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Open and empathic personalities see two things at the same time: the relationship of big-five personality traits and cognitive empathy with mixed percepts during binocular rivalry

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Abstract
Does our personality predict what we see? This question was studied in 100 university students with binocular rivalry paradigm by presenting incompatible images to each eye, allowing multiple interpretations of the same sensory input. During continuous binocular presentation, dominance of perception starts to fluctuate between the images. When neither of the images is fully suppressed, the two images combine into mixed percepts. We focused on the link between mixed percepts, big-five traits, and empathy. The results revealed that openness and agreeableness correlated with the occurrence of mixed percepts after the first dominant perception. However, these correlations of openness and agreeableness were mediated by cognitive empathy. In addition, openness had a direct association with reporting the initial percept in the onset of stimulation as a mixed percept, suggesting a mechanism that is separate from the one mediated by cognitive empathy. Overall, the results provide preliminary evidence suggesting that personality predicts what we see. Such individual differences in perceptual interpretations may be linked to both higher level cognitive mechanisms as well as lower level visual mechanisms.

Keywords Big-5 · Binocular rivalry · Empathy · Visual perception

Introduction

Binocular rivalry occurs when two sufficiently different images are presented simultaneously to each eye: the observer does not usually see them both at the same time but the images compete for access to consciousness (Blake, 2001). During continuous presentation, only one of the images dominate conscious perception at a time and observers typically experience alternations in the dominance even though the stimuli stay physically the same. To resolve the ambiguity between the inputs, the brain alternates the images in trying to solve the unstable situation by a single perceptual interpretation. Alteration rate, referring to the frequency of the dominance changes during binocular rivalry, varies between individuals (Miller et al., 2010). From the view of personality research, the phenomenon is interesting as the sensory input does not change, whereas the dominance and its alterations thus depend on the interpretation of the observer. This phenomenon provides a unique way to study whether personality affects what we see.

Different mechanisms at various levels of the visual system are responsible for initiating binocular rivalry and selecting the stimuli that become and stay dominant at a certain time (Tong et al., 2006; Wilson, 2003). According to a common explanation, two groups of neurons, coding the two images from the eyes, engage in excitatory-inhibitory interaction with each other (Blake, 2001). The switching of percepts is assumed to occur when the dominant percept is being weakened by cumulating adaptation, allowing the previously inhibited stimuli to become dominant. Increasing inhibition will enhance the strength of perceptual suppression (Klink et al., 2010), which results in lengthening of perception of the dominant stimulus and/or as decreasing mixed percepts where one of the two images is not fully suppressed. In addition to such low level visual mechanisms, behavioral studies suggest that attention play a role in binocular dynamics (Dieter et al., 2016), and consistent with this, functional brain imaging has revealed that also fronto-parietal brain regions, which overlap with areas associated with attentional control, are active during binocular rivalry (Knapen et al., 2011; Lumer et al., 1998).

While the basic mechanisms of binocular rivalry have been studied extensively for decades (Blake, 2001), growing

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interest in individual differences in binocular rivalry dynamics has arisen more recently. Alteration rate has been found to be affected in bipolar disorder (Nagamine et al., 2009; Ye et al., 2019), anxiety (Nagamine et al., 2007), and autism (Robertson et al., 2013) as well as obsessive-compulsive disorder, depression and schizophrenia (Ye et al., 2019). These findings raise the question whether normal variation in personality would be associated with perception during binocular rivalry.

The Big Five model is a dominant model of personality which considers personality as a combination of five main traits: Extraversion, Agreeableness, Conscientiousness, Openness and Neuroticism (Goldberg, 1993; McCrae & Costa, 1987). Few studies have, however, explored whether personality traits are associated with perception during binocular rivalry. Antinori, Smillie, and Carter (2017b) investigated the relationship between alteration rate and big-five personality traits. Conscientiousness was positively associated with the duration of the dominating percepts (i.e., the alteration rate was slower than average). This finding fits intuitively and at conceptual level with the description of Conscientiousness as being associated with thoroughness and self-control. The increased dominance duration in highly conscientious participants suggests that their inhibition system is working more efficiently than average.

In addition to the alteration rate, personality may be associated with differences in experiencing mixed percepts during binocular rivalry (Antinori et al., 2017a). Mixed percepts are experienced when parts of both stimuli are perceived as a piecemeal mosaic or the images are superimposed with or without depth (Blake et al., 1992; Yang et al., 1992). Antinori et al. (2017a) found that Openness was positively associated with the duration of mixed percepts. They concluded that people high in Openness process visual information at low levels differently than others, being more flexible in combining information within visual stimuli. One potential explanation for the flexibility was proposed to be lowered latent inhibition which has been reported in people high in Openness (Peterson et al., 2002; Peterson & Carson, 2000). During mixed percepts, neither of the two stimuli are fully inhibited, and perhaps the reduced inhibition system explains the fusion of the images.

Percepts during binocular rivalry depend on lower as well as higher level cognitive mechanisms (Alais, 2012; Dieter et al., 2016; Paffen & Alais, 2011). In this respect, they are is similar to perception in general, involving interactions between early visual cortex and higher areas such as frontal and parietal cortex (Knapen et al., 2011). The association between Openness and mixed percepts might thus be related also to individual differences in higher level cognitive functions, in addition to low-level visual functions. Openness is associated with adjectives such as 'intelligent,', 'imaginative,' 'original,', insightful,' 'curious,' 'broad-minded,' 'artistically sensitive,' and 'introspective wide interest' (McCrae & Costa, 1997; Woo et al., 2015). Openness correlates with cognitive flexibility and updating/monitoring of executive functioning (Murdok & Bridgett, 2013). Flexibility might enable creative combinations of information from both eyes. Open people typically score high in scales measuring empathy, especially perspective taking, a component in cognitive empathy that requires flexibility (Di Fabio & Kenny, 2018; Guilera et al., 2019; Melchers et al., 2016; Song & Shi, 2017).

Empathy, on the other hand, is a multidimensional feature, which involves two or more components (Carré et al., 2013; Decety & Jackson, 2004), at least cognitive empathy (ability to understand other people's perspectives), affective empathy/emotional contagion (emotional responses to other people's emotions), and emotional disconnection (disconnection from emotion protecting from excessive emotions). Neuropsychological studies suggest that cognitive empathy correlates with performance in tasks requiring cognitive flexibility (Shamay-Tsoory, 2009). Similarly, according to a recent meta-analysis (Yan et al., 2020), empathy, especially cognitive empathy, is closely related to subcomponents of executive functions, such as cognitive flexibility. Empathic persons are able to flexibility to adopt and shift the perspectives or viewpoints of self and other persons without confusing them. This ability to "mentalize" requires representations of the mental states of others and the executive control component of inhibition and selection between the perspectives. The enhanced mentalizing ability in highly empathic persons may extend also to *visual* perspective-taking, as suggested by Mattan et al. (2016). They used a third-person visual perspective-taking task in which the participants judged the visual perspectives of two simultaneously presented avatars. Empathy was associated with reduced cost of selecting between conflicting visual perspectives and overall improvement in performing the task. Thus, empathy may be associated with enhanced flexibility also in relatively low level visual perspective-taking.

In summary, openness correlates with cognitive empathy, and openness and cognitive empathy share similar higher cognitive/executive functions, particularly those required in flexible cognitive performance. Thus, it remains an open question whether the enhanced amount of mixed percepts reported in Openness (Antinori et al., 2017a) can be observed also in empathic persons. We aimed in the current study to conceptually replicate the association between Openness and mixed percepts by using binocular rivalry paradigm with 10-s continuous presentation of pictures of faces and houses, and to explore the relationship between Openness, empathy, and perception of mixed percepts during binocular rivalry. Functional brain imaging has suggested that the initial precepts at the onset of binocular rivalry task are based on different mechanisms than the percepts occurring during later viewing of the stimuli (Carter & Cavanagh, 2007; Stanley et al., 2011). By presenting several trials, we were able to measure separately the occurrence of initial mixed percepts at the onsets of stimulation and the later mixed percepts occurring during the rest of the trials. The percepts at stimulus onset should be sensitive to early visual mechanisms (Carter & Cavanagh, 2007; Stanley et al., 2011), whereas the later percepts may be contributed also by higher cognitive processes.

Method

Participants

We tested 100 participants who were students from introductory psychology course in the University of Turku. They had normal or corrected-to-normal vision. The participants were provided with course credits for participation. The sample size was determined on the basis that linear multiple regression requires 10–20 participants per predictor and the planned analyses involved at maximum 5 predictors (the big-five traits) in each analysis.

Six of the participants were excluded from the analyses of binocular rivalry after completing the tasks, because they did not show the phenomenon of binocular rivalry (on average, less than one change in dominance during 10 s trials). The mean age of the remaining 94 participants (87 females) was 24.3 years (SD = 4.7, range 19–44). Post-hoc power calculations revealed that, with 80% power and .05 alpha level, linear regression analyses involving three (domains of empathy) or five (personality traits) predictors require 76 or 91 participants, respectively, for detecting at least effects of medium size (R^2 = .15).

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the University of Turku (decision 11/9/2017). All participants gave a written informed consent.

Personality Measures

The Big Five personality traits were measures with PK5 (PK5, 2007). It is a 150-item questionnaire, which assesses each of the trait domains (extraversion, openness, conscientiousness, agreeableness and emotional stability/neurotism) with 30 items. The participants indicate their agreement or disagreement with each item on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). In a standardization study (n = 1107)(PK5, 2007), Cronbach's α was .94 for extraversion, .85 for openness, .85 conscientiousness, .89 for agreeableness, and .95 for emotional stability. In the present data, the corresponding values were .93, .85, .89, .91, and .94, respectively.

Basic Empathy Scale (BES) (Jolliffe & Farrington 2006) measures cognitive and affective factors of empathy, originally developed for young people. Here we used The Basic Empathy Scale in Adults (BES-A) (Carré et al., 2013), which has been developed for adults, to measure three factors of empathy with 20 items: emotional contagion, cognitive empathy, and emotional disconnection. The participants had to give their ratings on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). In the present sample, BES-A showed good or acceptable internal consistency, with a Cronbach's α of .87 for the sum score of the questionnaire, .75 for emotional contagion, .81 for cognitive empathy, and .75 for emotional disconnection.

During the same sessions, data was collected also for examining the relationships between psychopathological dispositions and perception of facial emotions (Puustinen, 2020). For that purpose, the participants filled in inventories measuring social anxiety, generalized anxiety, depression, narcissism, and mood. The data from these inventories are not reported in the present paper. Here we report all measures, conditions, and data exclusions made for the purpose of the present study.

Binocular Rivalry

Stimuli

Images of faces and houses were used as stimuli (Fig. 1). The face stimuli were from eight identities (4 females, 4 males), each identity expressing six different emotions: angry, disgusted, fearful, happy, neutral, and sad. The face images were selected from the set of The Karolinska Directed Emotional Faces (KDEF) (http://www.emotionlab.se/resources/kdef). Eight house images were selected from free image stocks in the internet. All the images were converted to gray-scale, and surrounded by a black oval mask. The luminance histogram of the images was equalized using Matlab (The MathWorks, Natick, MA) and the SHINE toolbox (Willenbockel et al., 2010) so that the stimuli had same luminance and contrast.

Procedure

Face-house pairs were presented on a CRT monitor (1024 X 768 pixels resolution, 85 Hz) within two 3.5 × 5.6° frames, positioned 4° away from the center of the screen to the left and right. The stimuli were viewed via a mirror stereoscope so that a face image was presented to one eye and a house image was presented to the other eye. First, empty frames were presented for 1 s, after which a fixation dot appeared within the frames for the next 500 ms, followed by the face-house pair. The stimuli remained visible for 10 s. The participants were instructed to report what they see by pressing and holding down the left arrow key for face, the right arrow key for house, or the down arrow key, located between the left and right arrow keys, when they saw a combination of a face and a house (mixed percept). The next trial was initiated by pressing the space bar. The computer recorded how many times each

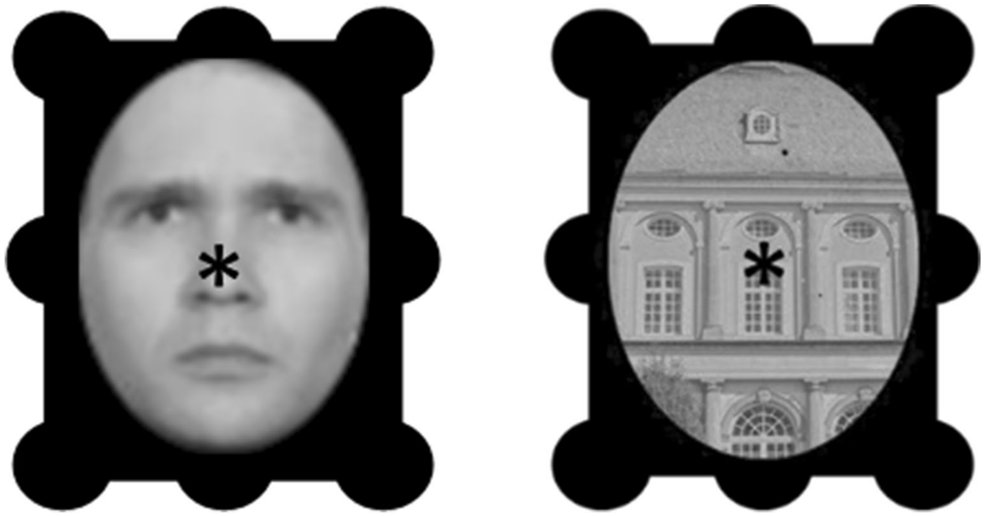

Fig. 1 Examples of the stimuli in the binocular rivalry task

button was pressed and for how long time (msec) they held each button down during each 10 s trial.

The six pictures of each of eight identities were presented twice, once in the left eye and once in the right eye, in random order. A total of 96 critical trials were presented in two blocks of 48 trials, separated by a brief resting period. The critical trials were preceded by practice trials that did not include any of the images from the experimental trials.

Statistical Analyses

The statistical analyses were performed with SPSS 25 (IBM Corp.) and with R version 3.5.2 (R Core Team, 2012), mediation package version 4.4.6 (Tingley et al., 2013), and Psycho package version 0.4.0 (Makowski, 2018).

The results of six participants were rejected from the analyses as they had on average less than two dominant perceptions per trial, indicating that they failed to show dominance alternations during binocular rivalry. This may have been due to either failing to follow the instructions, unknown technical problem in the procedure, or these participants simply did not experience the typical shifts of dominance during binocular rivalry. Whatever the reason for their performance was, these observers were outliers and many of the variables, listed below, could not be computed from their data. In addition, two of the participants never reported mixed percepts, either as the initial percept during the trials or after the initial percept. Therefore they were automatically removed from the variables measuring the durations of mixed percepts. In addition to the two participants who never reported mixed percepts, there were two additional participants who did not report mixed percepts after the initial percept; for these two participants the duration of the later mixed percepts could not be measured.

The binocular rivalry outcome variables were: *Dominance* (mean number of dominances of face or house images during 10 s trials), total number of *Mixed percepts* per trial, mean probability of mixed percept as the initial percept in the beginning of the trials (*Initial percept mixed*), mean number of mixed percepts per trial after the initial percept (*Later percept mixed*), mean probability of face or house percept as the initial percept in the beginning of the trials (*Initial percept face/house*), mean number of face and house percepts per trial after the initial percept (*Later percept face/house*), the mean duration (msec) of initial mixed percepts (*Initial mixed duration*, $n = 92$), mean *Later percept mixed duration* (msec)($n = 90$), and the mean *Dominance duration* (msec) of face/house percepts.

For the correlational (Spearman's rho) and linear regression analyses, the variables were standardized and centered to the mean. First, we run Spearman's nonparametric correlations between the personality measures and between the personality measures and binocular rivalry variables. Nonparametric correlations were used in these tests as Kolmogorov-Smirnov test indicated that five of the personality variables (Agreeableness and all four empathy measures) were not normally distributed ($p < .05$). The binocular rivalry variables Initial percept mixed, Initial percept face/house, and the durations of Mixed percepts, Initial percept mixed, and Later percept mixed were not normally distributed. The duration variables could be normalized with logarithmic transformations and their log values were used in the analyses instead of the original ones.

The linear regression analyses were run in two sets. In the first set, we examined how the big-five personality measures predicted each of the critical binocular rivalry variables (y ~ Openness + Extroversion + Agreeableness + Conscientiousness + Stability). In the second set of analyses, we studied how the domains of Empathy (Cognitive empathy, Emotional Stagnation, Emotional Disconnection) explained the binocular rivalry variables. Third, we tested with causal mediation analysis (Tingley et al., 2013) whether the effects of the big-five personality traits which had shown a relationship with binocular rivalry measures were mediated by the empathy domains that also had shown a relationship with them, and vice versa. Finally, we ran correlation analyses and linear regressions to rule out the influence of possible response biases. The VIF values were < 3 in every regression analysis, indicating no problems with collinearity.

The data and analysis scripts are available at OSF.io (https://osf.io/f7mub/?view_only=98012371f18f463da82814484e4a533c).

Results

Descriptive Statistics and Correlations

Descriptive statistics for the personality variables and binocular rivalry variables are presented in Table 1. The correlations (Spearman's rho) between personality traits are displayed in Table 2, and the correlations between personality measures and binocular rivalry variables in Table 3.

The personality trait Openness correlated positively with all measures of empathy, most clearly with Cognitive Empathy (r = .50), but not with other big-five traits. Cognitive Empathy correlated positively also with Extraversion and Agreeableness, whereas Emotional Stagnation correlated positively with Conscientiousness and negatively with Extraversion and Stability. All the empathy domains correlated with each other.

Openness correlated with the total number of Mixed percepts, the probability of the Initial percept being mixed, and with the number of Later percepts mixed. The total empathy score correlated with the total number of mixed percepts. More specifically, Cognitive Empathy correlated with the same variables as Openness did, as well as it had a negative correlation with Dominance duration. These analyses showed that Openness and Cognitive empathy are related to the occurrence of mixed percepts. Next, we studied more closely with linear regression analyses whether these relationships hold when the influence of other personality traits/empathy domains is controlled for.

Table. 1 Descriptive statistics for the personality measures and binocular rivalry variables (n = 94)

	Mean	SD	Min	Max	SE
Openness	109.9	14.3	72	138	1.5
Extraversion	89.8	19.8	44	133	2.0
Agreeableness	91.3	17.4	39	134	1.8
Conscientiousness	103.8	16.7	44	135	1.7
Stability	86.7	21.7	44	136	2.2
Empathy	81.6	9.4	34	99	1.0
- Cognitive	34.0	3.7	19	40	0.4
- Emotional	22.3	4.1	6.0	30	0.4
- Disconnection	25.3	3.8	9.0	30	0.4
Dominance	2.8	0.8	1.1	5.1	0.1
Mixed percepts	1.5	0.8	0.0	4.1	0.1
Initial percept mixed	0.5	0.3	0.0	1.0	0.0
Later percept mixed	1.0	0.6	0.0	3.3	0.1
Later percept face/house	2.3	0.8	0.5	4.6	0.1
Initial mixed duration (msec) [a]	2865	1528	284	7197	159
Later mixed duration (msec) [b]	1386	569	549	3721	60
Dominance duration (msec) [a]	3167	913	830	4995	94

[a] n = 92, [b] n = 90

Big-Five Traits

In the first set of linear regression analyses, we focused on the relationship between the big five personality traits and the binocular rivalry measures. In each analysis, the scores for the five traits were entered as the predictors and the outcome variable was one of the binocular rivalry measures.

Dominance

The overall model predicting dominance shifts with the five traits did not explain the variance in dominance, R^2 = .059, F(5,88) = 1.096, p = .369. None of the individual traits explained dominance, all ps > .085.

Initial Percept Mixed

The overall model on the probability of reporting the initial percept as mixed did not explain the results, R^2 = .056, F(5,88) = 1.052, p = .393. Of the five traits, only the effect of Openness was significant (β = .062, SE = .030, 95% CI [.001, .12], t = 2.02, p = .046), while p-values for the other traits were higher than .398.

Later Percept Mixed

The model explained 16.6% of the variance, R^2 = .166, F(5,88) = 3.49, p = .006. Within this model, the effect of Openness was significant (β = .17, SE = .059, 95% CI [.049, .28], t = 2.81, p = .006). In addition, the effect of Agreeableness was significant (β = .22, SE = .082, 95% CI [.060, .39], t = 2.72, p = .008). The other traits did not explain the occurrence of later mixed percepts, ps > .08).

Initial Mixed Percept Duration

The model on the mean duration of initial mixed percepts did not explain the variance, R^2 = .054, F(5,86) = 0.98, p = .438.

Table. 2 Intercorrelations between big-five personality traits (PK-5) and empathy scores (Bes-a)(n = 94)

	1.	2.	3.	4.	5.	6.	7.	8.
1. Openness								
2. Extraversion	.13							
3. Agreeableness	.16	.65***						
4. Conscientiousness	−.16	−.38***	−.44***					
5. Stability	.19	.54***	.46***	−.37***				
6. Empathy	.50***	−.02	.05	.19	−.13			
7. -Cognitive	.50***	.27**	.30**	.05	.19	.67***		
8. -Emotional	.27**	−.23*	−.16	.22*	−.40***	.75***	.21*	
9. -Disconnection	.33***	−.07	.00	.20	−.18	.81***	.32**	.58***

*p < .05, **p < .01, ***p < .001

Within this model, the p-values for the personality traits were higher than .11.

Later Mixed Percept Duration

The model on the mean duration of later mixed percepts also failed to explain the variance, $R^2 = .026$, $F(5,84) = 0.46$, $p = .808$. Within this model, the p-values for the personality traits were higher than .40.

Dominance Duration

The model did not explain the variance in the duration of face and house images' dominance, $R^2 = .059$, $F(5,88) = 1.10$, $p = .369$. None of the traits explained the duration of the percepts, ps > .14.

Empathy

In the regression models on empathy, we predicted the binocular rivalry measures with the three subdomains of empathy: cognitive empathy, emotional contagion, and emotional disconnection.

Dominance

The overall model did not explain the variance in the switches of dominance (adj. R2 = 1.52), $R^2 = .047$, $(3,90) = 1.48$, $p = .226$. Within this model, only the effect of Emotional Contagion was almost significant ($\beta = -.25$, $SE = .13$, 95% CI [−.50, 0], $t = -1.99$, $p = .050$), suggesting that high levels of it may be associated with lowered number of dominance switches. For other predictors, the p-values were higher than .07.

Initial Percept Mixed

The model did not explain the variance in experiencing the initial percept in the beginning of the trials as mixed, $R^2 = .041$ $F(3,90) = 1.27$, $p = .290$, and all p-values for the individual traits were higher than .11.

Table. 3 Intercorrelations between personality variables (PK-5, Bes-a) and binocular rivalry variables

	Dominance	Mixed percepts	Initial percept mixed	Later percept mixed	Later percept face/house	Initial mixed duration	Later mixed duration	Dominance duration
Openness	0.09	0.35***	0.24*	0.33**	0.17	−.13	−.13	−0.13
Extraversion	−0.09	0.03	0.02	0.02	−0.08	.08	.01	−0.07
Agreeableness	0.06	0.15	0.04	0.20	0.09	.00	−.03	−0.05
Conscientiousness	−0.06	0.07	0.06	0.07	−0.07	.15	.05	−0.10
Stability	0.03	−0.01	−0.05	0.00	0.01	−.02	−.10	0.10
Empathy	−0.05	0.22*	0.18	0.17	−0.01	.08	.07	−0.16
-Cognitive	0.00	0.38***	0.21*	0.39***	0.07	.08	.07	−0.24*
-Emotional	−0.13	0.06	0.10	0.02	−0.12	.16	.16	−0.14
-Disconnection	0.00	0.11	0.17	0.04	0.03	−.03	.01	−0.06

*p < .05, **p < .01, ***p < .001

Later Percept Mixed

The model explained 15.6% of the variance for the occurrence of mixed percepts after the initial percept, $R^2 = .156$, $F(3,90) = 5.54$, $p = .002$. Within this model, the effect of Cognitive Empathy was significant (β = .25, SE = .063, 95% CI [.12, .37], t = 3.95, $p < .001$), whereas Emotional Contagion ($p = .894$) and Disconnection ($p = .527$) did not show any significant effects.

Initial Mixed Percept Duration

The overall model did not explain the variance of the endogen, $R^2 = .033$, $F(3,88) = 0.989$, $p = .402$, neither did any of the subdomains of empathy within the model, ps > .11.

Later Mixed Percept Duration

The overall model was not statistically significant, $R^2 = .033$, $F(3,86) = 1.878$, $p = .139$. However, the effect of Emotional Contagion was significant (β = .057, SE = .025, 95% CI [.007, .11], t = 2.260, $p = .026$), suggesting that high emotional empathy was associated with relatively long durations of mixed percepts, while the other traits were not related to their duration (ps > .08).

Dominance Duration

The overall model did not explain the variance in dominance duration, $R^2 = .065$, $F(3,90) = 2.23$, $p = .091$. However, the effect of Cognitive Empathy reached statistical significance (β = −.034, SE = .017, 95% CI [−.067, −.00042], t = −2.139, $p = .035$): persons with high cognitive empathy may have experienced the dominance of faces or houses for a shorter time than average. Emotional Contagion ($p = .153$) and Disconnection ($p = .150$) were not related to the time that faces and houses dominated.

Control Analyses

It is difficult to separate the bias to report mixed percepts from real visual mixed experiences. Mixed percepts occur most likely in the beginning of the stimulation (Stanley et al., 2011) or during the changes of dominance (Blake, 2001). It is possible that the individual differences in the reported number of mixed percepts reflect differences in response criterion such that some of the observers have a lower response criterion to press the "mixed button" in response to even brief mixed experiences in the beginning of the trials or during switches of dominance, whereas others, although may experience brief mixed percepts similarly, might not report them. To study this issue, we run control analyses where percept durations were controlled for. These analyses are reported in Supplementary Information. The control analyses supported the main results of the previous analyses: openness explained the probability of experiencing mixed percepts in the beginning of the 10 s trials when cognitive empathy and initial mixed perception duration was controlled for, whereas cognitive empathy explained later mixed percepts when Openness and late mixed percept duration was controlled for. These results do not support the account that high number of reported mixed percepts simply reflects a lower response criterion for reporting mixed percepts which occur briefly between the shifts of dominance or in the beginning of trials.

Mediation Analyses

The associations between personality traits, empathy, and mixed percepts were used to determine the variables that warranted further exploration through mediation analyses. Openness and cognitive empathy correlated with each other, and both correlated with the probability that the initial or later percept was mixed. Therefore, we conducted mediation analyses (Tingley et al., 2013) to test whether cognitive empathy mediates the association between openness and *initial mixed percepts*. Two models were entered to the mediation analysis, which used bootstrapping and 1000 simulations: a mediator model (M) predicted Cognitive Empathy with Openness and the full model (Y) predicted initial mixed percepts with Openness and Cognitive Empathy. The results showed that the Total Effect was significant, β = .057, 95% CI [.002, .11], $p = .048$. This means that Openness explained the occurrence of initial mixed percepts, without taking into account the effect of Cognitive Empathy. The Average Direct Effect (ADE) of Openness on initial mixed percepts, after taking into account the indirect effect of Cognitive Empathy, was not statistically significant, β = 0.0374, 95% CI [−.023, 0.10], $p = .238$. However, Average Causal Mediation Effect (ACME) was not significant, β = .0196, 95% CI [−.017, .06], $p = .256$, suggesting that the 34% (95% CI [−63, 183]) mediation effect of Cognitive Empathy was not reliable. When the analysis was repeated with Openness as the mediator, no evidence for mediation was found, ACME: β = .020, 95% CI [−.018, .060], $p = .28$.

A mediation analysis on *later mixed percepts* was done similarly, with the Cognitive Empathy as mediator and Openness as the treatment variable. The Total Effect was significant, β = .168, 95% CI [.064, .28], $p = .002$, implying that Openness explained the occurrence of later mixed percepts, without taking Cognitive Empathy to account. The direct effect (ADE) of Openness on mixed percepts, after taking into account the indirect effect of Cognitive Empathy, was not statistically significant, β = 0.063, 95% CI [−.064, 0.19], $p = .306$. The ACME was significant, β = .105, 95% CI [.029, .19], $p = .004$, thus the analysis shows that Cognitive Empathy mediated the effect of Openness on reporting later mixed percepts (62% mediated, 95% CI [17, 177], p = .006). When this analysis was repeated with Openness as the mediator, no evidence for mediation was found, ACME: β = .03, 95% CI [−.04, .10], p = .324.

Agreeableness also correlated with Cognitive Empathy and predicted the occurrence of later mixed percepts. Therefore, we tested whether or not the association between agreeableness and later mixed percepts is mediated by cognitive empathy. The Total Effect was significant, β = .122, 95% CI [.023, .22], p = .020, showing that Agreeableness explained the occurrence of later mixed percepts, when the indirect effect of Cognitive Empathy was not considered. The direct effect (ADE) of Agreeableness, after taking into account the indirect effect of Cognitive Empathy, was not statistically significant, β = 0.051, 95% CI [−.084, 0.17], p = .422. The mediation effect (ACME) was significant, β = .071, 95% CI [.018, .15], p = .006, suggesting that Cognitive Empathy mediated the effect of Agreeableness on reporting later mixed percepts (58% mediated, 95% CI [11, 312], p = .020). Repeating the analysis with Agreeableness as the mediator, no evidence for mediation was found, ACME: β = .02, 95% CI [−.03, .06], p = .490.

Discussion

Perception during binocular rivalry is contributed by mechanisms at several cognitive levels. Although psychological disorders are associated with changed binocular rivalry dynamics (Nagamine et al., 2007, 2009; Robertson et al., 2013; Ye et al., 2019), the association between personality traits and binocular rivalry has not been extensively studied. One of the most interesting results concerning personality traits so far has been the association between Openness and experiences of mixed percepts, suggesting that open people may actually see the world differently (Antinori et al., 2017a). In the present study, we aimed to conceptually replicate and extend this association with different stimuli and procedure, and to explore it in relation to empathy, a disposition that is common in open people. Instead of presenting horizontal and vertical gratings (Antinori et al., 2017a), we used pictures of faces and houses as stimuli and a procedure where several 10 s trials were presented. This made it possible to separately study the initial perception emerging in the beginning of the stimulation and percepts occurring later during the trials.

The results replicated the finding that Openness is associated with experiences of mixed percepts (Antinori et al., 2017a). Openness correlated with the mixed percepts in the beginning of the stimulation and with the later mixed percepts occurring later during the 10 s trials. A new, unexpected finding was that Agreeableness also predicted late mixed percepts when the contribution of other personality traits was controlled for. Of the components of empathy, cognitive empathy was the only one that correlated with mixed percepts.

The results of the mediation analyses revealed that cognitive empathy was a significant mediator in the relation between personality traits and mixed percepts. Both Openness and Agreeableness correlated with cognitive empathy, which is in line with previous research showing that these two features are associated with empathy (Barrio et al., 2004; Melchers et al., 2016). After accounting for cognitive empathy, neither Openness or Agreeableness predicted the occurrence of late mixed percepts. Thus, open or agreeable persons tend to be high in cognitive empathy and hence they experience mixed percepts more frequently than average.

In addition to being a mediator, cognitive empathy was the only disposition that was associated with the length of dominance duration: high cognitive empathy predicted shorter dominance durations. This finding, together with increased frequency of late mixed percepts, could be interpreted to reflect weaker than average interocular inhibition in people high in cognitive empathy, because in mixed percepts neither image is fully suppressed or dominant. However, it does not seem probable that the items measuring cognitive empathy in BES-A (e.g., "I find it hard to know when my friends are frightened", "When someone is feeling 'down' I can usually understand how they feel") are solely related to low level binocular inhibition mechanisms. Therefore, the association between cognitive empathy and mixed percepts is likely to be contributed by interaction between higher and lower level functions.

Mixed percepts during binocular rivalry occur typically during the changes of dominance. Functional brain imaging has revealed that the frontal-parietal network is activated during transitions, especially long transitions, during which mixed percepts occur (Knapen et al., 2011). Whether or not such activity is causally related to initiation of perceptual switches or not is unclear. According to hybrid models (Sterzer & Kleinschmidt, 2007), destabilization of the currently dominant percept is the initial cause of perceptual alternations, maybe due to neural adaptation in low visual areas. The fronto-parietal areas might engage in interaction with the lower level visual areas, by initiating a reorganization and stabilization of representations through feedback signals to the lower level visual areas, a process which results in altered dominant percept. In this framework, the later mixed percepts in cognitively empathic persons might reflect flexible reorganization of representation through interaction between higher and lower level processes.

On the other hand, the association between Openness and the reports of initial mixed percepts was independent of cognitive empathy. However, the association between Openness and the reports of initial mixed percepts must be interpreted with caution, because its effect size was weaker (β = .062, 95% CI [.001, .12]) than the association of Openness with the later mixed percepts (β = .17, SE = .059, 95% CI [.049, .28]). If it is a reliable one, the association is likely to result from a mechanism different to that in cognitive empathy. The finding that the duration and frequency of initial mixed percepts correlated positively, whereas the relationship between frequency and duration of late mixed percepts showed a reversed pattern (Supplementary Information), supports the interpretation that the mechanism is different in initial and later percepts. Previous research suggests that the dominance at stimulus onset is particularly sensitive to early visual factors such as contrast and ocular dominance, leaving the contribution of higher cognitive processes less clear (Carter & Cavanagh, 2007; Stanley et al., 2011). Thus, it remains plausible that in Openness the occurrence of mixed percepts in the beginning of binocular stimulation results from low level mechanisms in visual areas, such as more flexible inhibition system (Antinori et al., 2017a), lowering the probability that one of the two representations would suppress the other one during the initial selection for dominance.

The associations between traits and mixed percepts appeared primarily in the number of mixed percepts, but not in their duration. Antinori et al. (2017a) reported the correlation between Openness and duration of mixed percepts with a procedure using continuous viewing of gratings during a single 120 s trial. However, they measured only the summed total duration of the mixed percept reports, not their frequency, whereas we did not report summed duration but the mean duration of single percepts. However, by multiplying the durations of single mixed percepts with their number produces a measure of summed duration, and in the present data openness predicts also the log-transformed summed duration of later mixed percepts in multiple regression with big-five traits as predictors, β = .24, p = .002. Therefore our data and those of Antinori are not in conflict regarding the association between Openness and mixed percepts.

In further studies it would be worth examining whether the mixed percepts of people high in cognitive empathy or openness contain more than average mixtures of elements from both images as a mosaic, or whether the images are superimposed with or without depth, as these types of percepts are based on different mechanisms (Yang et al., 1992). This would give a more detailed view on the link between personality and perceptual dynamics. Also the idea that the increased disposition to experience mixed percepts is related to cognitive flexibility requires explicit testing. Overall, the present results provide preliminary evidence suggesting that different personalities see things differently, and this phenomenon may be contributed by individual differences in the perceptual system at both low level visual and higher level cognitive processes.

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Code Availability The analysis codes for R are available at OSF.io (https://osf.io/f7mub/?view_only=98012371f18f463da82814484e4a533c).

Authors' Contributions Mika Koivisto: Conceptualization, Writing- Original draft preparation, Methodology, Formal analysis. Maija Virkkala: Conceptualization, Data collection, Writing- Original draft preparation. Mika Puustinen: Data collection, Methodology, Writing- Reviewing. Jetta Aarnio: Data collection, Writing- Original draft preparation, Writing- Reviewing.

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Declarations

Ethics Approval The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the University of Turku (decision 11/9/2017).

Consent to Participate All persons gave their informed consent prior to their inclusion in the study.

Consent for Publication In the informed consent, the participants gave their consent for publication of their results (without identifying details) in scientific journals.

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References

Alais, D. (2012). Binocular rivalry: Competition and inhibition in visual perception. *Wiley interdisciplinary reviews. Cognitive Science, 3*(1), 87–103.

Antinori, A., Carter, O. L., & Smillie, L. D. (2017). Seeing it both ways: Openness to experience and binocular rivalry suppression. *Journal of Research in Personality, 68*, 15–22. https://doi.org/10.1016/j.jrp.2017.03.005.

Antinori, A., Smillie, L. D., Carter, O., & L. (2017). Personality measures link slower binocular rivalry switch rates to higher levels of self-discipline. *Frontiers in Psychology, 7*. https://doi.org/10.3389/fpsyg.2016.02008.

Barrio, V. D., Aluja, A., & García, L. F. (2004). Relationship between empathy and the big five personality traits in a sample of Spanish adolescents. *Social Behavior and Personality: An International Journal, 32*(7), 677–681.

Blake, R. (2001). A primer on binocular rivalry, including current controversies. *Brain and Mind, 2*, 5–38.

Blake, R., O'Shea, R. P., & Mueller, T. J. (1992). Spatial zones of binocular rivalry in central and peripheral vision. *Visual Neuroscience, 8*, 469–478. https://doi.org/10.1017/S0952523800004971.

Carré, A., Stefaniak, N., D'Ambrosio, F., Bensalah, L., & Besche-Richard, C. (2013). The basic empathy scale in adults (BES-A): Factor structure of a revised form. *Psychological Assessment, 25*, 679–691.

Carter, O. L., & Cavanagh, P. (2007). Onset rivalry: Brief presentation isolates an early independent phase of perceptual competition. *PLoSONE, 2*, e343. https://doi.org/10.1371/journal.pone.0000343.

Decety, J., & Jackson, P. L. (2004). The functional architecture of human empathy. *Behavioral and Cognitive Neuroscience Reviews, 3*, 71–100. https://doi.org/10.1177/1534582304267187.

Di Fabio, A., & Kenny, M. E. (2018). Connectedness to nature, personality traits and empathy from a sustainability perspective. *Current Psychology: Research and Reviews, Oct, 2018*, 1–12.

Dieter, K. C., Brascamp, J., Tadin, D., & Blake, R. (2016). Does visual attention drive the dynamics of bistable perception? *Attention, Perception, & Psychophysics, 78*, 861–1873. https://doi.org/10.3758/s13414-016-1143-2.

Goldberg, L. R. (1993). The structure of phenotypic personality traits. *American Psychologist, 48*(1), 26–34. https://doi.org/10.1037//0003-066x.48.1.26.

Guilera, T., Batalla, I., Forné, C., & Soler-González, J. (2019). Empathy and big five personality model in medical students and its relationship to gender and specialty preference: A cross sectional study. *BMC Medical Education, 19*(57). https://doi.org/10.1186/s12909-019-1485-2.

Jolliffe, D., & Farrington, D. P. (2006). Development and validation of the basic empathy scale. *Journal of Adolescence, 29*, 589–611.

Klink, P. C., Brascamp, J. W., Blake, R., & van Wezel, R. J. A. (2010). Experience-driven plasticity in binocular vision. *Current Biology, 20*, 1464–1469. https://doi.org/10.1016/j.cub.2010.06.057.

Knapen, T., Brascamp, J., Pearson, J., van Ee, R., & Blake, R. (2011). The role of frontal and parietal brain areas in bistable perception. *Journal of Neuroscience, 31*(28), 10293–10301. https://doi.org/10.1523/JNEUROSCI.1727-11.2011.

Lumer, E. D., Friston, K. J., & Rees, G. (1998). Neural correlates of perceptual rivalry in the human brain. *Science, 280*, 1930–1934.

Makowski, D. (2018). The psycho package: An efficient and publishing-oriented workflow for psychological science. *Journal of Open Source Software, 3*(22), 470.

Mattan, B. D., Rotshtein, P., & Quinn, K. A. (2016). Empathy and visual perspective-taking performance. *Cognitive Neuroscience, 7*(1–4), 170–118. https://doi.org/10.1080/17588928.2015.1085372.

McCrae, R. R., & Costa Jr., P. T. (1987). Validation of the five-factor model of personality across instruments and observers. *Journal of Personality and Social Psychology, 52*(1), 81–90. https://doi.org/10.1037/0022-3514.52.1.81.

McCrae, R. R., & Costa, P. T. (1997). Conceptions and correlates of openness to experience. In R. Hogan, J. A. Johnson, & S. R. Briggs (Eds.). *Handbook of personality psychology* (pp. 825–847. Academic Press.

Melchers, M. C., Li, M., Haas, B. W., Reuter, M., Bischoff, L., & Montag, C. (2016). Similar personality patterns are associated with empathy in four different countries. *Frontiers in Psychology, 7*, 290. https://doi.org/10.3389/fpsyg.2016.00290.

Miller, S. M., Hansell, N. K., Ngo, T. T., Liu, G. B., Pettigrew, J. D., Martin, N. G., & Wright, M. J. (2010). Genetic contribution to individual variation in binocular rivalry rate. *Proceedings of the National Academy of Sciences, 107*(6), 2664–2668. https://doi.org/10.1073/pnas.0912149107.

Murdok, O., & Bridgett. (2013). Cognitive correlates of personality: Links between executive functioning and the big five personality traits. *Journal of Individual Differences, 34*(2), 97–104.

Nagamine, M., Yoshino, A., Yamazaki, M., Obara, M., Sato, S.-I., Takahashi, Y., & Nomura, S. (2007). Accelerated binocular rivalry with anxious personality. *Physiology and Behavior, 91*, 161–165. https://doi.org/10.1016/j.physbeh.2007.02.016.

Nagamine, M., Yoshino, A., Miyazaki, M., Takahashi, Y., & Nomura, S. (2009). Difference in binocular rivalry rate between patients with bipolar I and bipolar II disorders. *Bipolar Disorders, 11*(5), 539–546. https://doi.org/10.1111/j.1399-5618.2009.00719.x.

Paffen, C. L. E.,& Alais, D. (2011). Attentional modulation of binocular rivalry. *Frontiers in Human Neuroscience, 5*, 105. https://doi.org/10.3389/fnhum.2011.00105.

Peterson, J. B., & Carson, S. (2000). Latent inhibition and openness to experience in a high-achieving student population. *Personality and Individual Differences, 28*, 323–332.

Peterson, J., Smith, K., & Carson, S. (2002). Openness and extraversion are associated with reduced latent inhibition: Replication and commentary. *Personality and Individual Differences, 33*(7), 1137–1147. https://doi.org/10.1016/S0191-8869(02)00004-1.

PK5 (2007). *PK5-persoonallisuustestin käsikirja* [PK5 personality test manual]. Hogrefe, Psykologien Kustannus.

Robertson, C. E., Kravitz, D. J., Freyberg, J., Baron-Cohen, S., & Baker, C. I. (2013). Slower rate of binocular rivalry in autism. *Journal of Neuroscience, 33*(43), 16983–16991. https://doi.org/10.1523/JNEUROSCI.0448-13.2013.

R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria.

Shamay-Tsoory, S. G. (2009). Empathic processing: Its cognitive and affective dimensions and neuroanatomical basis. In J. Decety & W. Ickes (Eds.) *The social neuroscience of empathy* (pp. 215–232). MIT Press.

Song, Y., & Shi, M. (2017). Associations between empathy and big five personality traits among Chinese undergraduate medical students. *PLoS One, 12*(2), e0171665. https://doi.org/10.1371/journal.pone.0171665.

Stanley, J., Forte, J. D., Cavanagh, P., & Carter, O. (2011). Onset rivalry: The initial dominance phase is independent of ongoing perceptual alternations. *Frontiers in Human Neuroscience, 5*, 114. https://doi.org/10.3389/fnhum.2011.00140.

Sterzer, P., & Kleinschmidt, A. (2007). A neural basis for inference in perceptual ambiguity. *Proceedings of the National Academy of Science, 104*(1), 323–328. https://doi.org/10.1073/pnas.0609006104.

Tingley, D., Yamamoto, T., Hirose, K., Keele, L., & Imai, K. (2013). *mediation: R Package for Causal Mediation Analysis*. R package version 4.4.2, URL http://CRAN.R-project.org/ package=mediation.

Tong, F., Meng, M., & Blake, R. (2006). Neural bases of binocular rivalry. *Trends in Cognitive Sciences, 10*(11), 502–511.

Willenbockel, V., Sadr, J., Fiset, D., Horne, G. O., Gosselin, F., & Tanaka, J. W. (2010). Controlling low-level image properties: The SHINE toolbox. *Behavior Research Methods, 42*, 671–684.

Wilson, H. R. (2003). Computational evidence for a rivalry hierarchy in vision. *Proceedings of the National Academy of Sciences, 100*(24), 14499–14503.

Woo, S. E., Saef, R., & Parrigon, S. (2015). Openness to experience. In J. D. Wright (ed.), *International encyclopedia of the Social & Behavioral Sciences* (pp. 231–235). Elsevier. https://doi.org/10.1016/B978-0-08-097086-8.25072-1.

Puustinen, M. (2020). *Sosiaalisen ahdistuksen yhteys kasvonilmeiden havaitsemiseen binokulaarisessa kilpailussa* [A study on social anxiety and perception of facial expressions during binocular rivalry]. University of Turku. http://urn.fi/URN:NBN:fi-fe2020061744840.

Yan, Z., Hong, S., Liu, F., & Su, Y. (2020). A meta-analysis of the relationship between empathy and executive function. *PsyCh Journal, 9*, 34–43. https://doi.org/10.1002/pchj.311.

Yang, Y., Rose, D., & Blake, R. (1992). On the variety of percepts associated with dichoptic viewing of dissimilar monocular stimuli. *Perception, 21*, 47–62.

Ye, X., Zhu, R.-L., Zhou, X.-Q., He, S., & Wang, K. (2019). Slower and less variable binocular rivalry rates in patients with bipolar disorder, OCD, major depression, and schizophrenia. *Frontiers in Neuroscience, 13*. https://doi.org/10.3389/fnins.2019.00514.