



# I agree: binocular rivalry stimuli are common but rivalry is not

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I have recently argued that binocular rivalry (BR) is uncommon, despite discrepant monocular images being frequently encountered in daily life, because the images of proximate obstructions tend to be persistently suppressed from awareness by the better-focused images of objects near fixation (Arnold, 2011). This has the functionally adaptive consequence of enhancing the visibility of fixated objects. O'Shea has tapped his' encyclopedic knowledge of BR and come up with two facts on which, he suggests, this proposal falls short (O'Shea, 2011). I think this reflects a misapprehension, and it comes down to a perennial question, how long is a piece of string?

Readers should note the language above and in the original paper. I have argued that BR is uncommon, that exposure to unmatched monocular images in daily life does not typically result in BR, that images of proximate obstructions tend to be persistently suppressed from awareness. I would not, however, like to suggest that BR can never happen in daily life, nor that the images of proximate obstructions will invariably be eternally suppressed. This prudence was motivated by the very facts that O'Shea has now helpfully emphasized. But I should stress that these facts are entirely consistent with my conclusions.

So how long is persistent? A universal estimate is impossible assuming individual variability in the rate and extent of adaptation, so I will adopt a boredom threshold. Pick a word on this page and stare at it fixedly while placing a finger a couple of centimeters (perhaps an inch to the metrically challenged) in front of one eye. Wait. Wait some more. Keep waiting. I suspect the vast majority of readers will give into boredom before the word fades from view to be replaced by a blurry image of a finger. BR, as characterized by alternating perceptions, will not have begun because one of the two images (your blurry finger) was persistently suppressed. It is possible that this status is not eternal, but if it exceeds your boredom threshold I would regard it as persistent.

In real life suppression would usually only need exceed 333 ms (the typical interval between gaze shifts, see Otero-Millan et al., 2008). I suspect suppression of your finger in the above circumstances would persist for at least two orders of magnitude longer than that, sufficient for you to gaze into a loved one's eyes, with just one of your own, for a period that becomes awkward. Such suppression may well be eternal for many, but the requisite experiment to test this seems impractical.

What of the points raised by O'Shea? First he reminds us that I am far from the first to point out that images with much greater signal strength can persistently suppress awareness of weaker images. This has been referred to as "permanent suppression" (see Ridder et al., 1992; Ooi and Loop, 1994). Well no conflict there. He then points out that if one waits long enough a very blurry image can suppress awareness of a focused image (Levelt, 1968; Fahle, 1982, 1983; Arnold et al., 2007), and that some people can even experience BR by simply closing an eye (eventually the visible scene apparently rivals with an impression of darkness from the closed eye, see George, 1936). So how long is that piece of string? Suffice to say that in daily life the suppression of proximate obstructions is of sufficient duration to enhance the visibility of fixated objects over selective obstructions and to ensure that BR is seldom, if ever, experienced.

Readers should also consider that a simple demonstration with your own finger might better indicate how persistent suppressions of selective obstructions can be than published papers on blur and BR. The physical characteristics of a defocused retinal image are difficult to emulate, and studies that have simply added Gaussian blur to rival images fail to do so (Arnold et al., 2007). Better attempts to mimic optical blur may not have approached the magnitude of blur characteristic of selective obstructions of one eye (Fahle, 1982, 1983). When studying visual phenomena one should not ignore the evidence of one's own eyes.

So why should BR ever happen in daily life? In answer I am going to launch into a discourse on the effects of Troxler (1804) fading and sensory adaptation, and how these interact with eye movements. This should be very familiar to most BR researchers, so if you want to skip ahead four paragraphs, feel free.

Occasional reports of BR in daily life are related to an apparent fading of visual input that can be apparent when one maintains steady fixation, a phenomenon known as Troxler (1804) fading (see <http://en.wikipedia.org/wiki/File:Lilac-Chaser.gif> for a demonstration). In the extreme, if retinal images are completely stabilized the entire scene can seem to fade to gray. Troxler fading is disrupted by either large voluntary (Otero-Millan et al., 2008) or slight involuntary (Martinez-Conde et al., 2006) eye movements. Both dictate that images are almost never entirely stable on the retina for any appreciable time and thereby disrupt adaptation, the oft-cited cause of both Troxler fading (Martinez-Conde et al., 2006) and dominance changes during BR (Blake et al., 1990, 2003; Carter and Cavanagh, 2007; Alais et al., 2010).

It is interesting to note that Troxler fading is more apparent in peripheral vision. It is believed this happens because involuntary eye movements are less effective at disrupting adaptation by changing the receptive fields used to encode input in peripheral vision (where receptive fields are relatively large) than at fixation (where receptive fields are small). Shifting input from an adapted into an unadapted cell's receptive field can bring about a sudden change in relative signal strength (Georgeson, 1984). As this would happen less frequently in peripheral vision, it may contribute to the slower rate of BR there than at fixation (Blake et al., 1992).

Because of Troxler fading and adaptation, an initially strong signal can become weak and thus begin to rival with other weak signals. This is entirely consistent with my

proposal. Not only did I discuss the effects of adaptation at some length in the original article, and mention the importance of involuntary eye movements, but elsewhere colleagues and I have argued that the two most successful protocols for using binocular masking to persistently suppress awareness (Tsuchiya and Koch, 2005; Arnold et al., 2008) owe their efficacy to disrupting adaptation, thereby ensuring that masks retain a higher relative signal strength (see Arnold et al., 2008).

O'Shea has also pointed out that approximately equally blurred images are often encountered in the visual periphery, and that these might be subject to slow BR that is unnoticed due to inattention. At this juncture I would like to note that attention has been described to me as the Psychologist's weapon of mass explanation (D. Burr, personal communication), not because I think this point is particularly pertinent, but I do think it is amusing. On a more serious note, this suggestion poses no problem for my functional account. Inattention to peripheral stimuli might further contribute to BR being uncommon, but this would be irrelevant to my arguments concerning how suppressing awareness of proximate obstructions serves to facilitate visibility near fixation.

In a concluding statement O'Shea suggests that perceptual suppressions of proximate obstructions are consistent with what we know of BR and therefore pose no challenge to theory. To some extent I agree. I regard my contribution as being along the lines of pointing out that we all have a rather large appendage in front of our faces, but it is difficult to see the side of one's nose as it usually appears as a transparent thing, suppressed from awareness by the images of more distant better-focused objects. This, of course, is entirely consistent with a huge amount of BR research and with models of BR for which the concepts of signal strength and adaptation are central. My suggestion is simply that perception during BR is resolved in favor of the instantaneously higher strength signal, and that in daily life this has the functionally adaptive consequence of enhancing the visibility of distant fixated objects. I regard this as a very conservative proposal, but one which strongly

implies that BR is driven by an inherently visual operation, and thus not by a more abstract process designed to deal with perceptual ambiguity (Andrew and Purves, 1997; Leopold and Logothetis, 1999; Sterzer et al., 2009).

In conclusion, O'Shea has argued that:

- The tendency for images of proximate obstructions to be persistently suppressed by the focused images of objects near fixation is consistent with what we know about BR.
- Different images, approximately matched in terms of signal strength, are common in the periphery of vision, and this may result in slow unnoticed BR. Unmatched images corresponding with fixation, however, are almost invariably unequal in terms of signal strength, and this has predictable consequences for BR.
- Movement of the eyes is also an important factor in preventing BR in daily life.

All of these points are in perfect harmony with my proposal that BR is driven by an adaptation that enhances the visibility of distant fixated objects over that of more proximate obstructions.

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