

**Plaid Motion Rivalry: correlates with Binocular
Rivalry and Positive Mood State**

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Abstract

Recently Hupé and Rubin (2003) re-introduced the plaid as a form of perceptual rivalry by using two sets of drifting gratings behind a circular aperture to produce quasi-regular perceptual alternations between a coherent moving plaid of diamond shaped intersections and the two sets of component, “sliding” gratings. We call this phenomenon, plaid motion rivalry (PMR), and have compared its temporal dynamics with those of binocular rivalry in a sample of subjects covering a wide range of perceptual alternations rates. Supporting the proposal that all rivalries may be mediated by a common switching mechanism we found a high correlation between alternation rates induced by plaid motion rivalry and binocular rivalry. In keeping with a link discovered between the phase of rivalry and mood, we also found a link between PMR and an individual’s mood state that is consistent with suggestions that each opposing phase of rivalry is associated with one or the other hemisphere, with the “diamonds” phase of PMR linked with the “positive” left hemisphere.

1 Introduction

If two sets of gratings with different orientations are superimposed, a plaid pattern is created (Figure 1). This seemingly uninteresting stimulus comes alive when it is moved behind an aperture. Due to the well known and much studied “aperture problem” (Adelson and Movshon 1982; Fennema and Thompson 1979; Marr and Ullman 1981; Stumpf 1996; Wuerger et al 1996) the subsequent motion of the gratings is ambiguous and when the visual system is confronted with this ambiguity

an apparent oscillation in conscious visual perception is experienced. The unchanging physical motion of the plaid induces stochastic, quasi-regular alternations in conscious perception, between an integrated “diamonds” phase, where a plaid of diamond shaped intersections moves in one direction, and a component “sliding” phase, where the two sets of gratings are seen to slide over each other independently. (You can experience this perceptual alternation by viewing a plaid stimulus demonstration at the following website: <http://www.cns.nyu.edu/~hupe/arvo01demo/index.html>)

Traditionally plaid stimuli have been studied to investigate the principles of motion integration and segmentation (Grossberg et al 2001; Hupé and Rubin 2003; Mingolla 2003; Stoner and Albright 1992). Our aim however is to consider the moving plaid as a form of perceptual rivalry, (which we will refer to as plaid motion rivalry or PMR) where constant visual input gives rise to two or more perceptual interpretations that consecutively alternate between being consciously perceived and suppressed from awareness. Other well-known forms of perceptual rivalry include ambiguous figures such as the Necker cube and dynamic motion displays like the spinning wheel illusion.

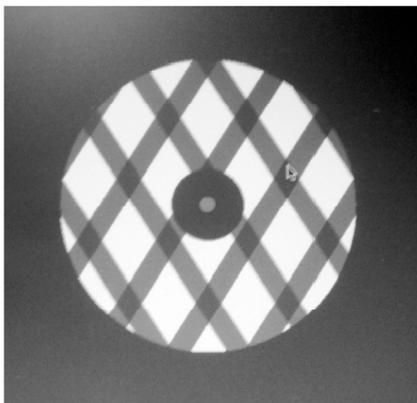


Figure 1. This is a picture taken of a computer generated plaid stimulus composed of grey rectangular wave gratings. In the current investigation this stimulus drifted directly upwards behind the circular aperture and the central masking patch and fixation point. Upon viewing this type of dynamic plaid stimulus a perceptual phenomenon arises that we refer to as plaid motion rivalry.

Binocular rivalry also involves the visual awareness and suppression of different perceptual interpretations (reviewed in Alais and Blake 2005), but differs from PMR and other forms of rivalry with respect to its mode of presentation. During PMR both eyes have simultaneous access to the one plaid stimulus, whereas binocular rivalry requires that a different stimulus be presented to each eye. For example when horizontal lines are presented to the right eye and vertical lines are simultaneously presented to the same retinal location of the left eye, the two different stimuli will alternate between being perceptually dominant or suppressed.

The aim of the current investigation is to address the question as to whether the timing of alternations induced by binocular rivalry are correlated with those experienced during plaid motion rivalry. It will also be established if a similar wide range of inter-individual variation in perceptual alternation rates exist for PMR as there does for binocular rivalry (Pettigrew 2001). This investigation follows on from earlier work in our lab that suggests the timing of perceptual alternations for a group of subjects tested on binocular rivalry, covering a wide range of alternation rates, will be correlated with the rates they record when tested on other forms of rivalry (Carter and Pettigrew 2003). For example if a subject demonstrates a slow binocular rivalry rate we propose they will also record a relatively slow rate for PMR. Such a prediction is based on the premise that the underlying switch that triggers the alternation in all forms of rivalry results from a common mechanism.

At this stage the actual origin and specific nature of the mechanism(s) by which a switch in perception takes place remains in the realm of theory and speculation (Blake and Logothetis 2002; Leopold and Logothetis 1999; Pettigrew 2001; Tong 2001). The current consensus appears to be that binocular rivalry represents a series of competitive neural processes and interactions of a multi-level and complex nature (Blake and Logothetis 2002; Crewther et al 2005; Dayan 1998; Laing and Chow 2002; Wilson 2003). These competition-type theories can also be extended to account for the perceptual alternations induced by ambiguous figures (Gomez et al 1995; Laing and Chow 2002; Leopold and Logothetis 1996) and dynamic motion displays like PMR (Hupé and Rubin 2003), however it continues to be argued by some authors that binocular rivalry may in fact be mediated by its own separate or different neural mechanisms (Andrews et al 2002; Meng and Tong 2004; Tong 2001) at lower levels of the visual cortex (Polonsky et al 2000).

Another alternative view incorporating the multi-level cortical aspects of rivalry proposes that alternations in perception are triggered by the activity of an underlying interhemispheric oscillatory brainstem network (Pettigrew 2001; Pettigrew and Miller 1998). Based on a unified extension of previous proposals from multiple sources (see Carter et al 2005 and Pettigrew and Carter 2005), this theoretical network reportedly includes a number of inter-connected brainstem nuclei with pacemaker activity responsive to modulation by cortical and sub-cortical feedback projections, and is thought to be responsible for the coordination of various and fundamental neurological rhythms such as circadian and ultradian cycles. A variety

of supporting evidence exists for this theoretical interpretation of perceptual rivalry (Carter and Pettigrew 2003; Funk and Pettigrew 2003; Hekel and Pettigrew in preparation; Miller et al 2000; Pettigrew and Carter 2002), with the most recent demonstrating the involvement of serotonin 1A receptors (implicating a role for the raphe nuclei) in the timing of perceptual alternations (Carter et al 2004; Carter et al 2005).

The second part of this investigation was designed to test specific predictions that are made by one aspect of the brainstem oscillator theory, which proposes a link between phase of rivalry and lateralized affective and cognitive processes (Pettigrew 2001). Such predictions were supported by a recent finding demonstrating a link between positive mood state (as measured by subjects' self-assessed mood ratings) and the disappearance phase of motion-induced blindness (MIB) (Pettigrew and Carter 2002), which is a newly described and rather unconventional form of perceptual rivalry (Bonneh et al 2001; Carter and Pettigrew 2003). Subjects who reported higher positive mood scores experienced the disappearance phase for a significantly greater proportion of the testing time compared with those subjects who reported lower positive mood scores. It has also been suggested that a depressed mood state is reflected in a somewhat opposite way, inducing a perceptual bias favouring the appearance phase of MIB (Pettigrew 2001).

Whether these findings demonstrate a characteristic that is inherent only to the perception of this particular form of rivalry is yet to be established. However, based

upon informal observations in individual subjects acting as their own controls (in contrast to the group study reported on in the following investigation) it has been proposed that similar effects of mood on perceptual bias can also be demonstrated in binocular rivalry, with a predominance of horizontal lines associated with positive mood and a bias favouring the perception of vertical lines linked with negative emotions and depression (Pettigrew 2001). The second part of this investigation therefore focused on the possibility that subjects' mood state may be reflected in the pattern of perceptual alternations they experience during PMR.

2 Experiment 1: The temporal dynamics of PMR and Binocular Rivalry

Hupé and Rubin (Hupé and Rubin 2003) have recently made some progress in this area by conducting an extensive study of the characteristic temporal dynamics induced by various manipulations of plaid parameters. They found significant intra-individual stabilities in the timing of PMR perceptual alternations, and of interest to us, the timing of those alternations differed across individuals, a finding that has also been demonstrated for binocular rivalry (Pettigrew and Miller 1998). Furthermore, while Hupé and Rubin did not directly compare PMR with binocular rivalry, their extensive investigations (Hupé and Rubin 2002; Rubin and Hupé 2005) revealed that PMR is subject to Levelt's second proposition (Levelt 1965), which he first elucidated for binocular rivalry, outlining the relationship between stimulus strength and the periods of perceptual dominance and suppression. Levelt's counter-intuitive second proposition was that increasing the predominance of one perceptual

alternative in rivalry was achieved by a reduction in time spent perceiving the alternative whose stimulus characteristics were unchanged, while the alternative that was made more prominent enjoyed no absolute increase in duration.

Encouraged by these results which lend support to the idea of a common mechanism(s) underlying both PMR and binocular rivalry we predicted that a positive correlation would exist between the timing of perceptual alternations induced by PMR and those induced by binocular rivalry.

Experiments were conducted to determine each subject's alternation rate for PMR (within a constant set of plaid parameters) and for binocular rivalry. For example, for a subject tested on binocular rivalry the duration of time between each perceptual switch was measured. The total number of perceptual switches was then divided by the total viewing time in order to calculate an alternation rate (Hz). Additionally, when normalised across subjects the stochastic nature of all perceptual rivalries studied to date generally reveals phase interval durations that approximate a gamma-like distribution (Borsellino et al 1972; Carter and Pettigrew 2003; Fox 1967; Kleinschmidt et al 1998; Muckli et al 2002). As a matter of convention we also therefore determined the distribution of normalised PMR phase durations for our sample of subjects which, along with alternation rates and subject frequency histograms were automatically calculated using a commercial software programme with data collection and analysis capabilities (BiReme Systems[®], www.bireme.com.au).

2.1 *Materials and Methods*

2.1.1 *Subjects*

The study recruited a total of 29 subjects aged between 16 and 55 years, and included members of the public as well as students and staff from the University of Queensland. Four subjects' data were excluded from further analysis; 3 failed to show the required visual acuity (6/9 or better) and a fourth continually perceived PMR as a rotating sphere, rather than alternating between the two common perceptual interpretations. The remaining 25 subjects were naïve as to the aims and hypotheses of the experiment although five were experienced at psychophysical experiments and demonstrated a degree of knowledge and awareness of perceptual rivalry. The University of Queensland Behavioural and Social Sciences Ethical Review Committee approved the study.

2.1.2 *Apparatus and stimuli*

The PMR stimulus (Figure 1) was generated using the Plaid_Program 2002, kindly given to us by Jean-Michel Hupé and Nava Rubin. The stimulus was displayed on a Personal Computer (PC Gateway EV500) with an 8 x 11 inch colour monitor. Subjects viewed the stimulus from a distance of 57 cm and data was collected using a commercial collection programme (BiReme Systems[□], www.bireme.com.au) run on an adjacent PC. The PMR stimulus consisted of symmetric rectangular-wave gratings forming a plaid that moved in a global direction of 90° (upwards). The speed of the gratings was 3°/second. The angle between the gratings' directions of

motion was 115° and the entire stimulus moved behind a centrally located circular aperture with a diameter of 8° . The area outside the aperture was dark grey and filled the remaining screen. The gratings consisted of grey bars superimposed on a white background. The duty cycle of the gratings, calculated as the width of the grey bars divided by the total cycle (total cycle = width of the grey bars plus the width of the inter-bar region) was 30%. The diamond intersection regions of the gratings were in the transparency range (i.e. darker grey relative to the bars – see Figure 1) which induces the illusion of transparency (Stoner et al 1990) when the gratings are seen to slide over each other during the sliding phase of perception. A central red fixation point (diameter = 0.4°) was overlaid on a dark grey masking patch (diameter = 2°) designed to reduce optokinetic nystagmus eye-movements (Hupé and Rubin 2003).

The binocular rivalry stimulus (consisting of green vertical and horizontal lines) was generated using a VisionWorks package and displayed on a green monochrome, 12 x 16 inch computer monitor (P46 phosphor, persistence = 500 nsec). To simultaneously project a different image to each eye, the vertical and horizontal lines alternated in rapid succession (120 Hz) and were viewed from a distance of 3 m through NuVision liquid crystal shutters. The shutters alternated in synchrony with the stimulus such that the left eye only viewed vertical lines and the right eye horizontal lines. Data was collected using the same collection programme (BiReme Systems) run on an adjacent PC. The stimulus consisted of drifting green vertical and horizontal square-wave gratings overlaid on a black background. The vertical

gratings moved from left to right and the horizontal gratings drifted upwards. The entire stimulus moved behind a circular aperture and subtended 1.5° of visual angle with a spatial frequency of 8 cycles/degree moving at 4 cycles/second.

2.1.3 Procedure

Each subject was tested on PMR and on binocular rivalry with a 5-minute break between each rivalry test. It was not possible to study both rivalries simultaneously, both for technical reasons and because of the problem of attending simultaneously to two processes. All experiments were conducted in a dimly lit room and the order of testing was counterbalanced. For both PMR and binocular rivalry, subjects were given an initial familiarisation and instruction period of approximately 1-2 minutes after which data was collected over four 100-second trials, with a 30-second break between each trial. A 5-second warning was given to subjects by the collection programme prior to the beginning of each trial.

During binocular rivalry testing, subjects indicated their perceptual switches by pressing one of two keys on a standard keyboard (V or B). The V key was highlighted by a small perspex disk with a vertically orientated ridge, while the B key had a small perspex disk with a horizontally orientated ridge. Subjects were instructed to press the V key when their perception changed to mostly vertical lines and when their perception switched to horizontal lines they were instructed to press the B key. As described in previous studies using this collection programme (Carter

and Pettigrew 2003; Pettigrew and Miller 1998), subjects were given the option of pressing the space bar to indicate periods of mixed/intermediate perception, which the programme automatically removed prior to analysis. This option was used minimally by nine of the participating subjects.

For PMR, subjects were instructed to press the B key to indicate a perceptual switch to the diamonds phase and when their perception changed to the sliding phase they were instructed to press the V key. When subjects were given a 5-second warning by the collection programme they were instructed to view the plaid and maintain fixation. This was found to successfully counteract the temporal phenomenon unique to the perception of plaids consisting of rectangular wave gratings (Hupé and Rubin (2003) found that for a temporally isolated trial the initial percept generally always consists of the diamonds phase and the time of this interval is longer than subsequent diamond phase intervals). None of the subjects used the space bar option (to indicate periods of mixed/intermediate perception) during PMR.

2.2 Results and Discussion

Consistent with the proposal that all perceptual rivalries are mediated by a common switching mechanism we found a significant inter-individual correlation between alternation rates induced by binocular rivalry and PMR (Pearson's correlation coefficient, $r = 0.84$, $p < 0.001$) (Figure 2). Additionally there was a diverse range of rates recorded for both PMR (0.08 Hz – 0.75 Hz) and binocular rivalry (0.14 Hz – 1.22 Hz). Subject frequency histograms illustrating the distribution and durations of

perceptual phase intervals (Figure 3) clearly demonstrate the inter-individual variation across the two stimuli. The majority of subjects (96%) recorded slower rates on PMR. The mean rates for PMR and binocular rivalry were 0.33 Hz (± 0.03) and 0.54 Hz (± 0.06) respectively. An analysis of variance found these to be significantly different ($F_{1, 24} = 11.60, p < 0.002$). Normalising the PMR data for each subject generated a frequency histogram that approximates a gamma-like distribution ($r = 0.97$) (Figure 4). This distribution is essentially similar to those obtained for binocular rivalry ($r = 0.94$) and MIB ($r = 0.96$) in prior experiments (Carter and Pettigrew 2003).

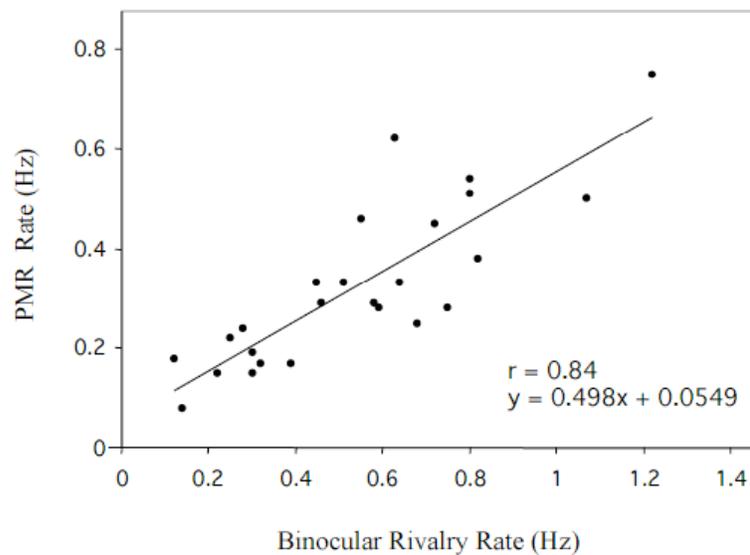


Figure 2. Correlated alternation rates for binocular rivalry (abscissa) and for plaid motion rivalry (ordinate). Both perceptual alternations cover a range of around 7x, yet the slowest subjects on binocular rivalry are the slowest subjects on PMR, with similar results for “fast switches” and those in between. $N = 25, r = 0.84, p < 0.001$. Binocular rivalry rates are consistently higher than the rates for PMR on the high strength apparatus used here, but would equalize if we used a display with a “weaker” stimulus (e.g. non-moving, or lower contrast).

The slower rates for PMR as compared to binocular rivalry may reflect differential contributions by different neural substrates and/or different visual/perceptual processes, as well as differences in “stimulus strength”. The binocular rivalry stimulus characteristics were chosen specifically to maximise rivalry rate and to emphasize the contrast between slow and fast switchers, which is greater at high stimulus strengths since fast switchers have a steeper curve relating stimulus strength to rivalry rate (see Pettigrew 2001). By reducing the binocular rivalry stimulus strength (for example by using stationary instead of moving gratings, or with sinusoidal instead of square wave gratings) it was possible to reduce binocular rivalry rates so they were closer to PMR rates (data not shown). Similarly, a smaller effect could be achieved by increasing the contrast of the PMR stimulus so that PMR rates increased. A systematic study to equalize PMR and binocular rivalry rates was not undertaken because of the large baseline of accumulated data with the stimulus strengths used as described, but could now be undertaken in the future.

Numerous scanning studies have implicated the involvement of different brain regions during different forms of rivalry (Castelo-Branco et al 2002; Kleinschmidt et al 1998; Polonsky et al 2000), including areas outside the visual hierarchy (Lumer et al 1998; Lumer and Rees 1999; Muller et al 2005; Srinivasan et al 1999). The neural substrates mediating the various perceptual phases of PMR and binocular rivalry are also likely to differ in location, magnitude and/or distribution, which potentially may have contributed to the differences in rate. Also differential

contributions between automatic, bottom-up (binocular rivalry) stimulus-driven visual processing (Meng and Tong 2004) and top-down explicit perceptual (Hochstein and Ahissar 2002) and attentional processes (Muller et al 2005) may have also played a role.

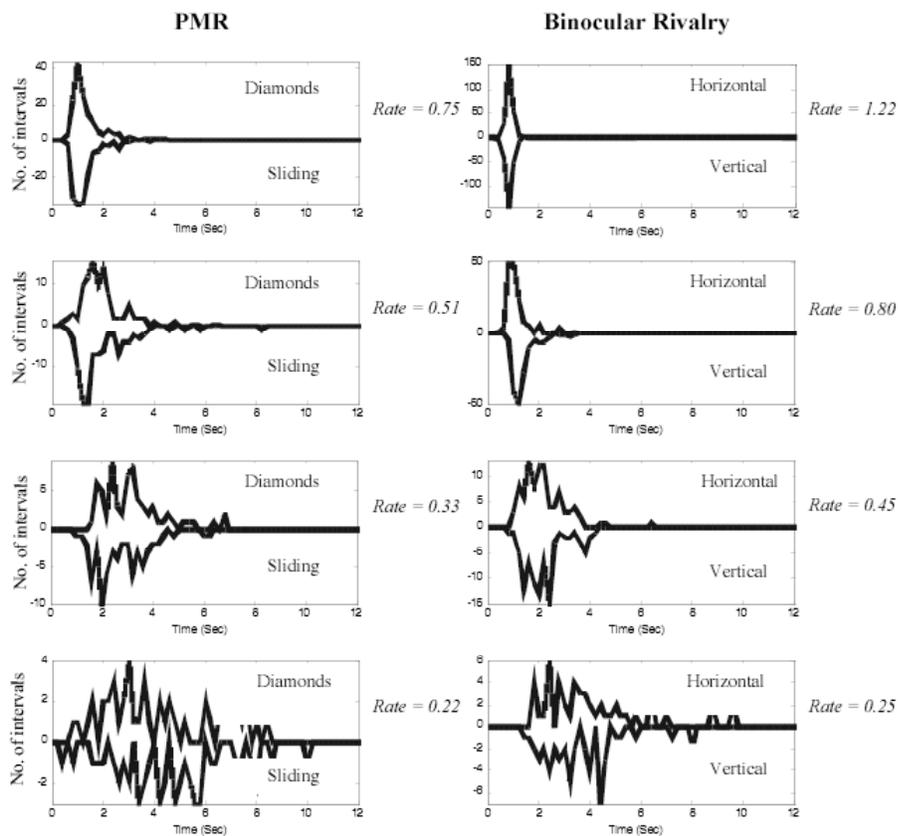


Figure 3. Examples of phase duration frequency histograms from four subjects tested on PMR and binocular rivalry. These demonstrate the inter-individual variation for both stimuli. Above the baseline represents the distribution of intervals (time between perceptual alternations) corresponding to the diamonds phase (PMR) and the horizontal lines phase (binocular rivalry). Below the baseline represents the distribution of intervals corresponding to the opposing phases of PMR (sliding) and binocular rivalry (vertical lines).

Regardless of the origin of these temporal differences the important finding is the strong inter-individual correlation between alternation rates, which suggests that the neural substrates and/or potentially different visual processes supporting the various phases of PMR and binocular rivalry are subject to a common switching mechanism. Obviously these results are open to interpretation, and while our proposed common switching mechanism may take the form of an oscillatory brainstem network (Pettigrew 2001) the results may also be equally compatible with the competition theories of rivalry. For example the recently proposed rivalry hierarchy, comprising a two-level competitive neural network model (Wilson 2003) describes the term “g”, a neural self-adaptation time constant that denotes the timing of the satiation process. Such a factor may also predict the correlated frequency aspects of rivalry, however this model and similar visual competition theories fail to address the question of rivalry phase, whose bias or relative predominance is predicted by the mood-related changes of the brainstem oscillator theory (Pettigrew 2001).

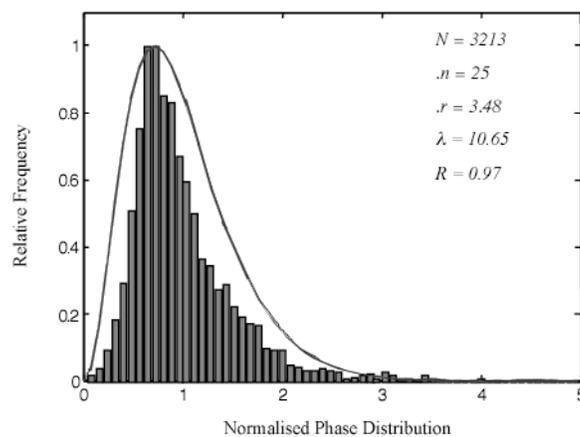


Figure 4. Frequency histogram for PMR representing the normalised distribution of the sliding/diamonds phase durations. This distribution is essentially similar to those obtained for binocular rivalry and MIB in normal volunteers. These are expressed as a fraction of the mean phase duration for all subjects. Phase durations approximate a gamma distribution. N = the total number of phase durations, n = number of subjects, R = correlation coefficient. λ and r are the values for the parameters that produce the gamma distribution that best approximates the normalised distribution of phase durations.

3 Experiment 2: The relationship between mood and PMR phases

The brainstem oscillator theory for rivalry is also sometimes referred to as the interhemispheric switching hypothesis (Miller et al 2000; Pettigrew and Miller 1998). In broad terms this original formulation suggests that part of the oscillator network (at the level of the ventral tegmental area) may function to facilitate a switch between each hemisphere's complementary viewpoint or cognitive style, and that relative hemispheric activity can bias the oscillator via feedback projections (Pettigrew 2001). This aspect of the theory, which can be interpreted in a variety of ways was partly derived from Ramachandran's formulation (Ramachandran 1994, 1995) outlining the complexity of hemispheric interactions and their respective cognitive styles. This formulation emphasizes the complementary roles of the two hemispheres: the integrative, hypothesis-driven style of the left hemisphere tends to deny discrepancies that interfere with its globally consistent, goal-orientated interpretation; whereas the veridical, discrepancy-detecting style of the right hemisphere, often referred to as an anomaly detector (Ramachandran 1995; Smith et al 2004; Smith et al 2002) is involved in actively monitoring all available information in order to highlight those discrepancies and bring them into conscious awareness.

The brainstem perceptual oscillator is therefore thought to facilitate a switch between functionally homologous regions of each hemisphere that are responsible for the formulation of alternative, but complementary perceptual interpretations, encompassing both cognitive and affective aspects of perception. With respect to

plaid perception and based upon Ramachandran's formulation, the diamonds phase consisting of a global integrated pattern of diamonds moving in a single direction would more likely be associated with the left hemisphere whereas the bi-directional and separated percepts of the complementary phase might be considered to be more in line with the discrepancy detecting style of the right hemisphere.

For binocular rivalry, hemispheric stimulation and disruption experiments (Miller et al 2000) have linked the horizontal lines phase with the left hemisphere and vertical lines with the right, however for a few volunteers these associations were found to be reversed. In general, due to a cultural bias for horizontally orientated human scripts the left hemisphere's association with horizontal lines may be related to its predisposition for language processes and sentence reading (Miller et al 2000; Pettigrew 2001).

One way to test such predictions for PMR is to investigate the relationship between rivalry phases and accepted hemispheric assignment (Pettigrew and Carter 2002), such as the lateralization of positive and negative mood states (Davidson 2001; Davidson et al 1990). For example, studies have shown that self-assessed positive and negative affect measures reliably correlate with anterior hemispheric activation asymmetry, linking a positive mood state with a dominance of activation in the anterior regions of the left hemisphere, and a negative mood state corresponding to the homologous areas of the right hemisphere (Tomarken et al 1992). Using mood measures to investigate such linkages for plaid motion rivalry will firstly determine

if perception of this stimulus reflects mood state and secondly reveal the possibility that hemispheric assignment exists for the opposing perceptual phases of PMR.

3.1 *Materials and Methods*

3.1.1 *Subjects and Procedure*

Ten subjects participating in Experiment 1 agreed to take part in this additional procedure involving the self-assessment of positive and negative mood variables. Following binocular rivalry and PMR testing, subjects completed the Positive and Negative Affect Schedule (PANAS) (Watson et al 1988). The PANAS is a simple form consisting of 10 positive adjectives (for example *interested, excited, inspired*) and 10 negative adjectives (for example *upset, hostile, scared*) that subjects rated on a scale of 1 – 5 (1 indicating the least intense and 5 corresponding to the most intense) according to how they felt during the then present moment. Each subjects' PANAS scores were calculated by adding their ratings to give an overall positive affect (PA) and a negative affect (NA) score of between 10 and 50. The proportion of diamonds phase and sliding phase experienced during PMR was calculated as a percentage of the total testing time (eg. Proportion of diamonds phase = total diamonds phase time / [total diamonds phase time + total sliding phase time]). The same calculation was also performed for the binocular rivalry data.

3.2 Results and Discussion

A significant positive correlation was found to exist between positive affect scores and the proportion of time subjects experienced the diamonds phase of PMR (Pearson's correlation coefficient, $r = 0.80$, $p < 0.005$) (Figure 5). Subjects therefore with the highest degree of self-assessed positive affect experienced the diamonds phase of PMR for a significantly greater proportion of the testing time compared with those subjects who reported lower PA scores. No relationship was found between negative affect scores and the proportion of time subjects experienced the sliding phase of PMR, however this was not surprising given the consistently low (mean score out of 50 was 14.4) and poor range of NA scores (11 – 20) recorded.

As far as we are aware this is the first time that coherent, global or integrated motion (diamonds phase) as a form of rivalry has been shown to share a relationship with positive mood state. Accordingly, perception during PMR would seem to be linked with asymmetrical hemispheric activation related to the generation of mood states, with the “positive” left hemisphere showing a preference for the diamonds phase. This linkage between the diamonds phase and the left hemisphere is also consistent with predictions based upon Ramachandran's formulation of the complementary cognitive styles of each hemisphere. The generation of alternative, complementary perceptual phases during PMR therefore follows theoretical predictions consistent with the interhemispheric switching hypothesis.

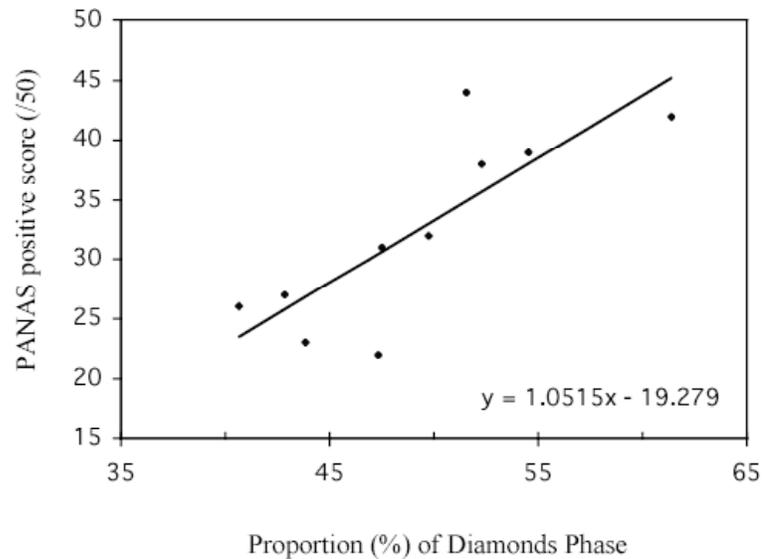


Figure 5. The relationship between diamonds phase of PMR and self-assessed positive affect as measured by PANAS ($N = 10$, $r = 0.80$, $p < 0.005$). Subjects with the highest positive mood scores experienced the diamonds phase for a relatively greater proportion of the testing time compared with those subjects who scored lower PA.

No relationship was found between affect scores and binocular rivalry phases when subjects were pooled as a group. Recent findings suggest binocular rivalry is only weakly influenced by top-down attentional processes compared to other forms of rivalry (Meng and Tong 2004; van Ee et al 2005), but there may be little connection between top-down attention effects and the mood-related bias for one phase, because MIB shows a strong mood-related correlation but is virtually immune to top-down attentional changes (Carter and Pettigrew 2003).

A likely factor in the failure to show a clear mood-related effect in the group is that individual volunteers can show perceptual changes in opposite directions, an effect explained in terms of differing individual hemispheric assignment for simple stimuli

like contours (Miller et al 2000). Strongly asymmetrical rivalries like PMR and MIB may not be subject to the same degree of inter-individual variation. Within subject design, where the volunteer is used as his/her own control, show clear mood-related effects on binocular rivalry.

To demonstrate that binocular rivalry can indeed show mood-related effects similar to those seen in other forms of rivalry, we would like to highlight the results of one of our volunteers whose pattern of perceptual alternations on both binocular rivalry and PMR were tightly coupled and appear to have been influenced by lateralized mood-related processes in a remarkably similar way. The subject's frequency histograms are displayed in Figure 6. It can be seen how longer intervals were recorded for the vertical lines phase of binocular rivalry and the sliding phase of PMR, resulting in very similar perceptual biases for these two phases.

It has previously been reported that depressed subjects display a marked bias for the vertical lines phase (reportedly linked with the right hemisphere) when tested on binocular rivalry (Pettigrew 2001). Interestingly, upon subsequent interactions with the subject, this young and healthy individual with no history of mental illness revealed that they were suffering from a mild episode of depression. Unfortunately when they were able to return to the lab two months later their depressive episode had persisted (to the extent that they were subsequently diagnosed and had commenced antidepressant medication), and upon retesting they again recorded

similarly polarised perceptual biases, with a predominance of the vertical lines phase of binocular rivalry and the sliding phase of PMR (results not shown).

Depression is a complex condition (Rotenberg 2004) and not simply a transient negative mood, however it has been associated with greater relative anterior activation of the right hemisphere (Davidson et al 2002; Tucker et al 1981). In light of this association, the subject's perceptual bias for the sliding phase and vertical lines phase is in accordance with both the cognitive style of the right hemisphere and the theoretical predictions of the interhemispheric switching hypothesis. Moreover, this result provides a clear demonstration of how patterns of perceptual alternations during binocular rivalry can also be similarly reflective of mood state.

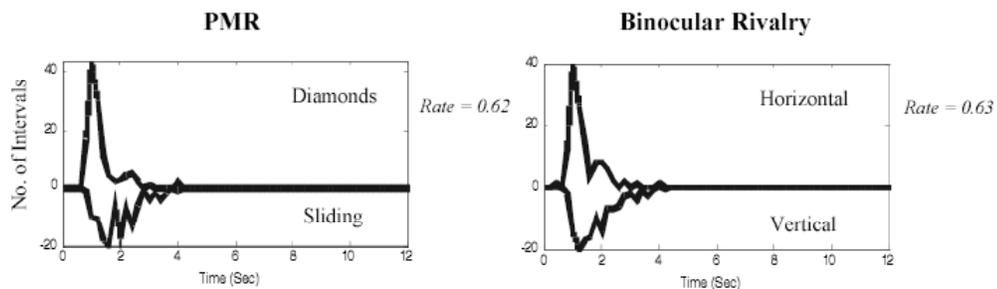


Figure 6. Distinctively similar phase duration frequency histograms for a depressed subject. These demonstrate that longer intervals were recorded for both the sliding phase of PMR and the vertical lines phase of binocular rivalry which may be linked with the right hemisphere and negative affect/depression.

4 Conclusion

For the group of subjects tested during this investigation there was a wide range of inter-individual variation in the timing of perceptual alternations induced by both binocular rivalry and plaid motion rivalry. Due to differences in stimulus strengths and characteristics, rivalry rates were slower for PMR compared with those recorded for binocular rivalry, however rates were significantly correlated across both phenomena. This suggests that while different visual/perceptual processes and neural substrates may contribute to the various perceptual phases of binocular rivalry and PMR, these processes and substrates appear to be subject to a common switching mechanism. These results are compatible with a number of theories for rivalry.

The second major finding of this investigation was that the diamonds phase of PMR, consisting of global, coherent or integrated motion appears to share a relationship with positive mood state. For one subject both a predominance of the sliding phase of PMR and the vertical lines phase of binocular rivalry appeared to demonstrate a clear association with a depressed mood state. These results provide further evidence for an emerging new dimension to the phase aspects of rivalry and present a challenge to competition theorists whose models focus primarily on processes within the visual hierarchy. While competition theories may account for the correlated frequency aspects of rivalry, such theories are yet to address how lateralized mood-related processes might distinctively influence the temporal pattern of rivalry phases. Overall the results of this investigation are consistent with

theoretical predictions of the brainstem oscillator theory and its interhemispheric switching hypothesis.

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