Attention, Perception, & Psychophysics (2023) 85:463–473
https://doi.org/10.3758/s13414-022-02638-5

Sound-induced flash illusions at different spatial locations were affected by personality traits

Heng Zhou[1] · Shuqi Li[1] · Jie Huang[1] · Jiajia Yang[3] · Aijun Wang[1] · Ming Zhang[1,2]

Accepted: 9 December 2022 / Published online: 20 December 2022

Abstract

Sound-induced flash illusion (SiFI) is an auditory-dominated effect in which observers will misperceive the number of flashes due to simultaneously presented beeps, which includes fission and fusion illusions. Although several individual differences have been found in SiFI, little is known about the effect of personality traits. In the present study, we presented flashes in near space and beeps in far space (Vnear_Afar) and flashes in far space and beeps in near space (Vfar_Anear) to better approximate the real world. We collected 103 participants' Big Five questionnaire results and their SiFI task performance to investigate the difference in trait level on the SiFI in the performance of accuracy, d' and c. The results show that all five personality traits had certain effects on the SiFI to different degrees, and different personality traits played different roles in the fission illusion and fusion illusion. The high agreeableness group was more prone to the fission illusion, and the report criteria were less strict. The report criteria of the low neuroticism group were stricter for the fusion illusion. The extraversion, conscientiousness and low openness groups were more prone to the fusion illusion in the Vnear_Afar condition than in the Vfar_Anear condition. The study indicated that personality traits were important but easily overlooked factors in multisensory illusion, which might make a difference between the fission illusion and the fusion illusion.

Keywords Sound-induced flash illusion · Personality trait · Spatial location · Fission illusion · Fusion illusion

Introduction

We live in a world full of multiple sensory information. When we receive stimuli across different sensory modalities, integrating them into a unified perception is a key ability. The process of integrating the information from different sensory modalities into a unified perception is called "multisensory integration" (De Gelder & Bertelson, 2003; Jack & Thurlow, 1973; Meredith & Stein, 1986; Talsma et al., 2010). Sensory dominance is a type of multisensory integration, which is when the sensations of one modality is more competitive than another modality and becomes dominant. Sound-induced flash illusion (SiFI; Shams et al., 2002) is a common sensory dominance effect in which when one visual flash is accompanied by two beeps, an observer will perceive the flashes as being presented as two, which is called the fission illusion. When two visual flashes are accompanied by one beep, an observer will perceive the flash as being presented as one, which is called the fusion illusion (Andersen et al., 2004; Shams et al., 2002).

Previous studies have found that SiFI varies widely between individuals. Mishra et al. (2007) found that the likelihood of SiFI between individuals ranged from 3% to 86%. This may be related to the development of multisensory integration (Cecere et al., 2015; Chan et al., 2018; McGovern et al., 2014), the perceptual sensitivity of sensory stimuli (McCormick & Mamassian, 2008; Sun et al., 2022) and the degree of sensory information dependence between

Heng Zhou, Shuji Li and Jie Huang contributed equally to this work.

✉ Aijun Wang
ajwang@suda.edu.cn

✉ Ming Zhang
psyzm@suda.edu.cn

[1] Department of Psychology, Research Center for Psychology and Behavioral Sciences, Soochow University, Suzhou, China

[2] Cognitive Neuroscience Laboratory, Graduate School of Interdisciplinary Science and Engineering in Health Systems, Okayama University, Okayama, Japan

[3] Applied Brain Science Lab Faculty of Interdisciplinary Science and Engineering in Health Systems, Okayama University, Okayama, Japan

individuals (Bidelman, 2016; Brighina et al., 2015; Chan et al., 2015; Moro & Steeves, 2018; Whittingham et al., 2014). Evidence from a large number of clinical groups also supported the effect of sensory information dependence on SiFI (Hirst et al., 2020; Keil, 2020). Patients with autism spectrum disorders were more prone to the fusion illusion (Bao et al., 2017), patients with schizophrenia had a significantly lower likelihood of the fusion illusion, and some studies have found that patients with schizophrenia are more prone to illusions at longer stimulus-onset asynchronies (Balz et al., 2016; Haß et al., 2016). However, patients with autism spectrum disorders or schizophrenia had higher scores for neuroticism and lower scores for extraversion, openness, conscientiousness and agreeableness (Kotov et al., 2010; Ohi et al., 2012; Schriber et al., 2014). In addition, previous studies showed that personality traits contributed to multisensory processing (rubber hand illusion) and can explain individual differences in this illusion (Burin et al., 2020); based on the above findings, we assumed that personality traits may be associated with SiFI.

The Big Five Inventory measures personality traits by dividing them into five dimensions (John et al., 1991), which include neuroticism, extraversion, openness, conscientiousness, and agreeableness. Numerous previous studies have shown that personality traits affect performance on sensory and perceptual tasks (Al-Samarraie et al., 2017; Avisar, 2011; Biggs et al., 2017; Coren & Harland, 1995). The previous studies used the NEO Personality Inventory (NEO-PI-R) and found that individuals with high conscientiousness performed faster and had higher accuracy in visual search tasks (Al-Samarraie et al., 2017; Biggs et al., 2017). Differing from the impact of conscientiousness on visual ability, the trait level of agreeableness in the NEO PI-R was related to poorer visual search performance (Avisar, 2011) and extraversion positively predicts visual acuity, while neuroticism negatively predicts color discrimination and hearing sensitivity (Coren & Harland, 1995). High neuroticism reflected overinvestment of attention in irrelevant distractors (Dhinakaran et al., 2014). SiFI is the illusion caused by auditory stimuli and is related to visual acuity (Kumpik et al., 2014; McCormick & Mamassian, 2008). It is reasonable to hypothesize that personality traits are likely to be important factors of SiFI.

Most studies have investigated the SiFI effect in the same and different spatial locations in 2D environments (Abadi & Murphy, 2014; DeLoss & Andersen, 2015). However, in daily life, people often encounter situations where the visual and auditory positions are different. Studies have shown that depth is an important but often overlooked dimension of perception in real life (Blini et al., 2018; Milner & Goodale, 2008). A previous study suggested that attentional resources in objects decreased with increasing distance from the observers, with the most attentional resources in the distance around the observers' body (Maringelli et al., 2001). The sensitivity of SiFI was found to be enhanced when attention resources were limited. Sun et al. (2022) found that when auditory stimuli were presented in far space and visual stimuli were presented in near space, SiFI was significantly enhanced, which may be related to attention resources. Personality traits such as extraversion, conscientiousness, and openness were also related to spatial attention location, and some studies have found that extraversion is positively correlated with spatial range (Ai et al., 2019; Alessandretti et al., 2018), conscientiousness is negatively correlated with the number of different spatial locations (Ai et al., 2019), high openness is closely related to a larger range of attention, and high conscientiousness is closely related to a smaller range of attention (Wilson et al., 2016). However, personality's preference for spatial locations was easy to overlook in perceptual tasks (Blini et al., 2018). Therefore, when audiovisual stimuli were presented at different spatial depths, how personality traits affect SiFI was also a question worth exploring.

Based on the above evidence, the goals of the present study were to explore two questions: first, to explore whether and how personality traits affected the SiFI, and second, to explore how different spatial locations regulated the effect of personality on SiFI. We modified the classical SiFI paradigm by introducing the dimension of depth. We placed the visual stimuli and auditory stimuli in two different spatial locations—that is, the visual stimuli were presented in near space with the auditory stimuli in far space, and the visual stimuli were presented in far space with the auditory stimuli in near space. All participants were divided into different personality trait groups based on their scores on the NEO-PI-R. We hypothesized that five personality traits affected SiFI to varying degrees, and the effect of personality traits on SiFI was influenced by different spatial locations of stimuli. Given previous studies, extraversion, conscientiousness and openness, were all closely related to spatial attention locations, we hypothesized that SiFI of the extraversion, conscientiousness and openness groups would be affected by the two spatial attention locations.

Method

Participants

A total of 103 participants (age: 17~27 years, 69 females) were invited to take the NEO-PI-R and SiFI tasks. They were all right-handed, had normal or corrected-to-normal hearing and vision, and had no history of neurological or psychiatric disorders. All participants gave informed consent before the experiment under the Declaration of Helsinki and were paid afterward. This study was approved by the Ethics Committee of the Department of Psychology, Soochow University. The sample size was calculated using the G*Power 3.1 toolbox.

Previous studies (Faul et al., 2007, 2009) have suggested that a hybrid design should have a medium effect size ($f = 0.25$). With $\alpha = 0.05$ and power = 0.80, the results show that the appropriate sample size was at least 82. The results show that there was sufficient power to achieve a moderate effect, so the sample size was appropriate.

Personality questionnaires

The Chinese version of the NEO-PI-R was used to obtain self-reported ratings of the Big Five personality traits, including neuroticism, extraversion, openness, agreeableness, and conscientiousness. The inventory includes 60 items, and the participants responded on a 5-point Likert scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). For each personality trait, a total score of corresponding items was calculated to represent the trait level. The NEO-PI-R has demonstrated good test–retest reliability and convergent and discriminant validity based on previous studies (Costa & McCrae, 1992; Young & Schinka, 2001).

Apparatus and materials

The visual stimuli were presented in near space and auditory stimuli in far space (Vnear_Afar), and then the visual stimuli were presented in far space and auditory stimuli in near space (Vfar_Anear), with a distance of 59 cm in near space and 378 cm in far space. In near space, the visual stimuli were presented on a monitor (Lenovo ThinkPad E480) with a screen resolution of 1,024 × 768 pixels and a refresh rate of 60 Hz at a distance of 59 cm. The auditory stimuli were presented on speakers (SONY CMT-SBT40D) placed on both sides of the screen. In far space, the visual stimuli were presented on a screen by a projector (EPSON CB-X06E) at a distance of 378 cm, and the auditory stimuli were presented on the same type of speaker. To ensure that the midline of the participants was aligned with the midline of the monitor, the participants' head position was stabilized using a chin rest throughout the experiment.

All experimental stimuli were provided using Presentation software (Neurobehavioral Systems Inc.). The visual flash stimulus was a white disc (visual angle 2°), which appeared at 5° below a central fixation point for 17 ms. The luminance of the background was 148 cd/m^2 (Shams et al., 2002). The auditory beep was a Hamming windowed sine wave, with a loudness of 75 dB and frequency of 3.5 kHz and a duration of 7 ms. The visual angle and luminance remained the same in near space and far space. Meanwhile, the loudness of the auditory beeps was matched in near and far space, which was manipulated by placing the decibel meter near the head of the participants. For ease of description, we used abbreviations for flash and beep (F for flash, B for beep).

Design and procedure

The experiment was a 2 (trait level: high vs. low) × 2 (spatial location: Vnear_Afar vs. Vfar_Anear) × 6 (condition: F1 vs. F1B1 vs. F1B2 vs. F2 vs. F2B2 vs. F2B1) mixed experimental design. In the Vnear_Afar spatial location, the flashes were presented on the near screen, and the beeps were presented from the far speaker. In the Vfar_Anear spatial location, the flashes were presented on the projector, and the beeps were presented from the near speaker (as shown in Fig. 1b). The relative location of the stimulus was randomized between the blocks, and the order between the near space and far space was counterbalanced across participants. We further considered the performance of each group with high or low scores on one personality trait. The groups of each personality trait level consisted of the high/low openness group, the high/low conscientiousness group, the high/low extraversion group, the high/low agreeableness group, and the high/low neuroticism group.

Participants were first invited to complete the Big Five Inventory in 15 minutes and were verbally given full instructions about the experiment. The experiment adopted a forced-choice task to examine the participants' subjective perception of the number of visual flashes presented. In the pretest stage, all participants were required to practice for 5 minutes to make sure that they were familiar with the experimental procedure and enable them to correctly distinguish the number of flashes without auditory beeps. In the experimental stage, visual flashes were presented once or twice accompanied by one, two, or no auditory beeps simultaneously. Participants were asked to focus on the central fixation point throughout the experiment and had to respond to the number of flashes they perceived with the right index finger or middle finger, pressing one button for a single flash and the other button for two flashes within 1,500 ms. Each participant was required to complete 600 trials with 50 trials for each experimental condition. The time interval between the trials was randomized from 400 ms to 700 ms with a step size of 100 ms. The total time for the experiment was approximately 55 minutes (as shown in Fig. 1a).

Data analysis

To examine the effect of the sound-induced flash illusion, we first performed a 2 (spatial location: Vnear_Afar vs. Vfar_Anear) × 2 (condition: F1B1 vs. F1B2) repeated-measures ANOVA and a 2 (spatial location: Vnear_Afar vs. Vfar_Anear) × 2 (condition: F2B1 vs. F2B2) repeated-measures ANOVA to produce the fission and fusion illusion. Then, we selected the high and low trait groups in each personality trait according to the method of ranking the score of every personality trait in the Big Five Inventory from high to low; the top 27% of the scores were grouped into the high trait group, and the bottom 27% of the scores were grouped into

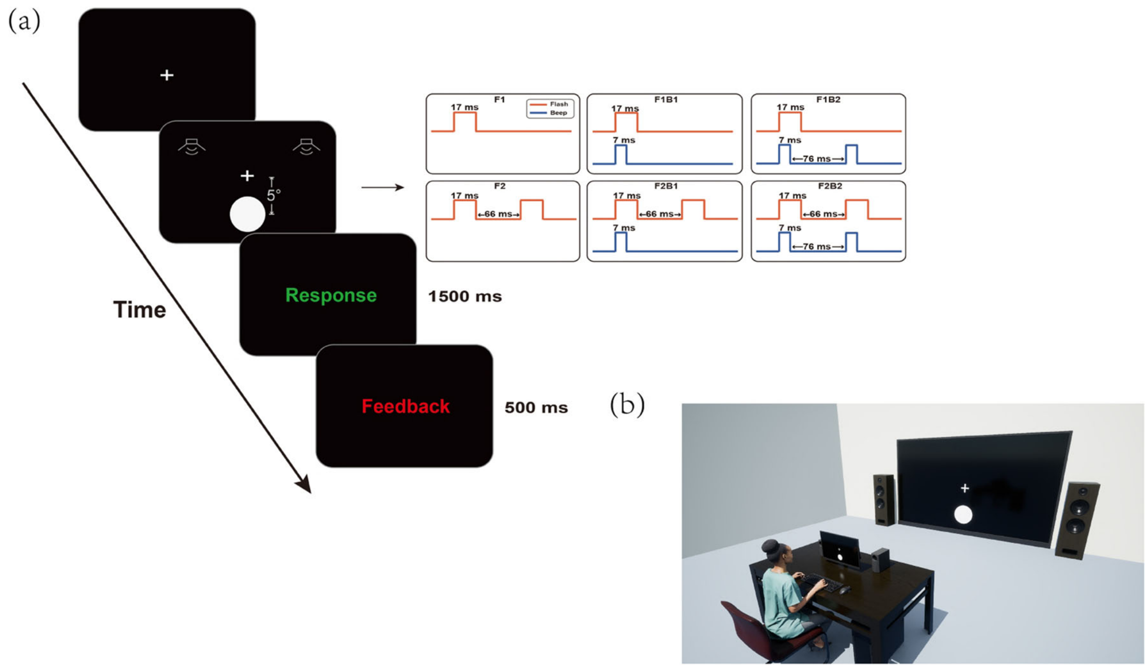

Fig. 1 **a** Experimental stimuli schematic diagram. F1 refers to a trial that presented only one visual flash, and F2 refers to a trial that presented two visual flashes. F1B1 refers to a trial that presented a single visual flash accompanied by an auditory beep, and F2B2 refers to a trial that presented two visual flashes accompanied by two auditory beeps. F1B2 refers to a trial that presented a visual flash accompanied by two auditory beeps. F2B1 refers to a trial that presented two visual flashes accompanied by an auditory beep. The duration of the auditory beep was 7 ms, the time interval between auditory beeps was 76 ms, the duration of visual flash was 17 ms, and the time interval between two visual flash stimuli was 66 ms (Andersen et al., 2004; Shams et al., 2002). **b** Schematic diagram of the experimental apparatus. (Color figure online)

the low trait group. We performed a 2 (trait level: high vs. low) × 2 (spatial location: Vnear_Afar vs. Vfar_Anear) repeated-measures ANOVA to examine the influence of trait level and spatial location on each illusion condition in every personality trait. In addition, we used signal detection theory to determine whether the change in the accuracy of illusion conditions results from changes in perceptual sensitivity, response bias, or both. The data were analyzed based on the approach reported by Chen et al. (2017). In the fission condition, the participants' accuracy in the F2B2 condition was identified as the hit rate, while their error rate in the F1B2 condition where the fission illusion occurred was identified as the FA rate. In the fusion condition, the participants' accuracy in F1B1 was identified as the hit rate, while their error rate in the F2B1 condition where the fusion illusion occurred was identified as the FA rate. The hit and FA rates were then transformed to z scores; d' and c were calculated using the following equations (Chen et al., 2017; Macmillan & Creelman, 2004):

$$d' = \mathrm{z}(\text{Hit rate}) - \mathrm{z}(\text{FA}). \quad (1)$$

$$c = -0.5 * [\mathrm{z}(\text{Hit rate}) + \mathrm{z}(\text{FA rate})]. \quad (2)$$

For the $p = 0$ and $p = 1$ event consideration, log-linear transformation was applied to calculate the hit and FA rates (adding 0.5 each to the hits and false alarms and adding 1 each to the total number of signal trials and no-signal trials) to avoid extreme values of d' (Vanes et al., 2016).

Statistical analyses were conducted using mixed-model ANOVAs to analyze the effect of spatial location and personality traits on the accuracy of illusion conditions, d' and c. The results of simple effect analysis were based on Bonferroni correction.

Results

Accuracy

The mean score of each high or low trait group and the corresponding accuracy in the SiFI are shown in Table 1. For F1 and F2 conditions, the results show that the mean accuracy of the two conditions were greater than 90%, far higher than the random level, which indicated that the participants had a good ability to distinguish flashes. To further verify the existence of the fission illusion, we conducted a 2 (spatial location: Vnear_Afar vs. Vfar_Anear) × 2 (condition: F1B1 vs. F1B2) repeated-measures ANOVA. The results showed that the main effect of spatial location was not significant, $F < 1$. The main effect of condition was significant, $F(1, 102) = 350.35$, $p < .001$, $\eta_p^2 = 0.78$, the mean accuracy of F1B2 condition (43%) was significantly lower than that of F1B1 condition (94%), indicating the fission illusion occurred. The interaction was not significant, $F < 1$. For the fusion illusion conditions, we conducted a 2 (spatial location: Vnear_Afar vs.

Table 1 Mean accuracy(%) and standard deviation(%) for all conditions between groups of each personality trait

Group		Score		Accuracy					
		Mean	*SD*	F1	F2	F1B1	F2B2	F1B2	F2B1
Openness	high	40.86	1.66	91.36 (6.38)	92.75 (7.92)	94.54 (5.65)	96.96 (2.99)	38.21 (28.48)	60.39 (28.48)
	low	31.04	2.71	93.14 (7.05)	91.14 (8.21)	93.14 (7.56)	96.75 (2.64)	47.18 (29.99)	66.14 (26.31)
Conscientiousness	high	41.46	2.11	93.07 (6.6)	91.86 (7.06)	95.43 (6.01)	97.07 (2.87)	40.5 (30.63)	61.46 (30.49)
	low	33.54	1.86	93.43 (6.42)	94.46 (7.04)	94.82 (5.04)	96.46 (3.85)	53.07 (28.35)	70.79 (21.75)
Extraversion	high	44.18	2	93.25 (6.74)	94.96 (5.66)	93.39 (6.95)	97.86 (1.77)	45.07 (30.88)	72.61 (22.97)
	low	35.29	2.33	93 (6.24)	91.07 (8.28)	94.29 (5.63)	95.07 (4.16)	49 (28.49)	70.96 (22.71)
Agreeableness	high	40.29	1.87	90.61 (7.47)	93.43 (6.13)	92.18 (7.22)	96.07 (4.18)	36.04 (27.92)	63.96 (26.38)
	low	29.96	1.8	93.64 (5.46)	90.25 (8.76)	93.39 (6.51)	96.57 (2.54)	54.61 (26.5)	65.25 (23.95)
Neuroticism	high	40.04	1.95	92.18 (6.96)	92.64 (8)	91.89 (7.07)	97.18 (2)	45.79 (30.73)	73.86 (23.81)
	low	30.25	1.84	93.61 (6.37)	90.25 (8.28)	93.79 (6.79)	96.46 (3.56)	52.21 (28)	64.07 (24.91)

Vfar_Anear) × 2 (condition: F2B1 vs. F2B2) repeated-measures ANOVA. The results showed that the main effect of spatial location was significant, $F(1, 102) = 5.11$, $p = .026$, $\eta_p^2 = 0.05$, the mean accuracy of the Vfar_Anear (84%) was significantly greater than that of the Vnear_Afar (81%). The main effect of condition was significant, $F(1, 102) = 157.78$, $p < .001$, $\eta_p^2 = 0.61$, the mean accuracy of F2B1 condition (68%) was significantly lower than that of F2B2 condition (97%), indicating the fusion illusion occurred. The interaction was significant, $F(1, 102) = 5.78$, $p = .018$, $\eta_p^2 = 0.05$. Results of simple effect analysis based on Bonferroni correction showed that for F2B1 condition, the mean accuracy of the Vfar_Anear (71%) was significantly greater than that of the Vnear_Afar (66%), $t(102) = 3.29$, $p = .007$, Cohen's $d = 0.23$. For F2B2 condition, there was no significant difference between the two spatial location conditions, $t < 1$. The results suggested that the fission illusion and the fusion illusion could be steadily observed, and the fusion illusion was affected by the spatial location, the fusion illusion was much greater in the Vnear_Afar condition than the Vfar_Anear condition.

Neuroticism group

For F1B2 and F2B1 conditions, we conducted a 2 (trait level: high vs. low) × 2 (spatial location: Vnear_Afar vs. Vfar_Anear) repeated-measures ANOVA, respectively. The results showed that none of the main and interaction effects were significant, *ps* > 0.5.

Extraversion group

For F1B2 condition, we conducted a 2 (trait level: high vs. low) × 2 (spatial location: Vnear_Afar vs. Vfar_Anear) repeated-measures ANOVA. The results showed that the main effect of spatial location was not significant, *p*s > .5. The interaction effect was significant, $F(1, 54) = 4.58$, $p = .037$, $\eta_p^2 = 0.08$. The results of the simple effect showed that for the low extraversion group, the mean accuracy of the Vnear_Afar (49%) was significantly greater than that of the Vfar_Anear (42%), $t(27) = 2.13$, $p = .043$, Cohen's $d = 0.40$, but for the high extraversion group, there was no significant effect, $t(27) = 1.01$, $p = .32$. For F2B1 condition, we performed the same analysis, and the results also showed that none of the main and interaction effects were significant, *ps* > .5. This suggested that the fission illusion of low extraversion group was susceptible to spatial location (see Fig. 2. 1a).

Openness group

For F1B2 condition, we conducted a 2 (trait level: high vs. low) × 2 (spatial location: Vnear_Afar vs. Vfar_Anear) repeated-measures ANOVA. The results showed that none of the main and interaction effects were significant, *p*s > .5. For F2B1 condition, we performed the same analysis, the results showed that the main effect of spatial location was significant, $F(1, 54) = 4.29$, $p = .043$, $\eta_p^2 = 0.08$, the mean accuracy of the Vfar_Anear (69%) was significantly greater than that of the Vnear_Afar (63%). The interaction effect was not significant, $F(1, 54) = 1.16$, $p = .29$. This suggested that the fusion illusion of openness group was susceptible to spatial location (see Fig. 2. 2a).

Conscientiousness group

For F1B2 and F2B1 conditions, we conducted a 2 (trait level: high vs. low) × 2 (spatial location: Vnear_Afar vs. Vfar_Anear) repeated-measures ANOVA, respectively. The results showed that none of the main and interaction effects were significant, *p*s > .5.

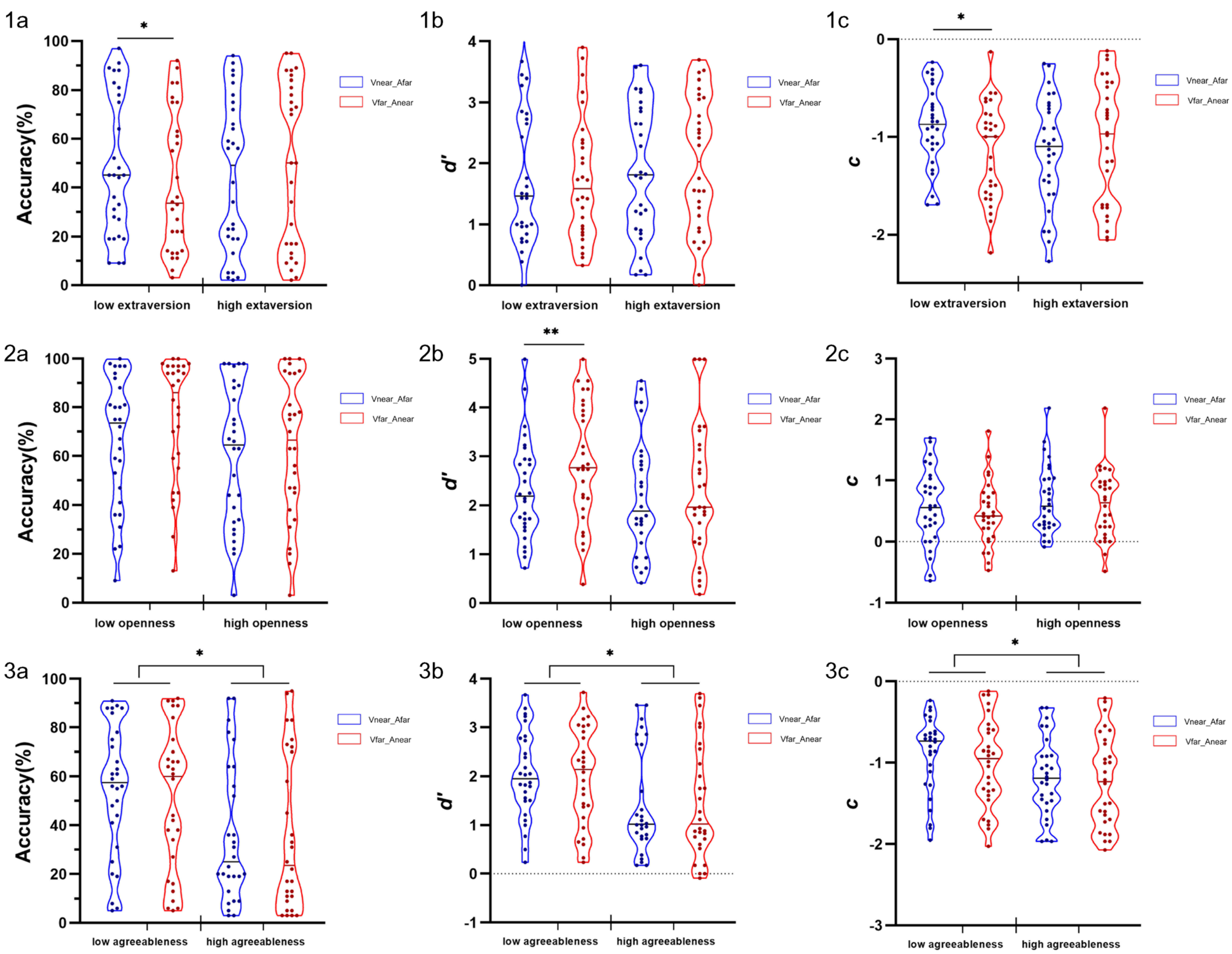

Fig. 2 **1a** The accuracy of the fission illusion between the individuals with low and high extraversion. **1b** Mean *d′* under the fission illusion for the individuals with low and high extraversion. **1c** Mean *c* under the fission illusion for the individuals with low and high extraversion. **2a** The accuracy of the fusion illusion between the individuals with low and high openness. **2b** Mean *d′* under the fusion illusion for the individuals with low and high openness. **2c** Mean *c* under the fusion illusion for the individuals with low and high openness. **3a** The accuracy of the fission illusion between the individuals with low and high agreeableness. **3b** Mean *d′* under the fission illusion for the individuals with low and high agreeableness. **3c** Mean *c* under the fission illusion for the individuals with low and high agreeableness. $^{**}p < .01$, $^{*}p < .05$

Agreeableness group

For F1B2 condition, we conducted a 2 (trait level: high vs. low) × 2 (spatial location: Vnear_Afar vs. Vfar_Anear) repeated-measures ANOVA. The results showed that the main effect of trait level was significant, $F(1, 54) = 5.07$, $p = .028$, $\eta_p^2 = 0.09$, the mean accuracy of the low agreeableness group (53%) was significantly greater than that of the high agreeableness group (36%). The main effect of spatial location and the interaction effect were not significant, $F < 1$. For F2B1 condition, we performed the same analysis, the results showed that that none of the main and interaction effects were significant, *p*s > 0.5. This suggested that the sensitivity of agreeableness trait to the fission illusion was different, and high agreeableness group was more likely to produce the fission illusion (see Fig. 2, 3a).

Signal detection theory analysis

To supplement the accuracy results, we conducted signal detection theory analysis on the data of each group of traits (see Table 2 and Fig. 2).

Sensitivity(*d′*)

In the results of sensitivity *d′*, we found that, for the fission illusion, only the agreeableness trait group had a significant main effect on trait level, the *d′* (2.02) in the low agreeableness

Table 2 Results of ANOVA for sensitivity *d′* and report criterion *c* of the fission illusion and fusion illusion in all trait groups

Group	main/interaction	Fission illusion						Fusion illusion					
		d'			*c*			*d'*			*c*		
		F	*p*	η_p^2	F	*p*	η_p^2	F	*p*	η_p^2	F	*p*	η_p^2
Neuroticism	Trait Level	<1			<1			<1			5.012	0.029*	0.085
	Spatial Location	<1			<1			1.593	0.212	0.029	<1		
	Interaction	<1			1.044	0.311	0.019	<1			<1		
Extraversion	Trait Level	<1			<1			<1			<1		
	Spatial Location	<1			1.939	0.17	0.035	5.109	0.028*	0.086	<1		
	Interaction	<1			8.053	0.006**	0.13	1.115	0.296	0.02	<1		
Openness	Trait Level	1.784	0.187	0.032	2.784	0.101	0.049	1.35	0.25	0.024	<1		
	Spatial Location	1.095	0.3	0.02	<1			7.834	0.007**	0.127	1.755	0.191	0.031
	Interaction	<1			1.115	0.296	0.02	4.221	0.045*	0.072	<1		
Conscientiousness	Trait Level	<1			<1			<1			1.362	0.248	0.025
	Spatial Location	<1			3.088	0.085	0.054	5.97	0.018*	0.1	1.85	0.179	0.033
	Interaction	2.299	0.135	0.041	1.85	0.179	0.033	<1			<1		
Agreeableness	Trait Level	4.42	0.04*	0.076	4.205	0.045*	0.072	<1			<1		
	Spatial Location	<1			1.697	0.198	0.03	3.324	0.074	0.058	<1		
	Interaction	<1			<1			<1			<1		

**$p < .01$, *$p < .05$

group was significantly higher than the *d′* (1.46) in the high agreeableness group. For the fusion illusion, the spatial location of the extraversion and conscientiousness group had significant main effects. The *d′* of Vfar_Anear (2.71) was significantly higher than the *d′* of Vnear_Afar (2.49) in the extraversion group. The *d′* for Vfar_Anear (2.69) was significantly higher than the *d′* for Vnear_Afar (2.39) in the conscientiousness group. In the openness group, the interaction between trait level and spatial location was significant, which showed that in the low openness group, The *d′* of Vfar_Anear (2.89) was significantly higher than the *d′* of Vnear_Afar (2.32), $t(27) = 3.43$, $p = .007$, Cohen's $d = 0.62$. However, there was no significant difference in the high openness group, $t < 1$.

Report criterion (*c*)

In the results of report criterion *c*, we found that there was a significant interaction between trait level and spatial location for the fission illusion in the extraversion group. In the low extraversion group, the *c* of Vfar_Anear (1.14) was significantly higher than that of Vnear_Afar (0.89). $t(27) = 2.99$, $p = .025$, Cohen's $d = 0.57$. However, there was no significant difference in the high extraversion group, $t(27) = 1.02$, $p = .32$. The main effect of trait level in agreeableness group was significant, the *c* in the low agreeableness group (−0.95) significantly higher than that in the high agreeableness group (−1.20). For the fusion illusion, we found that the main effect of trait level was significant in the neuroticism group, the *c* (0.62) significantly higher in the low neuroticism group than in the high neuroticism group (0.38).

General discussion

The current study investigated the effect of personality on SiFI and the regulation of spatial locations on the effect. Fission illusion and fusion illusion were observed from the accuracy results. The fission illusion of the high agreeableness group was significantly higher than that of the low agreeableness group. The fission illusion in the Vfar_Anear condition of the low extraversion group was higher than that in the Vnear_Afar condition. In the openness group, participants had a greater fusion illusion in the Vnear_Afar condition than in the Vfar_Anear condition. In addition, the results of sensitivity *d′* and report criterion *c* showed that all five personality traits were associated with SiFI. The agreeableness group showed that the high agreeableness group had lower discriminability to flash in the fission illusion, and the report criteria were less strict. The report criteria of the low neuroticism group were stricter for the fusion illusion. Low extraversion was less strict for the Vnear_Afar condition in the fission illusion. The extraversion group, conscientiousness group and low openness group had lower discriminability to flash in the fusion illusion in the Vnear_Afar condition than in the Vfar_Anear condition.

The results of both accuracy and signal detection theory showed that agreeableness had the effect on the fission illusion, and high agreeableness was more prone to the fission illusion, and it did not matter what spatial attention locations were. Generally, individuals with high agreeableness were usually friendlier and compassionate, but it was not surprising to find that they were more prone to the fission illusion (McCullough & Hoyt, 2002; Watson, 2000). SiFI is a typical multisensory phenomenon dominated by auditory stimuli, and the distribution of attention is involved in the integration of visual and auditory signals in SiFI (Mishra et al., 2010). When selective attention is weaker, the ability to suppress irrelevant information decreases, which in SiFI is reflected in the tendency to produce more illusions (DeLoss et al., 2013). Previous studies have found that high agreeableness is associated with a weaker selective attention ability (Avisar, 2011; Rodrigo et al., 2022). Avisar (2011) found that poorer visual search performance was related to high agreeableness, and the high agreeableness group had more difficulty in selective attention. In addition, high agreeableness was suggested to be related to lower activation of the right lateral prefrontal cortex, which was associated with response selection and suppression during a go/no-go task (Chikazoe, 2010; Rodrigo et al., 2022). This means that individuals with high agreeableness may find it more difficult to inhibit incorrect responses when faced with multiple response options for achieving a goal. Conversely, lower agreeableness was related to higher vigilance and was associated with a more conservative response bias in a visible tendency (Burton et al., 2010). Therefore, individuals with low agreeableness tended to hold stricter and more conservative judgment criteria than individuals with high agreeableness in the fission illusion.

Although only on the report criteria, neuroticism was somewhat influential of the fusion illusion. Neuroticism scores were often associated with psychiatric problems, neuroticism scores were higher in patients with schizophrenia, and neuroticism scores in people with autism were also higher than in the control group (Kotov et al., 2010; Ohi et al., 2012; Schriber et al., 2014). Previous studies have shown that patients with autism and schizophrenia are more prone to the fusion illusion (Ferri et al., 2018; Foss-Feig et al., 2010; Haß et al., 2016). The enhancement of the fusion illusion may be caused by the increase in the time window of the high neuroticism patients, which was attributed to the decrease in the overall time sensitivity (Ferri et al., 2018). In the current study, although we did not find differences in sensitivity between the high- and low-neuroticism groups, we found that the low-neuroticism group was stricter on report criteria for fusion illusions; thus, the low-neuroticism group may be less prone to the fusion illusion.

As expected, the influence of personality traits on SiFI was regulated by spatial location factors, especially, conscientiousness, openness and extraversion. Previous studies have shown that participants were more likely to perceive SiFI in the Vnear_Afar condition than in the Vfar_Anear condition (Sun et al., 2022). This may be due to the limited attention resources in the distance, and the dominant sensory in the audiovisual competition will receive more attention resources, thus leading to the enhancement of the sensory dominance (Sun et al., 2022; Yue et al., 2015). A large amount of evidence has shown that conscientiousness, openness, and extraversion are closely related to spatial attentional process (Koch et al., 2014; Noftle & Robins, 2007; Zabelina et al., 2016). Conscientiousness, which is closely related to the global precedence effect (Navon, 1977), reflects the tendency to focus on information in a broad versus narrow visual field (Büttner et al., 2014; Swift et al., 2020). Individuals with low openness generally exhibit a less flexible attention scope, and attention resources cannot be allocated adaptively to meet task requirements (Swift et al., 2020; Todd & Funder, 2015). Therefore, the conscientiousness and low openness group were more easily adjusted by spatial location factors in SiFI.

Extraversion showed interesting but seemingly contradictory results—that is, in fusion illusion, extroversion had higher discriminability in the Vfar_Anear condition, while in fission illusion, low extraversion was less accurate and stricter reporting tendency in the Vfar_Anear condition. The results of extraversion in the fusion illusion were consistent with the conscientiousness and low openness group. Previous studies have suggested that increased trait levels of extraversion were associated with improved change detection, and this trait may help in disengagement from stimuli (Bendall et al., 2021; Dhinakaran et al., 2014; Fine & Kobrick, 1976). However, individuals with low extraversion have less attentional resource availability (Eysenck, 1991) and smaller space attention range (Ai et al., 2019; Alessandretti et al., 2018). In the current study, individuals with low extraversion might pay less attention to distant beeps and made better judgments from nearby flashes in the Vnear_Afar condition.

In addition, the results of the current study also indicated that different personality traits specifically affected different illusions, with agreeableness and extraversion affecting the fission illusion while neuroticism, conscientiousness, openness and extraversion affecting the fusion illusion, except for agreeableness and neuroticism, the influence of the other three traits on SiFI was unavoidably regulated by spatial location factors. Previous studies have shown that the fission illusion and the fusion illusion are two types of illusions (de Haas et al., 2012; Mishra et al., 2007; Watkins et al., 2006). For fission illusion, from the localization of brain regions, the studies found fusiform gyrus (Chan et al., 2017), right angular gyrus (Chan et al., 2017; Watkins et al., 2007), and frontal inferior opercular (Mishra et al., 2007) apparently increased activity. Mishra et al. (2007) used ERP technology to find that individuals with the fission illusion would induce greater negative components located in the superior temporal gyrus at 110 ms and 130 ms.

The fusion illusion triggered early superior and inferior parietal activity (130~160 ms), primary and secondary visual cortex activity (300~320 ms) (Innes-Brown et al., 2013), and superior temporal and inferior frontal gyrus (~180 ms) activity (Mishra et al., 2008). Although the mechanisms underlying the differences between the fission and fusion illusions have not been clarified, we can confirm that personality traits play an important role in the fission illusion and fusion illusion. Nevertheless, our findings reported here shed new light on the relationship between personality traits and general multisensory illusions at different spatial locations, which could be important but easy-to-overlook reliable factors.

Conclusions

In summary, the participants were divided into groups according to their personality traits, and their SiFI behavior performance of the participants at different spatial locations was recorded. The current study showed that the fission illusion was affected by agreeableness and extraversion, and the fusion illusion was affected by neuroticism, conscientiousness, openness and extraversion. The influence of extroversion, accountability and openness on SiFI was regulated by spatial locations. This suggested that personality traits were important factors of the SiFI, which may be related to spatial attention.

Authors' contributions A.W., J.Y., and M.Z. were responsible for the experimental design, interpretation of the data and revision of the manuscript. J.H. and A.W. performed the experiments. H.Z. and S.L. were responsible for analyzing the data. H.Z., S.L., and J.H. drafted the manuscript.

Funding This research was supported by the 14th five-year plan of Jiangsu Province Education Science (B/2021/01/87), the Humanities and Social Sciences Research Project of Soochow University (22XM0017), the Interdiscipline Research Team of Humanities and Social Sciences of Soochow University (2022), the JST FOREST Program (Grant no. JPM- JFR2041), the Japan Society for the Promotion of Science KAKENHI (20K04381), and the National Natural Science Foundation of China (31700939 and 31871092).

Declaration

Conflicting interests The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Informed consent Informed consent was obtained from all individual participants included in the study.

Ethical approval All experiments were performed in accordance with the principles of the Declaration of Helsinki. This study was approved by the Academic Committee of the Department of Psychology, Soochow University, China.

References

Abadi, R. V., & Murphy, J. S. (2014). Phenomenology of the sound-induced flash illusion. *Experimental Brain Research, 232*(7), 2207–2220.

Ai, P. L., Liu, Y. Y., & Zhao, X. (2019). Big Five personality traits predict daily spatial behavior: Evidence from smartphone data. *Personality and Individual Differences, 147*, 285–291.

Alessandretti, L., Lehmann, S., & Baronchelli, A. (2018). Understanding the interplay between social and spatial behavior. *EPJ Data Science, 7*, 36.

Al-Samarraie, H., Eldenfria, A., & Dawoud, H. (2017). The impact of personality traits on users' information-seeking behavior. *Information Processing & Management, 53*(1), 237–247.

Andersen, T. S., Tiippana, K., & Sams, M. (2004). Factors influencing audiovisual fission and fusion illusions. *Cognitive Brain Research, 21*(3), 301–308.

Avisar, A. (2011). Which behavioral and personality characteristics are associated with difficulties in selective attention? *Journal of Attention Disorders, 15*(5), 357–367.

Balz, J., Keil, J., Romero, Y. R., Mekle, R., Schubert, F., Aydin, S., Ittermann, B., Gallinat, J., & Senkowski, D. (2016). GABA concentration in superior temporal sulcus predicts gamma power and perception in the sound-induced flash illusion. *NeuroImage, 125*, 724–730.

Bao, V. A., Doobay, V., Mottron, L., Collignon, O., & Bertone, A. (2017). Multisensory integration of low-level information in autism spectrum disorder: Measuring susceptibility to the flash-beep illusion. *Journal of Autism and Developmental Disorders, 47*(8), 2535–2543.

Bendall, R. C., Begley, S., & Thompson, C. (2021). Interactive influences of emotion and extraversion on visual attention. *Brain and Behavior: A Cognitive Neuroscience Perspective, 11*(11), 2387–2399.

Bidelman, G. M. (2016). Musicians have enhanced audiovisual multisensory binding: Experience-dependent effects in the double-flash illusion. *Experimental Brain Research, 234*(10), 3037–3047.

Biggs, A. T., Clark, K., & Mitroff, S. R. (2017). Who should be searching? Differences in personality can affect visual search accuracy. *Personality and Individual Differences, 116*, 353–358.

Blini, E., Desoche, C., Salemme, R., Kabil, A., Hadj-Bouziane, F., & Farnè, A. (2018). Mind the depth: Visual perception of shapes is better in peripersonal space. *Psychological Science, 29*(11), 1868–1877.

Brighina, F., Bolognini, N., Cosentino, G., Maccora, S., Paladino, P., Baschi, R., Vallar, G., & Fierro, B. (2015). Visual cortex hyperexcitability in migraine in response to sound-induced flash illusions. *Neurology, 84*(20), 2057–2061.

Burin, D., Pignolo, C., Ales, F., Giromini, L., Pyasik, M., Ghirardello, D., Zennaro, A., Angilletta, M., Castellino, L., & Pia, L. (2020). Relationships between personality features and the rubber hand illusion: An exploratory study. *Frontiers in Psychology, 10*, Article 2762.

Burton, L., Pfaff, D., Bolt, N., Hadjikyriacou, D., Silton, N., Kilgallen, C., ... Allimant, J. (2010). Effects of gender and personality on the Conners continuous performance test. *Journal of Clinical and Experimental Neuropsychology*, *32*(1), 66–70.

Büttner, O. B., Wieber, F., Schulz, A. M., Bayer, U. C., Florack, A., & Gollwitzer, P. M. (2014). Visual attention and goal pursuit: Deliberative and implemental mindsets affect breadth of attention. *Personality and Social Psychology Bulletin, 40*, 1248–1259.

Cecere, R., Rees, G., & Romei, V. (2015). Individual differences in alpha frequency drive crossmodal illusory perception. *Current Biology, 25*(2), 231–235.

Chan, J., Kaiser, J., Brandl, M., Matura, S., Prvulovic, D., Hogan, M., & Naumer, M. J. (2015). Expanded temporal binding windows in people with mild cognitive impairment. *Current Alzheimer Research, 12*(1), 61–68.

Chan, J. S., Wibral, M., Wollstadt, P., Stawowsky, C., Brandl, M., Helbling, S., Naumer, M., & Kaiser, J. (2017). *Predictive coding over the lifespan: Increased reliance on perceptual priors in older adults—A magnetoencephalography and dynamic causal modelling study.* bioRxiv.

Chan, J. S., Connolly, S. K., & Setti, A. (2018). The number of stimulus-onset asynchronies affects the perception of the sound-induced flash illusion in young and older adults. *Multisensory Research, 31*(3/4), 175–190.

Chen, Y. C., Maurer, D., Lewis, T. L., Spence, C., & Shore, D. I. (2017). Central-peripheral differences in audiovisual and visuotactile event perception. *Attention, Perception, & Psychophysics, 79*(8), 2552–2563.

Chikazoe, J. (2010). Localizing performance of go/no-go tasks to prefrontal cortical subregions. *Current Opinion in Psychiatry, 23*(3), 267–272.

Coren, S., & Harland, R. E. (1995). Personality correlates of variations in visual and auditory abilities. *Personality and Individual Differences, 18*(1), 15–25.

Costa, P. T., & McCrae, R. R. (1992). The five-factor model of personality and its relevance to personality disorders. *Journal of Personality Disorders, 6*(4), 343–359.

De Gelder, B., & Bertelson, P. (2003). Multisensory integration, perception and ecological validity. *Trends in Cognitive Sciences, 7*(10), 460–467.

de Haas, B., Kanai, R., Jalkanen, L., & Rees, G. (2012). Grey matter volume in early human visual cortex predicts proneness to the sound-induced flash illusion. *Proceedings of the Royal Society B: Biological Sciences, 279*(1749), 4955–4961.

DeLoss, D. J., & Andersen, G. J. (2015). Aging, spatial disparity, and the sound-induced flash illusion. *PLoS One, 10*(11), Article e0143773.

DeLoss, D. J., Pierce, R. S., & Andersen, G. J. (2013).Multisensory integration, aging, and the sound-induced flashillusion. *Psychology and Aging, 28*(3), 802–812.

Dhinakaran, J., De Vos, M., Thorne, J. D., & Kranczioch, C. (2014). Neuroticism focuses attention: Evidence from SSVEPs. *Experimental Brain Research, 232*(6), 1895–1903.

Eysenck, H. J. (1991). Biological dimensions of personality. In L. A. Pervin (Ed.), *Handbook of personality* (pp. 244–276). Guilford Press.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175–191.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*, 1149–1160.

Ferri, F., Venskus, A., Fotia, F., Cooke, J., & Romei, V. (2018). Higher proneness to multisensory illusions is driven by reduced temporal sensitivity in people with high schizotypal traits. *Consciousness and Cognition, 65*, 263–270.

Fine, B. J., & Kobrick, J. L. (1976). Note on the relationship between introversion-extraversion, field-dependence-independence and accuracy of visual target detection. *Perceptual and Motor Skills, 42*(3), 763–766.

Foss-Feig, J. H., Kwakye, L. D., Cascio, C. J., Burnette, C. P., Kadivar, H., Stone, W. L., & Wallace, M. T. (2010). An extended multisensory temporal binding window in autism spectrum disorders. *Experimental Brain Research, 203*, 381–389.

Haß, K., Sinke, C., Reese, T., Roy, M., Wiswede, D., Dillo, W., ... Szycik, G. R. (2016). Enlarged temporal integration window in schizophrenia indicated by the double-flash illusion. *Cognitive Neuropsychiatry, 22*(2), 145–158.

Hirst, R. J., McGovern, D. P., Setti, A., Shams, L., & Newell, F. N. (2020). What you see is what you hear: Twenty years of research using the sound-induced flash illusion. *Neuroscience & Biobehavioral Reviews, 118*, 759–774.

Innes-Brown, H., Barutchu, A., & Crewther, D. P. (2013). Neural responses in parietal and occipital areas in response to visual events are modulated by prior multisensory stimuli. *PLoS One, 8*(12), e84331.

Jack, C. E., & Thurlow, W. R. (1973). Effects of degree of visual association and angle of displacement on the "ventriloquism" effect. *Perceptual and Motor Skills, 37*(3), 967–979.

John, O. P., Donahue, E. M., & Kentle, R. L. (1991). *The Big Five Inventory—Versions 4a and 5*. University of California, Berkeley, Institute of Personality and Social Research.

Keil, J. (2020). Double flash illusions: Current findings and future directions. *Frontiers in Neuroscience, 14*, 298–304.

Koch, T., Ortner, T. M., Eid, M., Caspers, J., & Schmitt, M. (2014). Evaluating the construct validity of objective personality tests using a multitrait-multimethod-multi-occasion-(MTMM-MO) approach. *European Journal of Psychological Assessment, 30*, 208–230.

Kotov, R., Gamez, W., Schmidt, F., & Watson, D. (2010). Linking "big" personality traits to anxiety, depressive, and substance use disorders: A meta-analysis. *Psychological Bulletin, 136*(5), 768–821.

Kumpik, D. P., Roberts, H. E., King, A. J., & Bizley, K. B. (2014). Visual sensitivity is a stronger determinant of illusory processes than auditory cue parameters in the sound-induced flash illusion. *Journal of Vision, 14*(7), 60–65.

Macmillan, N. A., & Creelman, C. D. (2004). *Detection theory: A user's guide*. Psychology Press.

Maringelli, F., McCarthy, J., Steed, A., Slater, M., & Umiltà, C. (2001). Shifting visuo-spatial attention in a virtual three-dimensional space. *Cognitive Brain Research, 10*(3), 317–322.

McCormick, D., & Mamassian, P. (2008). What does the illusory-flash look like? *Vision Research, 48*(1), 63–69.

McCullough, M. E., & Hoyt, W. T. (2002). Transgression-related motivational dispositions: Personality substrates of forgiveness and their links to the Big Five. *Personality and Social Psychology Bulletin, 28*(11), 1556–1573.

McGovern, D. P., Eugenie, R., John, S., Martin, M. G. T., & Newell, F. N. (2014). The sound-induced flash illusion reveals dissociable age-related effects in multisensory integration. *Frontiers in Aging Neuroscience, 6*(250), 1–9.

Meredith, M. A., & Stein, B. E. (1986). Visual, auditory, and somatosensory convergence on cells in superior colliculus results in multisensory integration. *Journal of Neurophysiology, 56*(3), 640–662.

Milner, A. D., & Goodale, M. A. (2008). Two visual systems re-viewed. *Neuropsychologia, 46*, 774–785.

Mishra, J., Martinez, A., Sejnowski, T. J., & Hillyard, S. A. (2007). Early cross-modal interactions in auditory and visual cortex underlie a sound-induced visual illusion. *Journal of Neuroscience, 27*(15), 4120–4131.

Mishra, J., Martinez, A., & Hillyard, S. A. (2008). Cortical processes underlying the sound-induced flash fusion. *Brain Research, 1242*, 102–115.

Mishra, J., Martínez, A., & Hillyard, S. A. (2010). Effect of attention on early cortical processes associated with the sound-induced extra flash illusion. *Journal of Cognitive Neuroscience, 22*(8), 1714–1729.

Moro, S. S., & Steeves, J. K. E. (2018). Normal temporal binding window but no sound-induced flash illusion in people with one eye. *Experimental Brain Research, 236*(6), 1825–1834.

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology, 9*, 353–383.

Noftle, E. E., & Robins, R. W. (2007). Personality predictors of academic outcomes: Big five correlates of GPA and SAT scores. *Journal of Personality and Social Psychology, 93*, 116–130.

Ohi, K., Hashimoto, R., Yasuda, Y., Fukumoto, M., Yamamori, H., Iwase, M., Kazui, H., & Takeda, M. (2012). Personality traits and schizophrenia: Evidence from a case-control study and meta-analysis. *Psychiatry Research, 198*(1), 7–11.

Rodrigo, A. H., Di Domenico, S. I., Wright, L., Page-Gould, E., Fournier, M. A., Ayaz, H., & Ruocco, A. C. (2022). Interpersonal traits and the neural representations of cognitive control in the prefrontal cortex. *Cognitive, Affective, & Behavioral Neuroscience, 22*(5), 1001–1020.

Schriber, R. A., Robins, R. W., & Solomon, M. (2014). Personality and self-insight in individuals with autism spectrum disorder. *Journal of Personality and Social Psychology, 106*(1), 112–130.

Shams, L., Kamitani, Y., & Shimojo, S. (2002). Visual illusion induced by sound. *Cognitive Brain Research, 14*(1), 147–152.

Sun, Y. W., Zhou, H., Liu, C. M., Wang, A. J., Yue, C. L., & Zhang, M. (2022). Sound-induced flash illusion is modulated by the depth of auditory stimuli: Evidence from younger and older adults. *Attention, Perception, & Psychophysics, 84*, 2040–2050.

Swift, V., Wilson, K. E., & Peterson, J. B. (2020). Zooming in on the attentional foundations of the Big Five. *Personality and Individual Differences, 164*, 110000–110009.

Talsma, D., Senkowski, D., Soto-Faraco, S., & Woldorff, M. G. (2010). The multifaceted interplay between attention and multisensory integration. *Trends in Cognitive Sciences, 14*(9), 400–410.

Todd, E., & Funder, D. C. (2015). Personality. In D. Matsumoto, C. Hyisung, & M. G. Frank (Eds.), *APA handbook of nonverbal communication* (pp. 163–185). American Psychological Association.

Vanes, L. D., White, T. P., Wigton, R. L., Joyce, D., Collier, T., & Shergill, S. S. (2016). Reduced susceptibility to the sound-induced flash fusion illusion in schizophrenia. *Psychiatry Research, 245*, 58–65.

Watkins, S., Shams, L., Tanaka, S., Haynes, J. D., & Rees, G. (2006). Sound alters activity in human V1 in association with illusory visual perception. *NeuroImage, 31*(3), 1247–1256.

Watkins, S., Shams, L., Josephs, O., & Rees, G. (2007). Activity in human V1 follows multisensory perception. *NeuroImage, 37*(2), 572–578.

Watson, D. (2000). *Mood and temperament*. Guilford Press.

Whittingham, K. M., McDonald, J. S., & Clifford, C. W. (2014). Synesthetes show normal sound-induced flash fission and fusion illusions. *Vision Research, 105*, 1–9.

Wilson, K. E., Lowe, M. X., Ruppel, J., Pratt, J., & Ferber, S. (2016). The scope of no return: Openness predicts the spatial distribution of inhibition of return. *Attention, Perception, & Psychophysics, 78*(1), 209–217.

Young, M. S., & Schinka, J. A. (2001). Research validity of the NEO-PI-R additional evidence for reliability and validity. *Journal of Personality Assessment, 76*, 412–420.

Yue, Z., Jiang, Y., Li, Y., Wang, P., & Chen, Q. (2015). Enhanced visual dominance in far space. *Experimental Brain Research, 233*(10), 2833–2843.

Zabelina, D., Saporta, A., & Beeman, M. (2016). Flexible or leaky attention in creative people? Distinct patterns of attention for different types of creative thinking. *Memory & Cognition, 44*, 488–498.