Published in final edited form as:

Trends Cogn Sci. 2014 September ; 18(9): 447–448. doi:10.1016/j.tics.2014.06.001.

Inferior frontal junction biases perception through neural synchrony

Yaoda Xu*

Harvard University

Abstract

How the primate attentional control network interacts with posterior sensory regions to bias perception is not fully understood. Using magnetoencephalograph supplemented by functional magnetic resonance imaging, a recent study reported that human inferior frontal junction could play a key role in biasing perception through neural synchrony with posterior sensory regions.

Our visual world is filled with a continuous influx of visual information. The ability to attend, select and encode what is most relevant to the task at hand is vital to everyday visual cognition. For example, when driving on a busy street, we need to constantly attend to road signs, moving cars and pedestrians while ignoring a host of other nonessential visual inputs. Decades of cognitive neuroscience research has provided us with rich details of the neural mechanisms mediating attention and selection. In their influential review work, Corbetta and Shulman [1] outlined two parietal-frontal circuits that are involved in the control of top-down and bottom-up visual attention. Later work by Yantis and colleagues [2] highlighted the role of superior parietal lobule (SPL) in initiating attentional switching between different locations, different features of the same attended object and different input modalities. More recently, Xu and Chun [3] showed that goal-directed object representation can be achieved by distinct parietal mechanisms in a two-step process with inferior intra-parietal sulcus (IPS) selecting objects via their locations and superior IPS encoding the detailed features of the selected objects. In recent monkey neurophysiological studies [4][5], neural synchronies among frontal, parietal and sensory regions have been shown to play an important role in attentional modulation of sensory processing. Despite these advances, few research has examined in humans how the attentional control network interacts with posterior sensory regions to bias perception and whether neural synchrony plays a role in this process.

In a recent study, using magnetoencephalograph (MEG) supplemented by functional magnetic resonance imaging (fMRI) to optimize both temporal and spatial resolution, Baldauf and Desimone [6] addressed this critical question. They presented human subjects with two streams of images, with one containing a sequential presentation of faces and the

© 2014 Elsevier Ltd. All rights reserved.

*Corresponding author: Address: 33 Kirkland Street, Room 780, Cambridge, MA, USA, 02138, yaodaxu@wjh.harvard.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

other houses. The two streams were presented at slightly different temporal frequencies to allow each stream to be tagged by a unique frequency. Baldauf and Desimone overlapped the two image streams at the exact same spatial location and asked subjects to either attend the faces or the houses and detect a one-back image repetition in the attended stream. They then used fMRI to localize two sensory regions that show preference to the processing of faces and houses, which are the fusiform face area (FFA) [7] and the parahippocampal place area (PPA) [8], respectively. Baldauf and Desimone also localized a brain region involved in non-spatial attention in inferior frontal junction (IFJ). Using these regions of interests to guide the analysis of MEG signals, they examined the power of MEG signals at the tagging frequency for faces and houses. They found that FFA was more responsive to the face tagging frequency only when faces were attended and, similarly, PPA was more responsive to the house tagging frequency only when houses were attended. Thus, sensory responses in FFA and PPA were modulated by top-down attention according to the task demand. Interestingly, IFJ responded to the tagging frequency of the attended objects regardless of whether faces or houses were attended. In other words, IFJ was synchronized with FFA when faces were attended and PPA when houses were attended (Figure 1). By analyzing the phase lags between IFJ and FFA/PPA, Baldauf and Desimone further discovered that IFJ was leading FFA/PPA with a constant time lag of about 20 ms. The IFJ thus appeared to be the driver of the synchrony. Additional analysis with diffusion tensor imaging confirmed that IFJ is connected to both FFA and PPA, providing anatomical support for its role in biasing perception in posterior regions through neural synchrony.

Baldauf and Desimone [6] thus revealed for the first time how IFJ may participate in attention-biased perception through neural synchrony with posterior regions where the actual sensory signals are contained. These results are consistent with findings from a previous study by Asplund and colleagues [9]. By examining fMRI time courses, Asplund et al. found that IFJ was either coupled with the dorsal attention system in a top-down goal-directed task or ventral attention system in a bottom-up stimulus-driven attention capture task. They concluded that top-down and bottom-up attention are linked together through activities in IFJ, allowing the brain to be flexibly engaged in either type of attentional control. The MEG neural synchrony results from Baldauf and Desimone complement those from Asplund et al. by showing that IFJ can also be flexibly engaged in attentional selection of different objects appearing at the same spatial location. Together, these two studies highlight IFJ's ability to be coupled with different posterior mechanisms to bias perception.

These findings generate intriguing questions that await future research to address. For example, given the role of SPL in initiating attentional switching between different locations, different features of the same attended object and different input modalities [2], how does IFJ interact with SPL when attention is switched from attending to faces to attending to house in Baldauf and Desimone's study [6]? Is SPL the driver of IFJ? Dorsal lateral prefrontal cortex (DLPFC) has been shown to maintain task-relevant information by directing attention to internal representations of sensory stimuli and motor plans that are stored in more posterior regions [10]. How should we understand the unique roles of IFJ and DLPFC during attentional control and how do these two brain regions interact? Additionally, given that both MEG and fMRI provide correlational measures rather than causal connections between brain and behavior, it would be important for future monkey

neurophysiological studies and human transcranial magnetic stimulation studies to test the causal role of IFJ in attentional control and behavior.

Nevertheless, with the combination of different neuroimaging approaches including MEG and fMRI and measuring neural synchrony between different brain regions, the study by Baldauf and Desimone [6] opens up a whole new area of research whereby key questions regarding how attention may modulate perception in the human brain can now be addressed.

Acknowledgments

This work was supported by NIH grant 1R01EY022355 to Y.X.

References

1. Corbetta M, Shulman GL. Control of goal-directed and stimulus driven attention in the brain. *Nat Rev Neurosci.* 2002; 3:201–215. [PubMed: 11994752]
2. Serences JT, Yantis S. Selective visual attention and perceptual coherence. *Trends Cogn Sci.* 2006; 10:38–45. [PubMed: 16318922]
3. Xu Y, Chun MM. Selecting and perceiving multiple visual objects. *Trends Cogn Sci.* 2009; 13:167–174. [PubMed: 19269882]
4. Buschman TJ, Miller EK. Top-down versus bottom-up control of attention in the prefrontal and posterior parietal cortices. *Science.* 2007; 315:1860–1862. [PubMed: 17395832]
5. Gregoriou, et al. High-frequency, long-range coupling between prefrontal and visual cortex during attention. *Science.* 2009; 324:1207–1210. [PubMed: 19478185]
6. Baldauf D, Desimone R. Neural mechanisms of object-based attention. *Science.* 2014; 344:424–427. [PubMed: 24763592]
7. Kanwisher N, et al. The Fusiform face area: A module in human extrastriate cortex specialized for the perception of faces. *J Neurosci.* 1997; 17:4302–4311. [PubMed: 9151747]
8. Epstein R, Kanwisher N. A cortical representation of the local visual environment. *Nature.* 1998; 392:598–601. [PubMed: 9560155]
9. Asplund CL, et al. A central role for the lateral prefrontal cortex in goal-directed and stimulus-driven attention. *Nat Neurosci.* 2010; 13:507–512. [PubMed: 20208526]
10. Curtis CE, D'Esposito M. Persistent activity in the prefrontal cortex during working memory. *Trends Cogn Sci.* 2003; 7:415–423. [PubMed: 12963473]

Figure 1.

Interaction between IFJ and FFA/PPA. When showing two overlapping streams of faces and houses, the human IFJ was synchronized with FFA when faces are attended and PPA when houses were attended. Phase lags between IFJ and FFA/PPA revealed that IFJ was leading FFA/PPA with a constant time lag of about 20 ms. This suggests that IFJ may be the driver of the synchrony, allowing it to be flexibly engaged in attentional selection of different objects appearing at the same spatial location. From [6]. Reprinted with permission from AAAS.