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Eye rivalry and object rivalry in the intact and split-brain

Kay L. Ritchie^{a,*}, Rachel L. Bannerman^a, David J. Turk^b, Arash Sahraie^a^a School of Psychology, University of Aberdeen, Aberdeen AB24 3FX, Scotland, United Kingdom^b School of Experimental Psychology, University of Bristol, Bristol BS8 1TU, England, United Kingdom

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ABSTRACT

Both the eye of origin and the images themselves have been found to rival during binocular rivalry. We presented traditional binocular rivalry stimuli (face to one eye, house to the other) and Diaz-Caneja stimuli (half of each image to each eye) centrally to both a split-brain participant and a control group. With traditional rivalry stimuli both the split-brain participant and age-matched controls perceived more coherent percepts (synchronised across the hemifields) than non-synchrony, but our split-brain participant perceived more non-synchrony than our controls. For rival stimuli in the Diaz-Caneja presentation condition, object rivalry gave way to eye rivalry with all participants reporting more non-synchrony than coherent percepts. We have shown that splitting the stimuli across the hemifields between the eyes leads to greater eye than object rivalry, but that when traditional rival stimuli are split as the result of the severed corpus callosum, traditional rivalry persists but to a lesser extent than in the intact brain. These results suggest that communication between the early visual areas is not essential for synchrony in traditional rivalry stimuli, and that other routes for interhemispheric interactions such as subcortical connections may mediate rivalry in a traditional binocular rivalry condition.

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1. Introduction

When each eye is presented with a different monocular image, observers report perceptual alternations between the two stimuli as they compete for perceptual dominance (Breese, 1899; Wheatstone, 1838). The dynamics of this phenomenon, known as binocular rivalry, have been shown to be affected by various low-level features such as contrast (Mueller & Blake, 1989) and spatial frequency (Fahle, 1982). Attention and voluntary control have also been shown to influence the dynamics of binocular rivalry. Attending to one of the two rivaling percepts can increase the perceived duration of that percept (Meng & Tong, 2004), and when attention is exogenously cued to one stimulus over another, the uncued stimulus becomes suppressed (Mitchell, Stoner, & Reynolds, 2004). Participants are also able to choose to hold one percept over the other in awareness, and to control the speed of rivalry in various bi-stable image and binocular rivalry paradigms (van Ee, van Dam, & Brouwer, 2005). The high-level content of more complex rival stimuli has also been shown to have an effect on the durations of dominance of percepts in binocular rivalry. Fear-conditioned patches have been shown to dominate over neutral stimuli (Alpers et al., 2005), and emotional facial expressions dominate over neutral expressions (Alpers & Gerdes, 2007; Bannerman et al., 2008;

Coren & Russell, 1992; Yoon et al., 2009), even when presented in peripheral vision (Ritchie, Bannerman, & Sahraie, 2012).

A lingering debate in the binocular rivalry literature is whether it is the eyes or the objects that rival for dominance. Evidence for the eye rivalry theory centres around findings that when an eye is suppressed during binocular rivalry, sensitivity to stimuli presented to that eye is decreased. For example, incremental light detection thresholds are increased in the suppressed eye (Blake & Camisa, 1979; Wales & Fox, 1970), as are thresholds for motion detection (Fox & Check, 1968). It has, therefore, been argued that it is not the stimulus that is suppressed, but the eye itself (Blake, Westendorf, & Overton, 1980). Some more recent research has argued the opposite, that it is in fact the objects that rival. In a now-classic study, Logothetis, Leopold, and Sheinberg (1996) swapped the rivaling images between observers' eyes at a rate of 3 Hz. Instead of reporting perceptual switches at this rate, observers reported the same pattern of rivalry as when traditional rival pairs were presented with one image constant to each eye. This finding suggests that it was not the eyes, but the images themselves which compete for perceptual dominance.

An alternative paradigm to the eye-swapping technique of Logothetis and colleagues is to split the rival images themselves between the eyes. This technique, first reported using circles and horizontal gratings, split each image in half, presenting a patchwork of the two images to one eye with the complimentary patchwork to the other. It was found that observers tended to report perceiving the coherent full images rather than the patchwork

* Corresponding author. Address: Vision and Attention Laboratories, School of Psychology, University of Aberdeen, Aberdeen AB24 3FX, Scotland, United Kingdom.
E-mail address: kay.ritchie@abdn.ac.uk (K.L. Ritchie).

image presented to either eye (Diaz-Caneja, 1928, translated by Alais et al., 2000). Diaz-Caneja's technique has been extended by instead of splitting each image into two and presenting these 'half-and-half' images to each eye, presenting a true 'patchwork' whereby each monocular image contained varying extents of patches of two separate images (Kovács et al., 1996). The authors found that although the pattern coherence of the stimuli themselves influenced rivalry, most observers reported coherent percepts as well as the eye-based 'patchy' rivalry.

The reported durations of periods of dominance of coherence in Diaz-Caneja stimuli can be increased by introducing stimulus flicker. Knapen and colleagues found that by presenting Diaz-Caneja stimuli with a flicker of 18 Hz in both eyes, achieved by interspersing presentation of the stimuli with blanks, reported durations of the perception of coherent images increased compared to when the Diaz-Caneja stimuli were presented without flicker (Knapen et al., 2007). Recent work has combined the two ideas of eye- and object-based rivalry and suggested that the contribution of the two varies over time, with rivalry beginning with the dominant eye and then moving to object dominance over time (Bartels & Logothetis, 2010). This is of particular importance when long presentation durations are used.

In neurologically intact observers, Diaz-Caneja stimuli can be used to split each image between the eyes, and hence, direct the component parts to be processed in different hemispheres. In the brain of a callosotomised patient the processing of a centrally presented image will be split across the hemispheres in a comparable way. Binocular rivalry has previously been measured in split-brain patients, with both traditional gratings pairs and pairs comprising one grating and one face. It has been reported that in two patients (JW and VP), rivalry occurs for stimuli presented within both hemifields, and that this rivalry is more-or-less comparable between the two hemifields (O'Shea & Corballis, 2001, 2003). This pattern of results was found both for simple gratings rival pairs (O'Shea & Corballis, 2003) and for more complex face/gratings pairs (O'Shea & Corballis, 2001). In one further study, the authors presented both traditional (one image to each eye) and Diaz-Caneja (half image to each eye) rival grating stimuli in each hemifield of patient JW, and found that he reported coherent percepts in both stimulus conditions, but more often for the traditional than the Diaz-Caneja stimuli. The final experiment in their study presented two rival pairs to JW, either both within the same hemifield, or in opposite hemifields, but always with the same image (a grating or a noise patch) presented to each eye in each location. The authors found that JW reported high instances of joint predominance or synchrony between the two rival pairs when they were presented in the same hemifield, but not at all when the rival pairs were in opposite hemifields (O'Shea & Corballis, 2005). The authors concluded that rivalry occurred independently in each hemifield in the split-brain.

While previous studies using Diaz-Caneja stimuli have used simple gratings and spiral stimuli, in the current study we applied the Diaz-Caneja technique to face/house stimuli. Based on previous studies we predicted that faces would be perceived as more dominant than houses. We used traditional and Diaz-Caneja face/house rival pairs to investigate both eye and object rivalry.

2. Methods

2.1. Participants

Control participants: Eight control participants took part in the study (all female; mean age: 61.6 years, range: 61–62 years). All participants had normal or corrected to normal visual acuity and adequate stereo acuity (30 s arc) assessed by the RANDOT test

for stereoscopic vision (Stereo Optical Company, 2002). Participants were naïve to the purpose of the experiment. All participants gave informed consent, and the study was granted favourable ethical opinion by the School of Psychology Ethics Committee.

Split-brain participant: VP was 59 years old at the time of testing and underwent two-stage sectioning of the corpus callosum in 1979 to relieve severe epilepsy. It has been reported that there is some sparing of fibres in VP's anterior commissure and in the genu of the corpus callosum (Corballis et al., 2001; Gazzaniga et al., 1985). After the sectioning, VP presented some classic split-brain behaviours such as an inability to name objects placed in the left hand whilst not being able to see them. The spared fibres have left VP with some interhemispheric connectivity such that she has been reported to be able to categorise word pairs presented across the hemifields as rhyming or not rhyming (Funnell, Corballis, & Gazzaniga, 2000). Otherwise, she presented with a normal neurological examination. She has subsequently participated in numerous studies, and has normal vision corrected with glasses (see Sidtis et al., 1981 for a full clinical history).

2.2. Materials

The stimuli were photographs of houses, and photographs of two female identities (F1 and F3) each presenting three emotions (neutral, fearful, happy) taken from a standard set of facial expression pictures (Karolinska Directed Emotional Faces (KDEF), Lundqvist, Flykt, & Ohman, 1998). The house stimuli were each chosen to closely match one of the face stimuli in both shape and size. The face and house stimuli subtended $4.8^\circ \times 7.4^\circ$ at a viewing distance of 57 cm. All of the images were presented in blue and red against a uniform black background (0.7 cd/m^2) on a 21" CRT monitor for the control group and a MacBook Pro 5,1 with a 15" screen for VP. The laptop was set on a stand so as to present the stimuli to VP at eye-level. The experiment ran on E-Prime2 for the control participants and PsyScopeX Build 53 for VP. Rivalry was achieved by superimposing one blue and one red image on top of each other and having participants view the stimuli through red/blue filter glasses. The stimuli were viewed foveally with a central fixation point and were presented as both traditional stimuli, that is with one image presented to each eye (for example a face to the left eye and a house to the right eye), and as Diaz-Caneja stimuli, that is with half of each image presented to each eye (for example the left half of a face and the right half of a house to the left eye, and the right half of a face and left half of a house to the right eye, see Fig. 1).

2.3. Design and procedure

All participants viewed all three emotions (neutral, fear, happy) in both stimulus types (traditional and Diaz-Caneja). Participants were instructed that they would be presented with an image which would appear to change in different parts between looking like a face and looking like a house. Participants were asked to maintain fixation on a central fixation point and keep track of the changes in the image via button presses, responding to the right half of the image with their right hand and the left half of the image with their left hand. Following previous studies (Bannerman et al., 2008; Ritchie, Bannerman, & Sahraie, 2012), we did not record mixed percepts. Participants were told that each half of the image would either look *mostly* like a face or *mostly* like a house, and asked to respond accordingly. This was done so as not to over-complicate the response procedure. The response paradigm allowed the reporting of non-synchronised percepts even in the traditional stimulus presentation condition. The response keys for each percept (face and house) were counterbalanced between our control participants, with VP always responding with the same keys for each percept to minimise block-to-

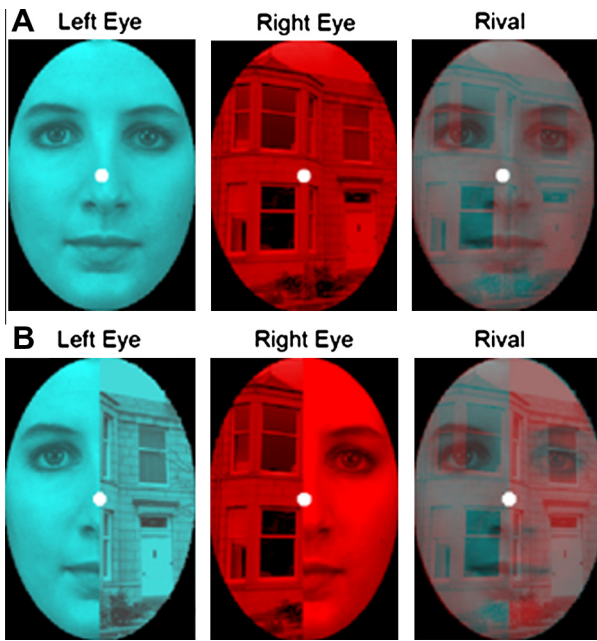


Fig. 1. Example stimuli. (A) Traditional stimuli. (B) Diaz-Caneja stimuli.

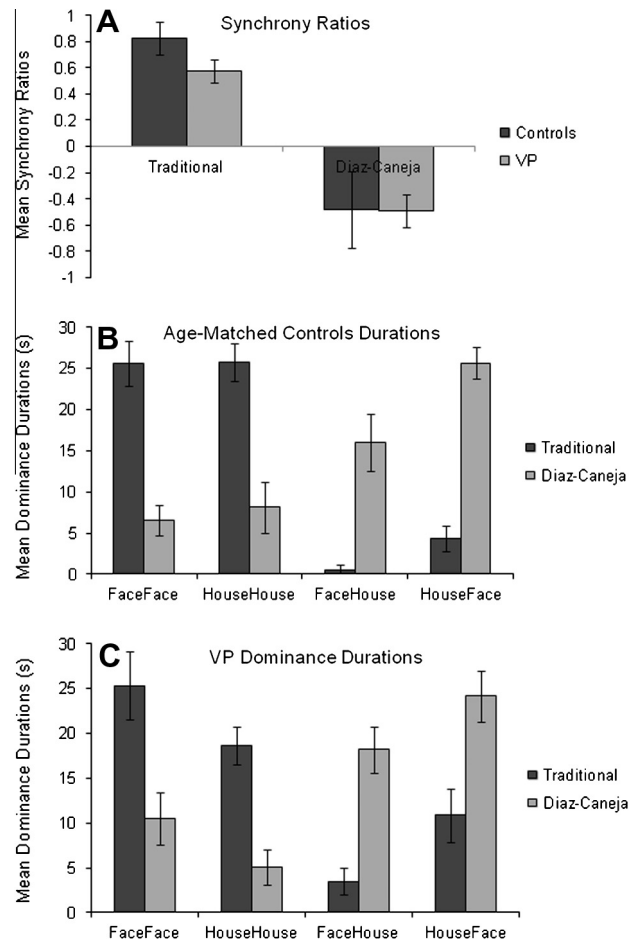


Fig. 2. Results. (A) Synchrony ratios $((T_{\text{synchronised}} - T_{\text{non-synchronised}})/(T_{\text{synchronised}} + T_{\text{non-synchronised}}))$ for control participants and VP. Error bars represent SEM. (B) Duration (s) of the perception of each possible combination of percepts in the left and right hemifields. Faceface denotes synchronised face (face perceived as dominant in both hemifields simultaneously), househouse denotes a synchronised house (house perceived as dominant in both hemifields simultaneously), facehouse denotes a face in the left hemifield and a house in the right hemifield, and houseface a house on the left with a face on the right. Dark bars represent the perception of each of these possible combinations of percept in the traditional stimulus condition, and light bars represent the Diaz-Caneja stimulus condition. Maximum duration is 60 s. (C) Durations of percepts for VP. Figures (B) and (C) show longer perceptions of synchronised percepts (faceface and househouse) for traditional stimuli, and longer perceptions of unsynchronised percepts (facehouse and houseface) for Diaz-Caneja stimuli.

block changes in task instructions. VP's responses were recorded using a IoLab Systems Psycscope X compatible response box. This was set up so that responses were vertically aligned (face/house) for each response hand. Each of our control participants completed 24 trials (split into three blocks of eight trials), with four trials of each emotion in each stimulus type, and VP completed five runs of these 24 trials. The trials lasted for 60 s, with each trial separated by a 3 s rest period during which a blank screen was displayed. All trial types were randomly interleaved. The trial order was fully randomised between participants, and each rival pair was presented to each participant twice, counterbalancing the images between the eyes. Prior to the main experiment participants were given three practice trials to familiarise themselves both with the stimuli and the coding procedure.

We determined VP's fixation to ensure that each half of the images was presented to the correct hemifield. Eye movements along the horizontal meridian would have shifted the processing of the halves of the stimuli between the hemispheres, perhaps aiding the perception of coherent percepts. We recorded VP's eye position using a Canon Ixus Digital Camera and examined the videos post hoc to determine VP's fixation accuracy. Each block began with a calibration for the purpose of monitoring eye position. During the calibration, the fixation point was presented in the centre of the screen, the same position in which the fixation point was presented superimposed on the stimuli on each trial, the fixation then moved to a position corresponding to the left of the stimulus, back to the centre, and then to a location corresponding to the right of the stimulus. VP was asked to follow the fixation point with her eyes, establishing dimensions within which her eye should remain for steady fixation. VP is well-practiced at fixating, and made very few eye movements per trial (mean = 2.14, range 0–4) away from fixation and immediately back again across the 41% of trials for which we had clear videos.

3. Results

There were no differences in perceived synchrony or dominance across the three emotions of faces presented, therefore all analyses were performed collapsed across emotions.

To measure the differences between eye rivalry and object rivalry, we looked at the durations for which coherent percepts (faces and houses) were perceived in each condition. We term the perception of a coherent face or house a 'synchronised' percept, and the perception of a half face/half house a 'non-synchronised' percept. In the traditional stimulus condition, the perception of coherent percepts is a result of combined eye and object dominance as each individual image was presented wholly to one eye or the other. In the Diaz-Caneja stimuli condition, however, perceiving a coherent percept would require synchrony of the perception of half of one eye's image with half of the image being present to the other (see Fig. 1B).

To investigate the differences in reported perception of synchronised and non-synchronised percepts, we calculated a synchrony ratio for each stimulus condition (Fig. 2A). This was calculated using the following formula:

$((T_{\text{synchronised}} - T_{\text{non-synchronised}})/(T_{\text{synchronised}} + T_{\text{non-synchronised}}))$ where 'synchronised' is the duration of the

perception of a coherent face and a coherent house, and 'non-synchronised' is the duration of the perception of a half face/half house and a half house/half face. These calculations were carried out using the grand means (the means of each participant's mean perceived durations for the control group, and the means of the perceived durations for each block of observations with VP). The ratio provides a number between 1 and -1 , with a positive value denoting longer durations of the perception of synchronised percepts, and a negative value denoting longer durations of the perception of non-synchronised percepts. In the traditional stimulus condition, the ratio value represents both eye and object rivalry as each eye receives a coherent image, whereas in the Diaz-Caneja condition the ratio value represents only eye rivalry.

We began by carrying out two one-sample *t*-tests comparing our control group's mean synchrony ratio values to zero. The mean ratio value for the traditional stimulus condition was significantly higher than zero ($t(7) = 20.621, p < .001$), and the mean ratio value in the Diaz-Caneja stimulus type condition was significantly lower than zero ($t(7) = -4.608, p < .01$). This indicated significant eye rivalry as opposed to object rivalry in the Diaz-Caneja stimulus condition.

We investigated the perception of synchronised percepts in our control group using a paired-samples *t*-test to compare the mean synchrony values for the traditional and Diaz-Caneja stimulus conditions. The mean synchrony ratios were significantly higher in the traditional stimulus condition ($M = .824, SD = .113$) than the Diaz-Caneja stimulus condition ($M = -.459, SD = .282, p < .001$). This shows that our control participants perceived coherent percepts for significantly longer in the traditional compared to the Diaz-Caneja condition. This can also be expressed as our control participants showing more eye rivalry in the Diaz-Caneja condition.

To investigate the differences in the perceived duration of the four possible percepts in our control group (Fig. 2B), we carried out a 2 (stimulus type: traditional, Diaz-Caneja) \times 4 (percept: faceface, househouse, facehouse, houseface) repeated measures ANOVA on the mean durations of the percepts in each condition. The ANOVA showed a main effect of percept ($F(3,21) = 11.119; p < .001; \eta_p = 0.614$) with Bonferroni pairwise comparisons showing that a coherent face (faceface, $M = 16.1$ s) was perceived for longer than a face in the left hemifield and a house in the right (facehouse, $M = 8.3$ s; $p < .01$), and that the houseface ($M = 15.0$) combination was perceived for significantly longer than the facehouse combination ($p < .05$). There was no difference between the perception of a coherent face and a coherent house ($p > .05$). This means that participants did not perceive a synchronised face for longer than a synchronised house, but when reporting a non-synchronised percept, participants tended to see the face for longer in the right hemifield than in the left. The ANOVA also showed an interaction between stimulus type and percept, reflecting the effect reported above whereby participants saw more synchrony (faceface and househouse) in the traditional stimulus condition than the Diaz-Caneja condition in which they saw more non-synchrony (facehouse and houseface).

We began our analysis of VP's data in the same way as that of controls, by carrying out two one-sample *t*-tests comparing VP's mean synchrony ratio values to zero. As in our control group, for VP the mean ratio value for the traditional stimulus condition was significantly higher than zero ($t(4) = 5.654, p < .01$), and the mean ratio value for the Diaz-Caneja stimulus condition was significantly lower than zero ($t(4) = -7.112, p < .01$). This indicated significant eye rivalry as opposed to object rivalry in the Diaz-Caneja stimulus condition.

We then investigated VP's reported synchronised percepts by carrying out a paired-samples *t*-test to compare the mean synchrony values for the traditional and Diaz-Caneja stimulus conditions. The mean synchrony ratios were significantly higher in the

traditional stimulus condition ($M = .507, SD = .200$) than the Diaz-Caneja stimulus condition ($M = -.465, SD = .146, p < .01$). These results show that VP perceived coherent percepts for significantly longer in the traditional compared to the Diaz-Caneja condition.

To investigate the difference in VP's perceived duration of the four possible percepts (Fig. 2C), we carried out a 2 (stimulus type: traditional, Diaz-Caneja) \times 4 (percept: faceface, househouse, facehouse, houseface) repeated measures ANOVA on the mean perceived durations of the percepts. The ANOVA showed a main effect of percept ($F(3,12) = 16.292; p < .001; \eta_p = 0.803$) with Bonferroni pairwise comparisons showing that a coherent face (faceface, $M = 17.9$ s) was perceived for longer than a face in the left hemifield and a house in the right (facehouse, $M = 10.8$ s; $p < .05$); and a house in the left hemifield and a face in the right (houseface, $M = 17.5$ s) was perceived for longer than a coherent house (househouse, $M = 11.8, p < .05$). The houseface combination was perceived for significantly longer than the facehouse combination ($p < .05$). The difference between the perception of a coherent face and a coherent house was approaching significance with the face being perceived as dominant for longer than the house ($p = .076$). This shows that, as in our control participants, when reporting a non-synchronised percept, VP tended to see the face for longer in the right hemifield than in the left. The ANOVA also showed an interaction between stimulus type and percept, reflecting the effect reported above whereby participants saw more synchrony (faceface and househouse) in the traditional stimulus condition than the Diaz-Caneja condition in which they saw more non-synchrony (facehouse and houseface).

We examined the differences between the perceived durations of coherent percepts by comparing the synchrony dominance ratios of our control sample and our split-brain participant using a method designed for comparing single patients to small groups (Crawford & Garthwaite, 2002; Crawford, Garthwaite, & Porter, 2010). The mean synchrony dominance ratio of our control sample was significantly higher than for our split-brain patient in the traditional stimuli condition ($p < .05$), meaning that our control participants perceived longer durations of coherent percepts than our split-brain participant. To explore this further, we compared the perceived durations of whole faces, whole houses, half-face-half-house, and half-house-half-face in the traditional stimuli condition for VP and our control sample. There was no difference in the perceived duration of a coherent face, or a coherent house between VP and the control participants (both $p > .05$). VP perceived significantly longer durations of non-synchronised percepts than the control sample, both the facehouse and houseface non-synchronised percepts (both $p < .05$). The results show that although VP perceived significantly more synchrony than non-synchrony in the traditional stimulus condition, she perceived non-synchronised percepts for significantly longer than the control sample.

In the Diaz-Caneja stimuli condition, there were no differences in the mean synchrony ratios between our control sample and our split-brain participant ($p > .05$). This shows that our split-brain participant perceived similar durations of coherent percepts as the control sample in the Diaz-Caneja condition.

4. Discussion

This study was the first to examine centrally presented face/house rivalry using both traditional and Diaz-Caneja stimuli in a split-brain participant and age-matched control group. Our results show that both control participants and a split-brain participant perceived longer durations of synchronised or coherent percepts when face/house rival stimuli were presented in a traditional compared to a Diaz-Caneja presentation. Synchrony was always perceived for a shorter duration in the Diaz-Caneja condition than

non-synchrony (see Fig. 2A negative synchrony ratios for the Diaz-Caneja condition), which means that eye rivalry was operating to a greater extent in this condition than object rivalry.

Where previous research has debated whether it is the eyes (Blake & Camisa, 1979; Blake, Westendorf, & Overton, 1980; Fox & Check, 1968; Wales & Fox, 1970) or the objects themselves (Diaz-Caneja, 1928; Knapen et al., 2007; Kovács et al., 1996; Logothetis, Leopold, & Sheinberg, 1996) that rival, we have found evidence for an interaction between the two mechanisms. We measured synchrony between the hemifields using a ratio derived from the total time for which synchronised or coherent percepts were perceived, minus the total time for which non-synchrony was perceived, divided by the total time. A synchrony value of 1 would denote complete synchrony, or complete object rivalry in the Diaz-Caneja condition; a value of -1 would denote no synchrony in the percepts, or total eye dominance in the Diaz-Caneja condition; and a value of 0 would indicate equal durations of synchrony and non-synchrony, or an equal contribution of both object and eye dominance. In both our split-brain participant, and our control sample, with Diaz-Caneja stimuli we observed synchrony values below zero but above -1 . This shows that although there was more non-synchrony than synchrony, indicating more eye than object rivalry, there was not a sole reliance on an eye rivalry mechanism, but perhaps an interaction between the two.

Where O'Shea and Corballis (2005) showed in their first two experiments that a split-brain participant perceived synchronised or coherent percepts with Diaz-Caneja stimuli presented within one hemifield, we have shown that when the Diaz-Caneja stimuli are presented centrally, thus across both hemifields, our split-brain participant perceived predominantly non-synchronised percepts. In order to perceive coherent percepts in rivalry, the corresponding halves of images processed in different hemispheres must be combined in a process relying on inter-hemispheric communication. While this is the case with traditional stimuli, it becomes even more important for the perception of synchronised percepts when the images are presented in the Diaz-Caneja condition. We have shown that both our control and split-brain participants are able to perceive coherent percepts in the traditional condition, but not the Diaz-Caneja condition. The results show that VP is able to integrate face stimuli across the hemifields, demonstrated by her reporting of coherent percepts in the traditional stimulus condition. The previously reported intact anterior commissure may connect face sensitive areas such as the fusiform face area (FFA) between the hemispheres (Corballis et al., 2001; Gazzaniga et al., 1985).

Our split-brain participant performed similarly to our control sample over all, supporting O'Shea and Corballis's (2001, 2003) previous work on rivalry in the split-brain. Where we did find differences between VP and our control sample was in the perceived duration of coherent percepts in the traditional stimulus condition. Synchrony ratios were significantly higher for our control sample than our split-brain participant in the traditional stimulus condition. Moreover, VP reported significantly longer durations of non-coherent percepts in this condition. Our paradigm allowed the reporting of non-coherent percepts in the traditional stimulus condition and so was more sensitive to this breaking-down of traditional rivalry in the split-brain participant. In the Diaz-Caneja conditions where each half of the image was presented independently, coherent rivalry also broke down in our age-matched control sample.

The results indicate that although VP perceived more synchrony than non-synchrony in the traditional stimuli condition, she was more likely to report eye rivalry, indicating a splitting of the images into their separate parts presented to the separate hemispheres. This is not surprising as the severed corpus callosum means that each eye's image would have been split across the

hemispheres. What is surprising is that despite this splitting, VP perceived more synchrony than non-synchrony for traditional rival stimuli. This surprising finding goes against O'Shea and Corballis's (2005) findings of a lack of synchrony between two separate rival pairs when those pairs were presented in opposite hemifields. While O'Shea and Corballis presented their stimuli at least 1.25° apart, our stimulus halves were presented directly adjacent to each other as one image (see Fig. 1). Although visual information from each hemifield of each eye is projected via the optic chiasm to the separate hemispheres, there exists an area of nasotemporal overlap around the vertical meridian in the split-brain. Fendrich and Gazzaniga have found that in the split-brain patient VP, there is an area of approximately 1° around the vertical meridian in which visual information may be available to each hemisphere (Fendrich & Gazzaniga, 1989). In an image matching task, VP could readily match images presented within each hemifield, but could not perform the task above chance level when the images were presented in opposite hemifields only 1.25° apart. Moreover, although VP has been shown to be able to transfer word information between the hemifields, this is not true of shape and colour information (Funnell, Corballis, & Gazzaniga, 2000). Although the dominance of a percept may be influenced by this small area of overlap, due to large stimulus size, it could not fully account for our findings. As the images subtended 4.8° in width, pertinent parts of the images, such as the eyes, are over 1° from the central fixation point. Therefore it is likely that the findings are not mediated by the small nasotemporal overlap. Due to the response paradigm in which VP was responding to each hemifield with each individual hand, it could be suggested that our observed results of synchrony between the hemifields may simply reflect synchrony between the two hands. Yet we believe that the issue of hand synchrony can be addressed by the data. If it were the case that VP was tending to synchronise her responding hands, we would have seen more synchrony than non-synchrony in all experimental conditions. This, however, was not the case, with VP (and our age-matched control participants) reporting significantly greater non-synchrony than synchrony in the Diaz-Caneja stimulus condition. The synchrony ratio values in both the traditional and Diaz-Caneja conditions are greater than -1 (which denotes complete non-synchrony or complete eye rivalry), but the difference in the reported perceptions of synchrony between the two stimulus type conditions is likely to indicate that responses reflected the perceived dominant percepts and not merely synchrony between the hands.

The execution of saccadic eye movements can lead to a switch in the perceived dominant percept in binocular rivalry (van Dam & van Ee, 2006). In a free-viewing binocular rivalry condition without a fixation point, the authors found a significant increase in the probability of a saccade being executed just before or at the time of a perceptual switch. It is of note that although the execution of saccades correlated with perceptual switches, the end location of the saccades, or the new fixation location, did not vary systematically with the reported dominant percept. This tells us that it is not the fixation at a specific point in the image which determines the dominant percept, but the execution of the saccade which may influence a perceptual switch. In face/house rivalry any saccade would produce changes in the image falling on the fovea, and as such changes can produce perceptual switches, it is important that fixation is maintained throughout trials. Moreover, the execution of saccades along the horizontal meridian necessarily brings parts of the image from one hemifield to the other, changing which specific features of the images are processed intra-hemispherically as opposed to inter-hemispherically. As VP's eye movements were monitored in 41% of trials, although unlikely, it remains a possibility that a number of saccades may have been made in the remaining trials, which may have influenced the results by allowing both halves of the images to fall in the same hemifield. Although these

eye movements may have influenced synchrony, the durations for which both halves of the images fell within the same hemifield were brief, and therefore this is unlikely to fully account for our findings.

Taken together, our findings show that face/house rivalry with traditional stimuli occurs in the split-brain when the stimuli are presented centrally so that the different halves of the image are processed mainly in contralateral hemispheres. Although our split-brain participant reported less dominance of synchronised percepts in the traditional condition than our neurologically intact control sample group, she did report perceiving coherent percepts across the hemispheric divide. Furthermore our split-brain participant's responses to Diaz-Caneja face/house stimuli were similar to those of our control sample with no significant differences between the two in terms of synchrony ratios. These results show that when the rival images are split across the hemifields between the eyes, eye rivalry is the dominant mechanism. Yet when whole images are split due to severed callosal fibres, the eye and object rivalry remain.

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