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Fixation on fixation impedes cognition: Reply to Kohly and Ono

ALEXANDER D. LOGVINENKO[1] and ROBERT M. STEINMAN[2]

[1] *School of Psychology, Queen's University of Belfast, Belfast BT9 5BP, UK*
[2] *Psychology Department, University of Maryland, College Park, MD, USA*

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This reply is confined to discussing the three major claims of Kohly and Ono's Commentary (2002) that are essential for supporting their criticism of our work. Their claims are unwarranted. Our discussion should permit the reader to reject these claims in their entirety. The three critical claims are:

1. 'the perceived distance of the illusory wall is not stable but varies with initial fixation'. (Kohly and Ono, 2002, p. 4.)
2. 'the inference made by Logvinenko *et al.* (2001) cannot be made conclusively from a real stimulus situation and, in turn, from their corresponding illusory situation'. (Kohly and Ono, 2002, p. 3.)
3. 'The stability (i.e. the apparent locations of the fused and non-fused elements remaining fixed) of the illusory wall found in Logvinenko *et al.*'s (2001) study is analogous to the stability of the visual world we experience in daily life'. (Kohly and Ono, 2002, p. 5.)

First, the wallpaper illusion *only requires* a fixation point when the stimulus is viewed for the first time. The fixation point helps the observer control his initial vergence eye movements. The provision of a fixation point to facilitate establishing the wallpaper illusion does not mean that this illusion requires a fixation point. With only very limited practice, observers have no difficulty perceiving the illusion without a fixation point. This has been known at least since Logvinenko and Sokolskaya (1975). It was pointed out again more recently by Logvinenko and Belopol'skii (1994). These two papers also established the fact that completely naïve observers *always* localise the illusory grid at the distance defined by the following equation irrespective of the initial fixation position:

$$I = Ab/(b - a), \tag{1}$$

where I is the predicted illusory distance, that is, the distance from the observer to the plane at which the illusory rods are perceived; A is the real (physical) distance from the observer to the grid; a is the horizontal distance between adjacent rods of the grid; and b is the observer's interpupilary distance.

It should be kept in mind that the illusory grid is localised at the predicted distance given by equation (1) only when the monocular images are fused and the rods look like real solid objects. Before fusion is achieved and the illusion perceived, the localisation of the rods is not certain. At this time the diplopic images of the rods may be perceived as either closer to, or farther from, the observer than what would be predicted by equation (1).

Note that the predicted distance (1) corresponds to what is usually referred in the literature on binocular vision as the first level of the Keplerian projection, e.g. Howard and Rogers (1995, p. 43). However, it is possible to fuse the ith left monocular image with the $(i + k)$th right monocular image. In this case, the rods will be localised at the kth level of the Keplerian projection. We call the integer $k = 1, 2, \ldots$ an *order* of the wallpaper illusion. It is easy to generalise equation (1) to predict the illusory distance for the wallpaper illusion of the kth order: a horizontal distance between the ith and $(i + k)$th rods should be put as parameter a in equation (1).

Generally, it takes some effort to fuse the monocular images at the second level of the Keplerian projection, i.e. to establish a wallpaper illusion of the second order, to say nothing of the still greater effort required to establish the third and higher orders. A physical point of fixation is often used to help observers, especially those who are naïve, to place the point of intersection of their visual axes where it must be for the initial fusion of the ith and the $(i+k)$th monocular images ($k > 1$). Different orders of the wallpaper illusion require that the fixation point is placed at a different distance, specifically, at the distance defined by equation (1). This requirement may lead to the superficial conclusion that the wallpaper illusion 'varies with initial fixation' as it did Kohly and Ono in their claim 1 above.

Note, however, that neither the presence of a physical fixation point, as such, nor a particular position of the point of intersection of the visual axes, are necessary for retaining the illusion after it is established. The illusory grid always localises at only one of the levels of the Keplerian projection, the level determined by equation (1), regardless of the vergence angle. In other words, the illusory grid is *never* localised in the space *between* the levels of the Keplerian projection. This has been known from introspective (i.e. psychophysical) observations for a very long time. Logvinenko *et al.*'s (2001) experiment established this fact behaviourally by showing that appreciable changes of vergence angles do not affect localization in the wallpaper illusion.

Next note that the dependence of this illusory shift on the order of the wallpaper illusion, itself, can be handled by both the vergence (oculomotor) and disparity (stereoscopic) explanations of the wallpaper illusion. Note, however, that our finding that the wallpaper illusion is not affected by appreciable changes of vergence angles, within the range between two adjacent levels in the Keplerian projection, supports only the disparity (stereoscopic) explanation. It effectively rules out the vergence (oculomotor) alternative.

Note also that the claim that the wallpaper illusion depends on initial fixation position could be justified *only* to the same extent as, say, a claim that stereopsis depends on initial fixation position. Indeed, it is well known that one can fuse stereograms without a stereoscope by adjusting one's vergence eye's movements. In this case, placing a fixation point at a proper distance helps a lot. However, it has been known since the classical experiment of Dove (1841) that vergence eye movements are not necessary for stereopsis because stereopsis can be established with exposures too brief to permit any eye movements. The Logvinenko *et al.* (2001) experiment actually supports a similar conclusion. We showed that vergence eye movements are not required for establishing or for preserving the wallpaper illusion. We also showed that a fixation point was not necessary, contrary to what Kohly and Ono claimed.

As to inconclusiveness of the inference made by Logvinenko *et al.* (2001), this claim (2 above) rests upon the inconclusiveness of Kohly and Ono's 'thought experiments', not on anything we did or said. They conclude from their 'Thought-Experiment 1' that one cannot draw conclusions about the role of vergence in the perception of distance in the three conditions they describe (Kohly and Ono, 2002, p. 7). We could not agree more with Kohly and Ono that their 'thought experiments' *cannot* lead to conclusions about the role of vergence in the perception of distance. They also *cannot* lead to the conclusion that vergence *is* a cue to distance. Their thought experiments are interesting, perhaps even ingenious, but they are *not* relevant to the issue. Kohly and Ono believe, erroneously, that 'the condition of Logvinenko *et al.*'s study . . . conceptually corresponds to condition (b) in Thought-Experiment 1' (Kohly and Ono, 2002, p. 8). They are misled by the fact that it is possible to construct a real grid whose proximal stimulus will be equivalent (at least 'conceptually') to the illusory grid. In their words, 'What is the value of the wallpaper illusion, if its proximal stimulus can be reproduced with a 'real' wall'? (Kohly and Ono, 2002, p. 8). Note that there is more than one 'real' grid that can produce the same proximal stimulus we used in our experiment. Every perception textbook worth its salt points out that a stereo-pair consisting of an array of identical items (e.g. dots, rods, etc.) must be ambiguous because in every Keplerian plane, there is a distal-stimulus configuration that corresponds to this stereo-pair. Likewise, the repetitive grid we used to produce the wallpaper illusion is ambiguous. In every Keplerian plane, there is a ghost grid that can be implemented as a physical grid, which has the same proximal stimulus (i.e. its retinal projection) as the real grid. The interesting question is why the visual system normally chooses the real grid.

Why don't we always see 'ghosts'? Even more intriguing is why do we sometimes see a ghost grid when the wallpaper illusion is perceived? One answer might be that we see the Keplerian configuration, which is closer to the vergence plane, that is, the plane where the visual axes intersect. We tested this possibility in our experiment, and concluded that this was not the reason because we found that it was possible to experience the illusion when the visual axes intersected much closer to the plane of the physical grid than to the plane at which the illusory rods appeared.

It should be kept in mind, however, that there is a limit as to how much closer than the plane of the physical grid the visual axes can intersect, while the illusion is preserved. The illusion will be lost if the eyes converge too much, i.e. if the vergence angle is too large. Hence, it is wrong to say, as Kohly and Ono do, that all we showed is that 'once obtained, the wallpaper illusion remains stable despite changes in eye position'. (Kohly and Ono, 2002, p. 2.) This is not what we reported. We actually found that the illusory localisation of the grid did not vary with the vergence angle *until* the intersection of the visual axes got too close to the plane of the physical grid. When it got too close, the illusion was lost. This fact undermines Kohly and Ono's claim that 'Just as the inference that vergence information is not a cue to distance cannot be made from the stability of our everyday visual experience, nor can it be made from the finding of Logvinenko *et al.* that the wallpaper illusion remained stable'. (Kohly and Ono, 2002, p. 6.) The stability of the visual world (i.e. the independence of the apparent localisation of objects from the eye movements used to examine them in three dimensions) is a completely different phenomenon than the relative robustness of the wallpaper illusion demonstrated in our experiments. After all, the wallpaper illusion *is* an *illusion* in the true meaning of this word, that is, it is a failure of *veridicality*. The stability of the visual world despite eye movements (versions or vergences) is an entirely different phenomenon. It is an example of an important perceptual *constancy*. In other words, during the wallpaper illusion we perceive the distance to the rods incorrectly, that is, we do not see them where they really are. For this reason, Kohly and Ono's suggestion that 'the vergence and version eye movements made in their hypothetical experimental situation provide reafferent information, which updates the visual system, confirming that the eyes have moved and not the illusory wall' (p. 6) is not convincing because, if this were to be the case, reafferent information should prevent, rather than cause, the wallpaper illusion. If reafference is the basis of constancy, it can hardly also be responsible for the failure to achieve constancy, which is precisely what happens when we speak of the wallpaper *illusion*.

We conclude by reminding the reader that: (i) our recent paper provided a very simple demonstration that the wallpaper illusion is not caused, or influenced appreciably, by vergence eye movements, (ii) we have presented strong arguments against Kohly and Ono's explanation of our results, which are based on reafferentation, and (iii) Logvinenko and Sokolskaya (1975) and Logvinenko and Belopol'skii (1994) had shown earlier that two illusory grids, localised at two different positions in space, could be observed at the same time provided the grid producing the illusion was aperiodical. This demonstration, supported by our recent eye movement paper, should be sufficient to reject the hitherto classical oculomotor explanations of the wallpaper illusion — an explanation that has been repeated frequently in the perception literature since it was introduced by Bishop Berkeley in 1709.

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