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Current controversies

Divided opinions on the split fovea

Andrew W. Ellis[a,b,*,1], Marc Brysbaert[c,1]

[a] Department of Psychology, University of York, UK
[b] York Neuroimaging Centre, University of York, UK
[c] Department of Psychology, Ghent University, Belgium

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For anyone new to this debate, we should begin by explaining the *split fovea theory*. That theory maintains that the human fovea is divided sharply down the middle so that any visual stimulus falling to the left of fixation is projected initially to the right cerebral hemisphere, while any visual stimulus falling to the right of fixation is projected initially to the left cerebral hemisphere. If a stimulus straddles fixation, the parts that fall to the left and right of the point of fixation will project initially to the right and left cerebral hemispheres respectively. Each hemisphere will 'see' only part of the stimulus, and transfer of information between the hemispheres will be required to create a representation of the complete stimulus. The same considerations apply whether the stimulus is an object, a face, or a written word. Split fovea theory contrasts with the more traditional *bilateral projection theory* according to which the fovea projects simultaneously to both cerebral hemispheres. On this view, as long as a stimulus is contained within the fovea, both hemispheres will see it in its entirety, and there will be no need for interhemispheric transfer.

Our own research has concentrated on exploring the implications of split fovea theory for understanding visual word recognition (Ellis & Brysbaert, 2010). Arbitrating between the split fovea theory or the bilateral projection theory matters when it comes to explaining human word recognition. Split fovea theory proposes that when fixation falls upon a written word in reading, those letters that fall to the left of the fixation point project initially to the right cerebral hemisphere while those letters which fall to the right of fixation project to the left hemisphere. It is assumed that the two parts of a word must be brought together if it is to be recognised. Some theories propose that there is transfer of information between the hemispheres in both directions, so that both hemispheres acquire a complete representation of the word and process it further (e.g., Shillcock, Ellison, & Monaghan, 2000). Others theories propose that transfer is asymmetrical, with visual information being gathered into the language-dominant hemisphere (which for most people is the left hemisphere) for further processing (e.g., Whitney, 2001).

If the split fovea account of word recognition is correct, then influential cognitive, computational and neurological theories of reading will require serious modification. For example, proponents of the split fovea theory have argued that the processing of those portions of centrally fixated words may project to the left or the right hemisphere reflects the properties of the hemisphere which first handles that part of a word. Thus, various studies have suggested that effects on visual word recognition of factors like letter length, neighbourhood size and case alternation depend which hemisphere initially processes a portion of a word (Ellis, 2004; Ellis & Brysbaert, 2010). Other studies have derived and tested predictions concerning the 'optimal viewing position' for words in participants with left or right hemisphere language dominance (Brysbaert, 1994; Hunter, Brysbaert, & Knecht, 2007) or EEG responses to Chinese words with different characteristics (Hsiao, Shillcock, & Lee, 2007).

Jordan and Paterson (2009) published a critique of split fovea theory and the evidence held to support it. They argued that the balance of evidence continues to support the bilateral projection theory. We provided our own review of the evidence in Ellis and Brysbaert (2010), explaining why we continue to believe that the split fovea theory is worthy of serious consideration and, in the process, addressing various points raised by Jordan and Paterson (2009). Jordan and Paterson (2010) have generated a short response to Ellis and Brysbaert (2010). We welcome Jordan and Paterson's (2009, 2010) commentaries. All scientific theories are provisional: critical analyses help to sharpen theories and refine evidence (cf. Van der Haegen, Drieghe, & Brysbaert, 2010). But we have read Jordan and Paterson's (2010) response carefully and cannot find any points of substance that were not previously raised by Jordan and Paterson (2009). We therefore refer readers to Ellis and

* Corresponding author at: Department of Psychology, University of York, Heslington, York YO10 5DD, UK. Tel.: +44 1904 433140; fax: +44 1904 433181.
E-mail address: awe1@york.ac.uk (A.W. Ellis).

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Brysbaert (2010) for detailed statements of our position on these issues.

We would like to take this opportunity to make three brief points. The first point is that, as noted above, split fovea theory does not only apply to visual word recognition. For example, the right cerebral hemisphere is dominant as far as most aspects of face processing are concerned, leading to left visual field advantages in tasks such as judging the identity, gender or emotion of faces (Haxby, Hoffman, & Gobbini, 2000; Yovel, Tambini, & Brandman, 2008). The left hemisphere appears, however, to be dominant for the more linguistic task of processing the speech information that comes from the shape and movement of the lips and face. 'Lip reading' tasks therefore yield a right visual field advantage in contrast to the left visual field advantage shown by most face processing tasks (Campbell, 2008). Split fovea theory predicts that when a face is viewed centrally, within the fovea, the left side will project to the right hemisphere and should therefore be more important when it comes to determining the identity, gender and expression of the face. The right side will project to the left hemisphere and should therefore be more important when it comes to determining what the person is saying. Bilateral projection theory predicts no left–right differences for foveated faces. There is a tradition of research using 'chimeric' images composed of the left side of one face and the right side of another. When such stimuli are presented under relatively free viewing conditions, the left side dominates as far as the perception of identity, gender and expression are concerned, while the right side dominates for lip reading (Ashwin, Wheelwright, & Baron-Cohen, 2005; Bourne, 2008; Butler et al., 2005; Butler & Harvey, 2006; Campbell, 1986; Coolican, Eskes, McMullen, & Lecky, 2008). These studies were not conducted with split fovea theory in mind, and would need to be repeated with purely foveal stimuli, eye movement monitoring, etc., but they offer a degree of hope that split fovea predictions might apply to faces as well as words.

Our second point brings us back to reading. It is to note that interhemispheric transfer is not the only way to bring the left and right halves of a word together in the same hemisphere. Imagine someone reading the phrase *split fovea theory* in a passage of text. The first fixation might fall between the *p* and the *l* of *split*. The effective visual field when a reader fixates a line of text is such that processing would be expected to extend to the first few letters of *fovea* (Rayner, 1998, 2009). This means that the initial letters of *fovea* will have been processed within the right visual field and projected to the left hemisphere when the eyes were fixated on *split*. The next fixation might take the eyes to a position between the *o* and the *v* of *fovea*, placing *fo-* in the left visual field and *-vea* in the right. All that the left hemisphere needs to do in order to create a unified representation of *fovea* is to retain the letters *fo-* from the previous fixation and combine them with the letters which project directly to it on the current fixation (*-vea*). The need for interhemispheric transfer is eliminated. Further research is needed to distinguish the relative contributions of interhemispheric transfer during a fixation versus integration across fixations to solving the problems created by a split fovea.

Which brings us to our third and final point. Brysbaert (1994, 2004) has argued that the split fovea theory is very easy to test. Split fovea predicts differences in the location of the 'optimal viewing position' in words for people with left and right hemisphere language dominance; the bilateral projection theory does not. All one has to do, therefore, is compare those two groups of individuals on tasks involving foveal word recognition (cf. Hunter et al., 2007). If Jordan and Paterson have reasons to doubt the conclusions reached by Brysbaert (1994, 2004) and Hunter et al. (2007), the easiest way to settle the issue is to repeat those studies using whatever stimulus parameters and fixation controls they consider necessary. We await the results of those replications and extensions with interest.

The split fovea theory and the bilateral projection theory are both theories. The fact that one has been around longer than the other is of no consequence when it comes to arbitrating between them. They cannot both be right, though they may well both be wrong. Rhetoric is irrelevant: all that matters is the evidence.

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