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Seeing it both ways: Openness to experience and binocular rivalry suppression

Anna Antinori, Olivia L. Carter, Luke D. Smillie *

Melbourne School of Psychological Science, University of Melbourne, Parkville, Victoria, Australia

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ABSTRACT

Openness to experience is characterised by flexible and inclusive cognition. Here we investigated whether this extends to basic visual perception, such that open people combine information more flexibly, even at low-levels of perceptual processing. We used binocular rivalry, where the brain alternates between perceptual solutions and times where neither solution is fully suppressed, mixed percept. Study 1 showed that openness is positively associated with duration of mixed percept and ruled out the possibility of response bias. Study 2 showed that mixed percept increased following a positive mood induction particularly for open people. Overall, the results showed that openness is linked to differences in low-level visual perceptual experience. Further studies should investigate whether this may be driven by common neural processes.

1. Introducion

Trait *openness to Experience* (hereafter, openness) represents a scientific frontier in personality psychology —it was the last of the five major personality domains to gain acceptance, and is still the least well understood (for a recent review see DeYoung, 2014). A common theme linking the various characteristics described by Openness is flexible and inclusive cognition: Open people are more curious, creative (Kaufman et al., 2016; Silvia et al., 2008) and motivated to explore the world and engage with possibilities (DeYoung, 2014; McCrae & Costa, 1997). People high in openness may even *experience* the world differently to the average person as a result of their "breadth, depth, and permeability of consciousness, and ...[their]... recurrent need to enlarge and examine experience" (McCrae & Costa, 1997, p. 826). In this paper, we ask whether this tendency toward inclusive cognition — which we could think of as increased flexibility in binding of different representational elements in the brain — extends to basic visual perception. This objective is in line with recent research showing that stable difference in personality mirror differences in structural and functional properties of the brain (Passamonti et al., 2015). Our interest here is to determine whether similar relations between personality and visual perceptual processing exist.

Several previous studies indirectly suggest that open people experience things differently: For instance, openness predicts performance on divergent thinking tasks (Kaufman et al., 2016; Silvia et al., 2008), which require one to identify multiple diverse uses for ordinary objects. For open people this seems to happen effortlessly, suggesting a more flexible way of combining information, perhaps even at low-levels of perceptual processing. For example, people high in openness display reductions in *latent inhibition* (i.e., attenuated attentional processing following repeated stimulus exposure) suggesting individual differences in pre-conscious attentional mechanisms (Peterson & Carson, 1999; Peterson, Smith, & Carson, 2002). Latent inhibition reflects an adaptive attentional 'gating' system for screening out irrelevant information, but for open people this system appears to be more flexible, resulting in continued processing of stimuli from which the average individual has disengaged. However, we are aware of no previous research examining whether openness relates to how people actually *see* visual stimuli.

To address this question, we examined how openness relates to the well-known perceptual phenomenon called *binocular rivalry*, where contrasting stimuli are presented simultaneously to each eye (for a review see Tong, Meng, & Blake, 2006). When faced with this incompatible visual information, observers typically report alternation or 'flipping' between these two continuously presented stimuli every few seconds. Interestingly, another perceptual experience called 'mixed percept' occasionally occurs between these serial alternations. In these cases the two stimuli appear fused into one, and complete suppression of either stimulus is inhibited

* Corresponding author at: Melbourne School of Psychological Sciences, Faculty of Medicine, Dentistry & Health Sciences, University of Melbourne, 3010 Victoria, Australia.
E-mail address: lsmillie@unimelb.edu.au (L.D. Smillie).

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(Yang, Rose, & Blake, 1992). The processes underlying mixed percept remain unclear, with some authors suggesting a role of neural plasticity (Klink, Brascamp, Blake, & van Wezel, 2010) and others emphasizing an imbalance of excitatory and inhibitory neural activity (Said, Egan, Minshew, Behrmann, & Heeger, 2013). One interesting feature of mixed percept, however, is that it shows between-person variability and within-person stability over time (Miller et al., 2010), suggesting a possible relation with personality.

In this paper, we hypothesised that the susceptibility to the mixed percept experience may be related to openness. Because openness reflects the tendency to actively explore information and engage with complex possibilities (DeYoung, 2014), people high in openness may also be more likely to experience creative solutions to the incompatible rivalry stimuli. Furthermore, the sustained processing of non-instrumental stimuli by open people during latent inhibition (Peterson & Carson, 1999; Peterson et al., 2002), may also occur during rivalry, thereby impeding the complete suppression of either percept. If openness does indeed predict mixed percept, it would constitute the first empirical evidence that open people may have different *visual* experiences to the average individual.

To investigate this in study 1 we conducted two experiments. In the first experiment we presented individuals with a simple binocular rivalry task (red and green orthogonal gratings to alternate eyes) and administered the Big Five Aspects Scales (BFAS; DeYoung, Quilty, & Peterson, 2007) which includes a measure of Openness/Intellect (O/I). This compound label reflects an early debate about how to best conceptualise the fifth personality domain (see Saucier, 1992), and the full scale can be divided into separate openness and intellect sub-scales. While intellect is conceptualised as engagement with semantic or abstract information, openness is conceptualised as engagement with aesthetic or perceptual information (DeYoung, 2013, 2014). In line with this, intellect (but not openness) predicts working memory performance (DeYoung, Shamosh, Green, Braver, & Gray, 2009) while openness (but not intellect) predicts implicit learning of patterned sequences (Kaufman et al., 2010). Given the inherently perceptual nature of the mixed percept phenomenon, we therefore hypothesised openness more so than intellect would be associated with mixed percept.

In the second experiment (study 1b) we sought to rule out the possibility that open people report more incidence of mixed percept simply because they have a more lenient response threshold for reporting more mixed. To do so, we manipulated the size of the visual stimuli. The incidence of mixed percept reported during a 'typical' rivalry task is characterised by individual differences (Miller et al., 2010). However, the *absolute duration* of mixed percept is also sensitive to the stimulus characteristics. Specifically, the overall incidence of mixed percept increases with larger stimulus size, reflecting physiological properties of the visual cortex (for a more detailed description of the phenomenon see Blake, O'Shea, & Mueller, 1992). Thus, by using larger stimuli we predicted that the increased contribution of low-level properties of the visual cortex would lead to a reduction of the influence of personality on one's perceptual experience when viewing the task.

In study 2, we administered the same rivalry task following a positive mood induction procedure involving perceptually and aesthetically pleasing imagery, to which open people appear particularly responsive (Fayn, MacCann, Tiliopoulos, & Silvia, 2015; McCrae, 2007; Silvia & Nusbaum, 2011). This served the purpose of exploring whether differences in one's perceptual experience may be influenced not only by stable factors (personality) but also by transient states (mood). With respect to the effects of mood on perceptual rivalry, a number of studies have shown that mood can alter the competition for visual awareness by favouring the stimulus congruent to one's mood (Anderson, Siegel, & Barrett, 2011). In addition, positive mood tends to specifically decrease observers' inhibitory control in filtering unattended information, favouring more inclusive processing (Rowe, Hirsh, & Anderson, 2007). Finally, contextualised perspectives on personality (e.g., DeYoung, 2015; Tett & Guterman, 2000) suggest that effects of personality will be most pronounced in the context of trait-relevant stimuli or situations. In the case of the current study we were interested in whether one mood condition in particular would act as a trait-relevant cue especially for open people. This would be expected to increase the relative impact of factors associated with openness on perceptual processing and lead to an increased susceptibility to experiencing the mixed percept for open people.

2. Study 1

2.1. Method

2.1.1. Participants

We recruited 134 University of Melbourne undergraduate students, who participated in the research for course credit. All participants had normal or corrected to normal vision. We excluded 11 participants prior to analysis: 5 because they did not report alternating stimuli, indicating that rivalry did not occur, and 6 because they responded for less than 50% of the total duration of the trial. There was therefore a final N of 123 participants (30% Male, aged $M = 19.49$, $SD = 2.92$). This sample provides 80% power to detect the average effect size in personality psychology (i.e., $r \sim 0.25$; Fraley & Marks, 2007). All studies were approved by the University of Melbourne Human Research Ethics Committee, in accordance with the Declaration of Helsinki.

2.1.2. Personality questionnaire

The Big Five Aspects Scales (BFAS) DeYoung et al. (2007) is a 100-item measure of the Five Factor Model (McCrae & Costa, 1987). It provides assessment of each of the five *domains* (Extraversion, Neuroticism, Agreeableness, Conscientiousness, and O/I) along with each of their two lower level *aspects* (DeYoung et al., 2007). Respondents indicate the extent to which they agree or disagree with each of the items on a 5-point rating scale ranging from 1 (strongly disagree) through 3 (neutral) to 5 (strongly agree). Cronbach's alpha for each trait domain and its component was acceptable (see Table 2).

2.1.3. Binocular rivalry

2.1.3.1. Apparatus and stimuli. The rival targets were stationary green and red gratings (stimulus sizes 1.4°, with a spatial frequency of 4 cpd) oriented ±45° from vertical, within a circular frame. Stimuli were generated in Matlab™ using the Psychophysics Toolbox extension (Brainard, 1997; Pelli, 1997), displayed on an Apple computer monitor (23-in. monitor, 60 Hz frame rate, 1280x800pixel resolution), and viewed through a mirror stereoscope (viewing distance 33 cm).

2.1.3.2. Instructions. Participants were instructed to continuously report what they were experiencing via key press. When perceiving the red or green grating they had to press and hold down the left or right arrow key, respectively. Participants were instructed to report any instances of mixed percept (time where the two stimuli appeared as a grid or patchwork combination of the two percepts) by holding down both the left and right arrow keys simultaneously.

2.1.3.3. Response recording. Data were recorded continuously throughout a single 120 s trial. While some rivalry studies use multiple short (e.g., 10–20 s) trials, we opted for a single 120 s trial to

Table 1
Correlations between mixed percept and personality traits (Study 1 and 1b).

Big aspect scales (BFAS)	Mixed percept		
	Study 1 (n = 123)	Study 1b Replication (n = 79)	Study 1b larger stimuli (n = 79)
Openness/intellect	0.22**	0.22*	0.02
Openness	0.15*	0.15	0.04
Intellect	0.18*	0.20*	0.08
Conscientiousness	0.05	−0.08	0.001
Orderliness	0.04	−0.20	−0.07
Industriousness	0.08	0.10	0.06
Extraversion	0.22*	−0.06	−0.01
Enthusiasm	0.08	−0.07	−0.05
Assertiveness	0.27**	−0.02	0.08
Agreeableness	0.01	0.23*	0.16
Politeness	−0.08	0.19	0.11
Compassion	0.08	0.19	0.15
Neuroticism	−0.23**	−0.09	−0.03
Withdrawal	−0.09	−0.16	−0.16
Volatility	−0.24**	−0.02	0.06

Note:
* $p < 0.05$.
** $p < 0.001$.

reduce the impact of stimulus onset, which is often associated with an initial period of fusion (Wolfe, 1983) or strong biases in perceptual state that are distinct from sustained viewing conditions (Carter & Cavanagh, 2007; Stanley, Forte, & Cavanagh, 2011). Prior to the experimental task, participants underwent a 60 s training session to ensure they understood the instructions. Mixed percept was calculated as the total duration that participants pressed both the left and right arrow keys simultaneously for at least 220 ms (this threshold was chosen as a consequence of the response sampling rate and the desire to exclude the very brief periods of dual button response during transitions between left and right arrow presses). The calculated duration was then expressed as a percentage of the trial duration (% Mixed).

2.2. Results

As reports of mixed percept were severely skewed, Spearman's rank-order correlation was used to examine the association between mixed percept ($M = 0.11$; $SD = 0.09$) and personality. Mixed percept was positively correlated with O/I and extraversion, and negatively correlated with neuroticism (see Table 1; for full correlation matrix see Supplementary material Table 1). These correlations are unlikely to be independent, and are consistent with the existence of higher order traits located 'above' the Big Five (DeYoung et al., 2007). Indeed, after accounting for the relation between O/I and mixed percept within a hierarchical regression, $F(1,122) = 5.15$, $p = 0.025$, the remaining Big Five domains did not account for significant incremental variance, $F^{ch}(4,117) = 2.13$, $p = 0.081$, nor contribute uniquely to prediction (all $ps > 0.05$; see Table 2).

In the current study we focused on mixed percept. Findings previously published by our group provide a more detailed account of the impact of personality and mood on switch rate (Antinori, Smillie, & Carter, 2017). Of most relevance to the current studies is the finding that people reporting more mixed percept are also characterised by shorter mean percept durations so it is not the case that people report longer periods of mixed percept because they generally switch more slowly between states and end up with a higher proportion of mixed percept reported overall. There was no significant relation between openness /intellect and mean percept duration (a significant correlation was seen with industriousness) or mood manipulation (Antinori et al., 2017).

3. Study 1b (Control and Replication)

3.1. Method

3.1.1. Participants

A new sample was recruited consisting of 79 University of Melbourne undergraduates who participated in exchange for course credit (19% Male, aged $M = 19.47$, $SD = 3.48$). All participants had normal or corrected to normal vision.

3.1.2. Binocular rivalry

3.1.2.1. Apparatus and stimuli. Two different stimulus sizes were used: small (1.4°) —identical to study 1 — and large (2.3°). The two stimuli sizes were presented twice to all participants in blocks of 60 s in random order (i.e., 240 s total). Personality measures were identical to study 1(alpha values provided Table 2). All other apparatus, instructions and stimuli characteristics were identical to the first experiment in study 1.

3.2. Results

As expected, when using larger stimuli there was no relation between mixed percept and any BFAS personality traits, including near-zero correlations with I/O and its two subscales. Conversely, when using the smaller stimuli, identical to that used in study 1a, the previously observed correlation with O/I was replicated (see Table 1, the full correlation matrix for this analysis is available in Supplementary material Table 2). With respect to the impact of stimulus size on mixed percept, an increase in mixed percept was observed only when comparing study 1 ($M = 0.11$, $SD = 0.12$) to the bigger stimuli used in study 1b (bigger stimuli $M = 0.28$, $SD = 0.16$).

Table 2
Summary of hierarchical regression analysis for variables predicting mixed percept.

Variable	Model 1			Model 2		
	B	*SE B*	*β*	*B*	*SE B*	*β*
Constant	−0.85	3.31				
Openness/intellect	2.07	0.91	0.20*			
Constant				3.66	6.54	
Openness/intellect				1.20	0.97	0.12
Neuroticism				−1.25	0.81	−0.15
Extraversion				2.03	1.01	0.20
Agreeableness				−0.29	1.06	−0.02
Conscientiousness				−1.19	0.89	−0.13
R^2		0.04			0.11	
F for change in R^2		5.15*			2.13	

Note. N = 123.
* $p < 0.05$.

On the other hand, no significant effect of stimulus size on mixed percept was seen within study 1 ($M = 0.27$; $SD = 0.12$).

To probe these results further, we ran a further analysis to investigate whether open people not only perceive a greater duration of mixed percept, but also perceive it more frequently. However, in neither study 1 nor study 1b did openness, or its two lower-order aspects correlate with the number of mixed percept responses. With respect to the relation of the number of mixed percept responses and other personality traits, in study 1 the there was a (negative) correlation only with neuroticism $r(128) = -18$, $p = 0.04$, while in study 1b no traits were correlated with the number of mixed percept responses ($p > 0.05$).

In summary, the relation between O/I and mixed percept was successfully replicated in a new sample of participants when using the original stimulus size. However, when a larger stimulus is used (increasing the relative contribution of neurophysiological properties of early visual cortex) the relation with personality was no longer maintained. This finding is important as it gives us confidence that the effect is a true impact of personality on perception rather than an artefact reflecting a response bias of open individuals having a lower criteria threshold for reporting mixed percept. This is because any influence of response bias should be insensitive to stimulus size.

4. Study 2

4.1. Method

4.1.1. Participants

A third sample was recruited consisting of 91 University of Melbourne undergraduates who participated in exchange for course credit (28% Male, aged $M = 19.06$, $SD = 2.50$). The number of participants was informed by previous research using this paradigm (e.g., Smillie, Cooper, Wilt, & Revelle, 2012). Each subject was randomly assigned to either one of the three experimental conditions: Neutral (n = 33), Pleasant (n = 29), and Appetitive (n = 29), described below.

4.1.2. Apparatus and stimuli

All rivalry stimuli/instructions and personality scales were described in study 1a (alpha values provided in Table 3).

4.1.3. Guided imagination procedure

Participants were tested individually in a dimly lit testing booth. The guided imagination task presents short vignettes via a computerized slideshow and accompanying music via headphones, and has been used previously for inducing mood states (see Smillie et al., 2012). Each vignette (3 per condition) described a different scenario and remained on the screen for 2 min. Scenarios in the Pleasant condition involved vivid descriptions of aesthetically pleasing imagery (e.g., "*You are walking peacefully through a quiet and picturesque forest*"). As a control condition, three neutral scenarios described daily mundane situations, Neutral condition (e.g., "*You are putting a few things away in the kitchen on a weekend afternoon*"). As a second control condition, three appetitive scenarios described positive, rewarding events that had no salient aesthetic or perceptual features (e.g., *You buy a lottery ticket and win $10,000 instantly*). Participants were instructed to imagine how they would feel and what they would think in each different scenario. The music used for each mood condition was: Venus from "The Planets" by Holst for the Pleasant condition; Waltz of the Flowers from the "Nutcracker Suite" by Tchaikovsky for the Appetitive condition; the Largo movement from "The New World Symphony" by Dvorak for the Neutral condition.

4.1.4. State affect

To test the impact of the guided imagery procedure on mood, participants were asked to rate on a 4-point Likert scale ranging from 'Not at all' to 'Very well' how much their current feelings ("right now") matched a list of four items drawn from the 12-Point Affect Circumplex Questionnaire (12-PAC; Yik, Russell, & Steiger, 2011). It was expected that the Pleasant condition would elicit positive pleasant mood (items: *relaxed, content*) while the Appetitive condition would elicit activated positive mood (items: *excited, lively*).

4.2. Procedure

Participants firstly completed a baseline measure of state affect. They then underwent the mood induction procedure they were assigned to. At the end of the mood induction participants filled the post-mood induction state affect, before then performing the binocular rivalry task. While performing the binocular rivalry task, participants continued to listen to the music that had accompanied the mood induction procedure. Finally, participants completed the BFAS questionnaire.

4.3. Results

4.3.1. Preliminary statistics

A One-Way Analysis of Variance (ANOVA) for independent groups confirmed that experimental groups did not differ significantly in any of the personality traits or baseline affect measures (see Table 3).

4.3.2. Mood induction

To confirm that the mood induction procedure had its intended effect, we conducted a mixed ANOVA 2 (pre/post) × 2 (activated/pleasant positive) × 3 (mood condition). This resulted in a significant three-way interaction, $F(2,88) = 39.47$, $p < 0.001$, $\eta_p^2 = 0.47$, indicating that the pre-post change in affect was influenced both by mood conditions and affect type. As expected, pleasant positive affect significantly increased in the Pleasant condition $t(28) = -4.22$, $p < 0.001$, $\eta^2 = 0.40$ and decreased in the Appetitive condition $t(28) = 3.58$, $p < 0.001$, $\eta^2 = 0.32$ but did not change in the Neutral condition $t(32) = -1.79$, $p = 0.08$. Moreover, activated positive affect significantly increased in the Appetitive condition, $t(28) = -4.40$, $p < 0.001$, $\eta^2 = 0.42$, and decreased in the Pleasant condition $t(28) = 3.92$, $p < 0.001$, $\eta^2 = 0.36$, but did not change in the Neutral condition $t(32) = 1.49$, $p = 0.15$.

4.3.3. Pleasant, aesthetic imagery and mixed percept

We then examined whether the vivid aesthetic imagery in the Pleasant condition resulted in increased mixed percept, compared to the two control conditions. As the homogeneity of variance assumption was violated ($p = 0.001$), Brown-Forsythe F tests was performed, revealing a significant effect of mood condition on percentage of mixed percept, $F(2,66.101) = 3.78$, $p = 0.03$, $\eta^2 = 0.80$. Moreover, planned contrasts confirmed that those in the Pleasant condition reported a marginally greater duration of mixed percept ($M = 0.17$, $SD = 0.12$) compared to those in the other two conditions (Neutral $M = 0.14$, $SD = 0.09$; Appetitive $M = 0.10$, $SD = 0.06$), $t(38.162) = 2.01$, $p = 0.05$ Cohen's $d = 0.65$ (see Fig. 1). Unexpectedly, however, this difference was significant relative only to the appetitive ($p = 0.02$) but not the neutral condition ($p = 0.40$).

We then used moderated regression to examine whether the effect of our pleasant mood induction on mixed percept was more pronounced for open individuals. This showed that the relation between openness and mixed percept differed between the neutral and pleasant conditions, $b = 0.11$, 95% CI [0.014, 0.204], $t = 2.31$, $p = 0.02$, and between the pleasant and appetitive conditions,

Table 3
Descriptive statistics for all experimental groups for all experiments.

	Study personality		Study mood		
Variable	Study 1	Study 1b	Pleasant	Neutral	Appetitive
Openness/intellect	3.59_a	3.58_a	3.58_a	3.63_a	3.65_a
	0.52	0.47	0.39	0.52	0.72
	(.86)	(.85)	(.72)	(.79)	(.90)
Openness	3.68_a	3.71_a	3.74_a	3.85_a	3.66_a
	0.64	0.61	0.61	0.64	0.77
	(.79)	(.80)	(.72)	(.78)	(.82)
Intellect	3.49_a	3.45_a	3.42_a	3.41_a	3.64_a
	0.62	0.59	0.55	0.72	0.89
	(.79)	(.85)	(76)	(.82)	(.92)
Conscientiousness	3.15_a	3.17_a	2.99_a	2.98_a	3.30_a
	0.58	0.52	0.54	0.51	0.62
	(.82)	(.80)	(.81)	(.88)	(.86)
Orderliness	3.25_a	3.27_a	3.07_a	3.11_a	3.44_a
	0.68	0.69	0.65	0.68	0.76
	(.81)	(.77)	(.72)	(.86)	(.81)
Industriousness	3.06_a	3.07_a	2.90_a	2.84_a	3.17_a
	0.68	0.56	0.64	0.53	0.63
	(.87)	(.82)	(.79)	(.79)	(.77)
Extraversion	3.46_a	3.48_a	3.50_a	3.53_a	3.35_a
	0.54	0.49	0.55	0.59	0.61
	(.91)	(.90)	(.89)	(.91)	(.89)
Enthusiasm	3.67_a	3.71_a	3.79_a	3.80_a	3.53_a
	0.61	0.66	0.67	0.60	0.74
	(.86)	(.87)	(.87)	(.85)	(.90)
Assertiveness	3.24_a	3.24_a	3.22_a	3.26_a	3.16_a
	0.66	0.57	0.56	0.72	0.66
	(.89)	(.87)	(.81)	(.89)	(.86)
Agreeableness	3.96_a	3.95_a	3.97_a	3.96_a	3.85_a
	0.44	0.44	0.45	0.42	0.67
	(.84)	(.80)	(.85)	(.70)	(.74)
Politeness	3.84_a	3.83_a	3.83_a	3.81_a	3.72_a
	0.50	0.50	0.55	0.52	0.75
	(.72)	(.78)	(.82)	(.84)	(.82)
Compassion	4.06_a	4.06_a	4.10_a	3.82_a	3.98_a
	0.61	0.57	0.55	0.52	0.69
	(.87)	(.82)	(.81)	(.89)	(.85)
Neuroticism	2.84_a	2.96_a	2.75_a	2.95_a	2.92_a
	0.65	0.62	0.54	0.59	0.60
	(.90)	(.87)	(.86)	(.89)	(.79)
Withdrawal	3.09_a	3.09_a	2.94_a	3.00_a	3.06_a
	1.53	0.61	0.58	0.59	0.67
	(.81)	(.80)	(.76)	(.77)	(.77)
Volatility	2.73_a	2.85_a	2.55_a	2.90_a	2.77_a
	0.76	0.75	0.66	0.81	0.68
	(.88)	(.82)	(.81)	(.90)	(.82)
Pre-pleasant positive			6.03_a	6.17_a	6.00_a
			1.23	0.80	1.28
			(.72)	(.79)	(.77)
Post-pleasant positive			7.07_a	6.39_a	5.17_b
			0.96	1.30	1.95
			(.70)	(.78)	(.75)
Pre-active positive			4.96_a	4.39_a	5.03_a
			0.98	1.17	1.15
			(.71)	(.77)	(.78)
Post-active positive					
			4.27_a	4.15_a	6.10_b
			1.25	1.17	1.14
			(.77)	(.72)	(.74)

Note. Mean = upper row, standard deviations = middle row, cronbach's alpha = lower row. Between each study/experiment mean in the same row with different subscripts differ significantly, $p < 0.05$.

$b = 0.10$, 95% CI [0.028, 0.171], $t = 2.79$, $p = 0.01$. This interaction is depicted in Fig. 2. In contrast to these findings, the relation between intellect (i.e., the other aspect of O/I) and mixed percept did not differ between the neutral and pleasant condition $b = 0.05$, 95% CI [−0.045, 0.147], $t = 1.06$, $p = 0.29$, nor between the pleasant and appetitive conditions $b = 0.05$, 95% CI [−0.039, 0.142], $t = 1.14$, $p = 0.26$. The full correlation matrix of BFAS and Mixed percept for each mood condition is available in Supplementary material (See Supplement material Tables 3–5).

5. Discussion

Openness to experience has long been associated with flexible and inclusive cognition, as shown by its links with liberal values (Xu, Mar, & Peterson, 2013) and creativity (Kaufman et al., 2016; Silvia et al., 2008). Studies also demonstrated that open people flexibly engage with the environment by processing stimuli that others tend to ignore (Peterson et al., 2002). Building on this literature, our three studies show this flexibility extends to basic, low-

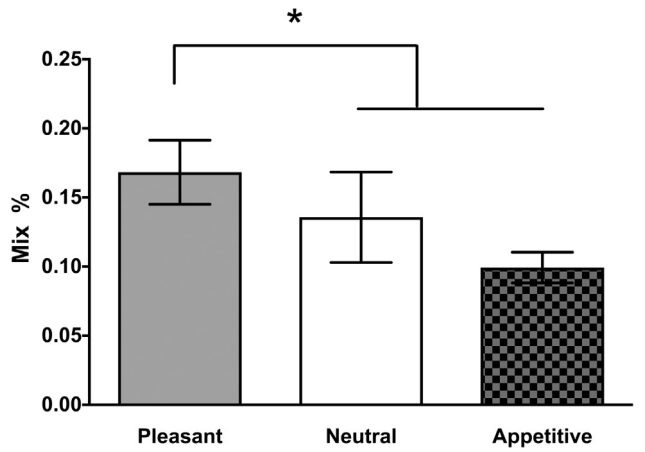

Fig. 1. Mix% for different mood manipulation. $^{*}p < 0.05$. Error bars represent SEM.

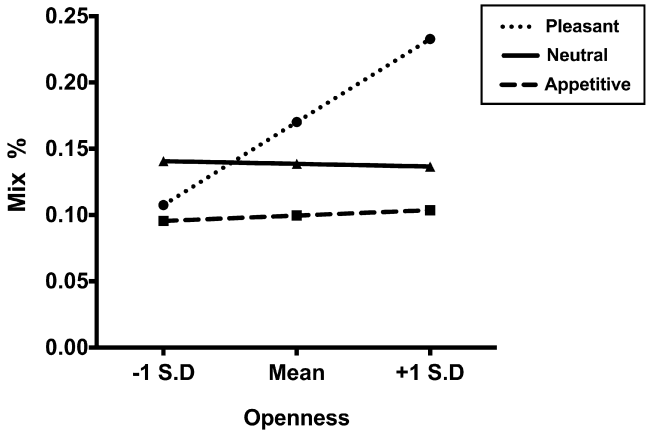

Fig. 2. Relation between openness and mix percept following different mood manipulations (Pleasant, Neutral, Appetitive). To note the increase of mix in the pleasant condition characterised by perceptual-aesthetic elements for participants high in openness (1 *SD* above the mean trait).

level visual perceptual experience: Just as open people are often described as being able to 'see' more opportunities when presented with familiar objects (Silvia et al., 2008), we provide the first evidence that they may literally also 'see' more possibilities, in that they identify more flexible ways of combining information within basic visual stimuli.

Our findings used the classic binocular rivalry paradigm, during which perceptual experience typically alternates between two stimuli presented to each eye, but occasionally comprises a perceptual solution encompassing aspects of each stimulus (i.e., mixed percept). Our first study confirmed our hypothesis that open people are more susceptible to this inclusive perceptual experience than their less open counterparts—a result replicated in the control experiment of study 1b. In line with current theory and research linking openness with perceptual processing and intellect with semantic processing (DeYoung, 2013, 2014), we predicted mixed percept would be related only to the openness aspect of O/I. However, this pattern of divergence did not emerge, with the intellect aspect of the scale (vs. openness) contributing more strongly to the relation with mixed percept in both samples. This suggests that the roles of openness and intellect in perceptual processing may be less distinct than first thought. A similar interpretation might be reached from the observation by Fayn et al. (2015) that both openness and intellect predicted reactivity to novelty in visual art stimuli. Also unexpected were the correlations between mixed percept and other traits of the Big Five (e.g., with extraversion in study 1, and agreeableness in study 1b). However these associations disappeared after controlling for O/I, and were not replicated across our studies. In contrast, the relation between O/I and mixed percept was robust across our three samples. Our follow-up study 1b was jointly motivated to assess the reproducibility of the results obtained in study 1 while also ruling out response bias toward reporting mixed percept. Our data showed that under identical stimulus conditions, the relation between openness and mixed percept was replicated in an independent sample. Critically, however, this association disappeared with larger rivalry stimuli. If the increased reports of mixed percept resulted from an increased tendency for open individuals to simply report their percept as mixed, then this pattern should have been seen with both sets of stimuli. However, as the contribution of low-level cortical properties on mixed percept is thought to be greater when using larger stimuli (Blake, O'Shea, & Mueller, 1992), we predicted and found that the impact of personality was reduced. Thus, providing strong evidence of genuine differences in the visual experience of open people.

The lack of relationship found in the current paper between mixed percept and any personality traits, when using bigger stimuli, is interesting in its own right. To date, relatively few studies have specifically investigated mixed percept. Although it is well accepted that the competition between rivalrous images occur at multiple stages in the visual hierarchy, where mixed percept occurs remains unclear. However, when using larger stimuli our data together with Blake et al.'s study (1992), suggests that mixed percept may be influenced more by low-level visual processes, rather than higher factors.

In study 2 we explored the effect of guided imagination of perceptual and aesthetic stimuli on mixed percept. In line with the activation theory (Tett & Guterman, 2000, see also DeYoung, 2015), which states that trait-relevant cues and stimuli activate trait-relevant processes, we predicted that the aesthetic stimuli in our guided imagination procedure would increase the susceptibility of open people to experiencing the mixed percept. Results provided support for this hypothesis with open people reporting more mixed percept following imagination of pleasant aesthetic imagery. This finding is consistent with the idea that particularly the openness subfactor is characterised by the engagement with the perceptual/aesthetic information. This also shows that a 'transient' manipulation of an internal state can have a clear effect on one's visual experience and that rivalry is sensitive not only to 'stable' variables, such as personality, but also to 'transitory' ones, such as mood.

Results from our guided imagination procedure were only partly in line with our predictions, with mixed percept increasing in the Pleasant condition only compared to one control condition (Appetitive), but not the other one (Neutral). This may suggest Neutral vignettes were more perceptually salient than we anticipated. For instance, one vignette describes driving along a long straight road, which may have triggered imagination of expansive (if affectively muted) landscapes. Despite this, our primary prediction was supported, as the impact of the Pleasant condition on mixed percept was indeed strongest for people high in openness.

With respect to the potential underlying mechanisms that may connect mixed percept and O/I, we speculate a common or overlapping neurochemical basis. For instance, Openness/Intellect has been linked with both dopamine (DeYoung, 2013) and serotonin (Kalbitzer et al., 2009). Similarly, rivalry alternations have been linked with a number of neurotransmitters, including serotonin (Carter et al., 2005, 2007), noradrenaline (Einhäuser, Stout, Koch, & Carter, 2008), and GABA (van Loon et al., 2013).

Little research has specifically investigated the mixed percept state, however, one recent study (Cao, Zhuang, Kang, & Hong,

2016) found that acute alcohol administration lead to an increase of mixed percept. Interestingly psylocibin— an hallucinogenic compound structurally similar to serotonin—has also been shown to increase instances of mixed percept (Carter et al., 2007) and is known to have has selective, long-lasting effects on trait openness (MacLean, Johnson, & Griffiths, 2011). Out of curiosity we compared effect sizes reported here with the previously reported effects of psilocybin on mixed percept (215 mg dose; Carter et al., 2007). The effect of psilocybin was equivalent to a Cohen's *d* of 0.93 and approximately twice as large as the effects reported in the current study (i.e., a correlation of r = 0.21 equates to a Cohens' *d* of 0.45). Assuming these effect sizes are reliably estimated, they potentially suggest that the impact of being two standard deviations above the mean on openness — a normally distributed personality trait — may be comparable to that of a direct pharmacological manipulation, with respect to the experience of mixed percept.

Future research investigating such mechanisms may clarify the processes underlying both binocular rivalry and openness to experience. Furthermore, another way future studies may build upon the current findings is to investigate the relation between openness and mixed percept across multiple rivalry sessions within each participant. Although rivalry is reported to show high test-retest stability (Miller et al., 2010), using multiple extended response trials may help to reduce any impact of noise in the data and allow for within-subject replication of the present findings, adding further support to our conclusions. While the primary findings were replicated in a different sample we suspect that the relations emerged between openness and mixed percept would be even stronger with rivalry tested in multiple sessions. Future studies would also benefit from testing more participants, however it is important to note that the effect sizes reported in the current paper were close to the average effect size within personality research for variables not sharing method variance (Richard, Bond, & Stokes-Zoota, 2003) and within the middle third of effect sizes in the whole of psychology (Hemphill, 2003).

In conclusion, we provided the first evidence that individuals reporting greater openness to experience may also have characteristically different low-level visual perceptual experiences. Given the apparent similarity between the higher cognitive features of openness (e.g., divergent thinking) and the lower-level features revealed in the present research (i.e., mixed percept), it is possible that common neural processes may be involved.

Author contribution

All authors developed the study concept and contributed to the study design; A. Antinori collected the data; A. Antinori and L. Smillie performed the data analyses; A. Antinori drafted the manuscript; L. Smillie and O. Carter provided critical revisions to the manuscript. All authors approved the final version of the manuscript for submission.

Declaration of conflict interests

The authors declared that they had no conflict of interest with respect to their authorship or the publication of this article.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jrp.2017.03.005.

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