (S1), followed by a superseding void preparatory period, and finally, there is a task-relevant second stimulus (S2) (Fig. 1). For S1 cues with specific instructions were used in order to enable the participants to be attentive only on targets at the cued location and suppress information regarding all other stimuli from other locations. As all the uncued stimuli would only serve as distractions from the actual task, subduing them only improved the participant's performance in the task (Snigdha Banerjee, 2011).

The cues for each trial in both tasks were auditory in nature (Fig. 1). The participants were cued to attend either the left or right in a balanced manner. For both the tasks, S2 was presented from the left, right or both speakers with equal odds (0.3). The S2 output in the auditory task was in the form of 'band-delimited noise bursts' (Snigdha Banerjee, 2011). Participants responded by clicking the computer's left mouse button upon detection of S2 containing a gap at the cued location and suspended reactions if not. 'Bilateral trials' (S2 at both speakers) were a part of the design to study the suppression of stimuli at the uncued site (Snigdha Banerjee, 2011) as the participants were asked to only focus on the cued location.

For the visual task, S2 was a 'grey-and-white Gabor patch' that appeared on the monitor (Fig. 1). A Gabor patch is a sine wave strident seen through a Gaussian window (Fig. 2) (Jeremy M. Wolfe, 2015). Gabor patches are widespread stimuli in visual tasks since they have features that counterpart the 'receptive field' properties of neurons in the 'primary visual cortex' (Jeremy M. Wolfe, 2015). The participants, upon interacting with S2 at the cued location, responded with a click of the left mouse button of a computer mouse and suspended reactions if not (Snigdha Banerjee, 2011).

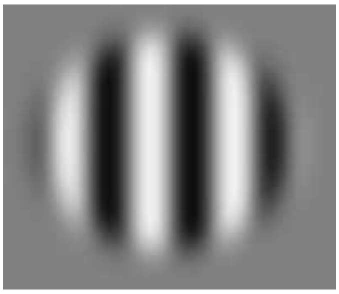

Figure 2

For the analysis of the behavioural data in the study, a repeated-measures ANOVA was used to examine the performance of the visual and the auditory tasks (modality X cue direction). A repeated measure ANOVA was also conducted on the 'reaction time data' for both visual and auditory tasks (modality X cue direction). For the analysis of the electrophysiological data (alpha-band oscillations), the Temporal Spectral Evolution (TSE) method was utilized to examine the alpha-band activity (Snigdha Banerjee, 2011). The Temporal Spectral Evolution enables analysis of the alterations in the 'spectral content' occurring throughout a sensory, cognitive or motor task (Vázquez Marrufo M, 2001).

The results of the behavioural data indicate a Mean (+/-) SD performance for the auditory task to be 78.68 (+/-) 13.57% for cue-left and 72.14 (+/-) 17.55% for cue-right conditions (Fig 3). For the visual task, the Mean (+/-) SD performance was 60.08 (+/-) 23.32% for cue-left and 62.13 (+/-) 26.31% for cue right conditions (Fig 3) (Snigdha Banerjee, 2011).

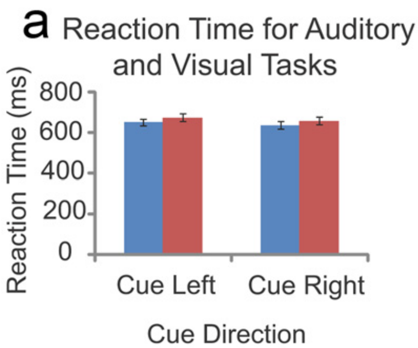

Figure 3

The results of the electrophysiological data were analysed in two stages which were (1) The intention in the first phase was to evaluate the first hypothesis which was whether earlier categorized, spatially explicit, alpha effects would be mutual to both audio-spatial and visuospatial settings. (2) The second phase intended to evaluate if overall attentional distribution processes in the alpha band activity would be common or separable between sensory modalities (Snigdha Banerjee, 2011).

In the first stage, Figure 4 represents 'alpha-band Temporal Spectral Evolution' geographies as a utility for 'cueing conditions' (cue left subtracted from cue right) for both the visual and auditory tasks (600-940 ms after S1). 'Bilateral parieto-occipital' alpha centres are apparent for both sensory systems. It can be valued from the activation pattern of the brain in figure 4 that the locus of the 'alpha-lateralization effects' is highly comparable between the sensory systems (Snigdha Banerjee, 2011).

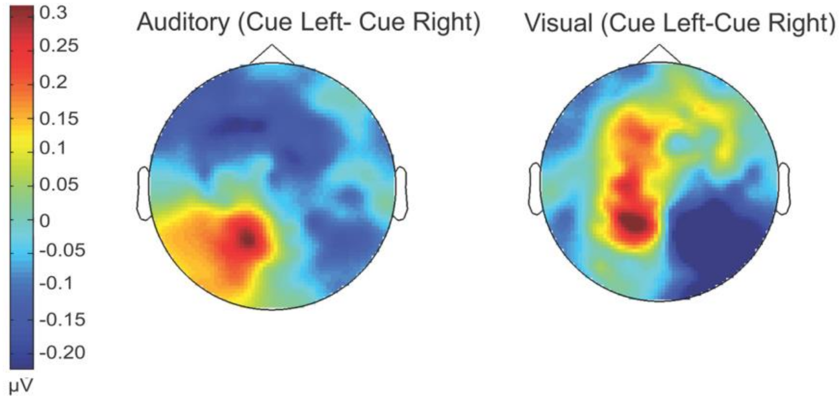

Figure 4

In the second stage, prospective alpha-band locus variances amid the auditory and visual tasks were investigated. The area of the brain observed was the occipital lobe and the parietal lobe. For 700–800 ms after S1 for both tasks, a substantial interaction between modality X region of interest was detected (p = 0.048). The same interaction was detected for the 800-950 ms period as well for both tasks (p = 0.040). For these two phases (700-800 ms & 800-950 ms), 'alpha power' was highest in the right parietal cortex for both auditory and visual tasks. The attention deployment during the auditory task showed the superior lateral distribution in comparison to the visual task (Snigdha Banerjee, 2011). For the 900-940 ms phase, the focus of highest activation of alpha-band power for auditory and visual tasks stayed distinctive, and there was a significant interaction between modality X region of interest. Figure 5 demonstrates that the distinction was clear and determined the different activation regions in the brain for the two tasks during the three phases (700-800 ms, 800-950 ms & 900-940 ms). The white and black circled areas show the different area of activation for the tasks (Snigdha Banerjee, 2011).

The results of this study displayed that the alpha-band mechanism is activated for both auditory and visual-spatial tasks and the alpha-band mechanism activated in different cortical regions in the brain. This indicates that the supramodal system is individually coordinating with two different sensory systems. Therefore, the results of this study support the interactive thesis (Snigdha Banerjee, 2011).

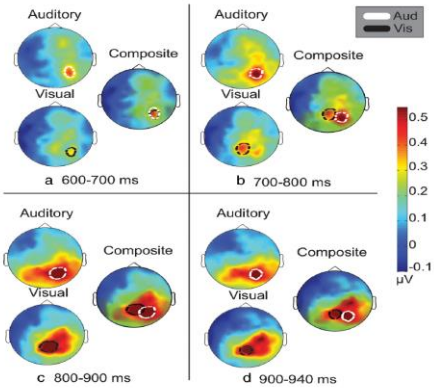

Figure 5

In a formative study, (Farah MJ W. A., 1989) examined the consequence of 'cross-sensory' combinations (auditory and visual sensory) on the attentional detachment capacities of parietal lesion patients. The researchers articulated that, if auditory cues obstructed the following deployment of spatial attention to a visual stimulus, it would provide backing for a 'supramodal role' for right parietal areas in governing spatial attention (Farah MJ W. A., 1989). The results indicated patients displaying impairment in their capacity to disengage attention irrespective of the sensory modality of the preliminary cue (Farah MJ W. A., 1989). Therefore, this study showed evidence of the interactive thesis.

In the study, (Snigdha Banerjee, 2011) found evidence of a feedback mechanism between the superior temporal sulcus and the occipital cortex. After deployment of spatial attention, when all the information is processed, there was evidence of neural activity from the superior temporal sulcus to the occipital lobe (Snigdha Banerjee, 2011). There is no explanation yet for this feedback mechanism. However, future research possibilities certainly lie in determining exactly what is achieved through the feedback mechanism.

One limitation in the design of the study was in the order in which the tasks were designed for every trial. The auditory tasks always came first followed by the visual tasks (Snigdha Banerjee, 2011). The reasoning for this has already been established while talking about the 'method and materials' used in this essay. As the visual task always came second in every task, the participants experienced some degree of fatigue and this showed in their performance as the performance in the visual tasks slightly declined after the first round of tasks (Snigdha Banerjee, 2011). However, this limitation did not have a significant effect on the outcome of the study as those effects were due to genuine neural activity and not a result of fatigue (Snigdha Banerjee, 2011).

CONCLUSION

In conclusion, the results of this study showed that there was a similar alpha-band activation for both auditory and visual-spatial attention. Also, there were topographical differences in the brain activation during alpha-band activation (Snigdha Banerjee, 2011). All this further helps establish the presence of a Supramodal system for attentional deployment. Further analysis also showed the temporal lobe is the control tower (Supramodal system) for both sensory systems (Farah MJ W. A., 1989) (Snigdha Banerjee, 2011).

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Conflict of Interest
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