Can you believe your eyes? Positive schizotypy is associated with increased susceptibility to the Müller-Lyer illusion

Supplementary Materials

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A.) Instructions for the Muller-Lyer illusion

To standardize viewing conditions as much as possible, participants were given the following instructions before they were shown the illusions.

‘The next test is a perception test. More specifically, we want to know how you perceive the length of the lines.

We ask you to report on your experience without measuring the lines or using any tools to compare them.

It is important that you can see the test clearly, so we would ask you to adjust the brightness of your display/screen to the strongest possible setting if possible and try to create lighting conditions that allow you to see the screen clearly.

If you wear glasses or contact lenses for reading, please put them on before you start the test.’

B.) Data quality control

Conducting an online study allows less control over data collection, however we predefined several exclusion rules in order to maintain data quality. First, after responding to the illusions, participants were asked to report if they used any kind of help during the trials (e.g. their finger or a ruler to measure the length of the shafts); those who reported so were excluded from the analysis (N = 42). Moreover, participants who reported seeing the two lines in the *ratio-80%* condition identical in length or who reported seeing the lower line longer were also excluded from the study (N = 29). We argue that these participants either did not understand the task, did not take it seriously or had fundamental visual deficits that seriously affect their perception.

During data processing, unexpectedly, we found participants of and above the age of 60 (N = 13), they were removed from the sample in order to avoid confounding by aging-related factors, following standard procedures in cognitive testing (Roberts & Allen, 2016).

Second, in the exploration phase of the raw illusion response data (independently of other factors, e.g.schizotypy) the consequence of the failure to randomization became evident in the form of anomalous responses to the first illusion. Here, participants were shown the *ratio-120%* condition, where the lower line is in reality 20% longer than the upper one, however,

we noticed an unexpectedly high rate of ‘same length’ responses (see the bottom right facet of Figure 2). We argue that participants expected it to be the well-known original illusion, where the lines are of the same length, even if they appear to be different.

In order to detect invalid MSS-B questionnaire responses a relative speed index (median response time divided by MSS-B completion time for each participant) was calculated (Leiner, 2019). Participants with a relative speed index greater than 2 (indicating twice as fast completion time compared to the average participant) were excluded from further analysis (N = 12).

Furthermore, participants with reported neurological disorders (N = 34) were excluded from the analysis as neurological disorders such as Parkinson’s disease have been associated with altered susceptibility to visual illusions (Notredame et al., 2014). The inclusion of participants with reported neurological disorders did not have an effect on the results.

All aforementioned steps of data cleaning were conducted before, thus independently of modeling.

C.) Model averaging

Model formula (lme4 syntax)	AICc	max. VIF
illusion_effect ~ angle_factor + ratio + mss_pos_sum + (ratio | participant)	2072	1
illusion_effect ~ angle_factor + ratio + mss_pos_sum + age + (ratio | participant)	2070	1
illusion_effect ~ angle_factor + ratio + mss_pos_sum + sex + (ratio | participant)	2065	1.01
illusion_effect ~ angle_factor + ratio + mss_pos_sum + device + (ratio | participant)	2072	1.01
illusion_effect ~ angle_factor + ratio + caps_sum + (ratio | participant)	2074	1
illusion_effect ~ angle_factor + ratio + caps_sum + age + (ratio | participant)	2073	1.01
illusion_effect ~ angle_factor + ratio + caps_sum + sex + (ratio | participant)	2067	1.01
illusion_effect ~ angle_factor + ratio + caps_sum + device + (ratio | participant)	2074	1.01
illusion_effect ~ angle_factor + ratio + mss_dis_sum + (ratio | participant)	2076	1.01
illusion_effect ~ angle_factor + ratio + mss_dis_sum + age + (ratio | participant)	2074	1.02
illusion_effect ~ angle_factor + ratio + mss_dis_sum + sex + (ratio | participant)	2070	1.01
illusion_effect ~ angle_factor + ratio + mss_dis_sum + device + (ratio | participant)	2076	1.01
illusion_effect ~ angle_factor + ratio + mss_neg_sum + (ratio | participant)	2076	1
illusion_effect ~ angle_factor + ratio + mss_neg_sum + age + (ratio | participant)	2074	1
illusion_effect ~ angle_factor + ratio + mss_neg_sum + sex + (ratio | participant)	2070	1.01
illusion_effect ~ angle_factor + ratio + mss_neg_sum + device + (ratio | participant)	2076	1.01
illusion_effect ~ angle_factor + ratio + mss_sum + (ratio | participant)	2075	1
illusion_effect ~ angle_factor + ratio + mss_sum + age + (ratio | participant)	2073	1
illusion_effect ~ angle_factor + ratio + mss_sum + sex + (ratio | participant)	2068	1.01
illusion_effect ~ angle_factor + ratio + mss_sum + device + (ratio | participant)	2075	1.01

Table S1. The models included in model averaging.*The model structures are indicated using the syntax of the lme4 R package. ratio: ratio of the two lines (100%, 120%); angle_factor: categorical variable coding the angle of the shafts with 4 levels; mss_pos_sum: positive schizotypy subscale score of the MSS-B; caps_sum: total score on the CAPS; mss_sum: total score on the MSS-B; mss_neg_sum: negative schizotypy subscale score of the MSS-B; sex: dummy variable coding sex, male was set as baseline; device: categorical variable coding the device the participant used to complete survey with 4 levels. AICc: corrected Akaike Information Criterion; VIF: variance inflation factor.*

Predictors	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*
Angle: 30°	-0.81	-1.21 – -0.42	**<0.001**	-0.81	-1.21 – -0.42	**<0.001**	-0.81	-1.21 – -0.42	**<0.001**	-0.81	-1.21 – -0.42	**<0.001**
Angle: 45°	-1.06	-1.46 – -0.67	**<0.001**	-1.06	-1.46 – -0.67	**<0.001**	-1.06	-1.46 – -0.67	**<0.001**	-1.06	-1.46 – -0.67	**<0.001**
Angle: 60°	-0.89	-1.29 – -0.50	**<0.001**	-0.89	-1.29 – -0.50	**<0.001**	-0.89	-1.28 – -0.50	**<0.001**	-0.89	-1.29 – -0.50	**<0.001**
Ratio: 120%	1.08	0.45 – 1.70	**0.001**	1.08	0.46 – 1.71	**0.001**	0.95	0.36 – 1.53	**0.001**	1.02	0.42 – 1.63	**0.001**
MSS-B: Positive schizotypy	0.84	0.04 – 1.64	**0.039**	0.82	0.03 – 1.61	**0.041**	0.86	0.05 – 1.67	**0.037**	0.88	0.07 – 1.68	**0.033**
Age				-0.79	-1.58 – 0.00	0.051						
Sex: female							1.44	0.44 – 2.44	**0.005**			
Device: laptop										2.76	0.36 – 5.15	**0.024**
Device: tablet										1.64	-1.62 – 4.90	0.323
Device: smartphone										0.85	-0.86 – 2.56	0.328
ICC	0.81			0.81			0.79			0.80		
Observations	2104			2104			2104			2104		
AICc	2071.623			2069.812			2065.265			2071.641		

Table S2. Summaries of models predicting illusion susceptibility from positive schizotypy.
Std Beta: fully standardized coefficients; CI: 95% confidence intervals; ICC: Intraclass correlation coefficient reflecting the ratio of between-person and total variance in the dependent variable; AICc: corrected Akaike Information Criterion

Predictors	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*
Angle: 30°	-0.81	-1.21 – -0.42	**<0.001**	-0.81	-1.21 – -0.42	**<0.001**	-0.81	-1.21 – -0.42	**<0.001**	-0.81	-1.21 – -0.42	**<0.001**
Angle: 45°	-1.06	-1.46 – -0.67	**<0.001**	-1.06	-1.46 – -0.67	**<0.001**	-1.06	-1.46 – -0.67	**<0.001**	-1.06	-1.46 – -0.67	**<0.001**
Angle: 60°	-0.89	-1.28 – -0.50	**<0.001**	-0.89	-1.28 – -0.50	**<0.001**	-0.89	-1.28 – -0.50	**<0.001**	-0.89	-1.28 – -0.50	**<0.001**
Ratio: 120%	1.07	0.45 – 1.69	**0.001**	1.07	0.45 – 1.70	**0.001**	0.93	0.35 – 1.51	**0.002**	1.01	0.41 – 1.62	**0.001**
CAPS: Anomalous perceptions	0.59	-0.20 – 1.39	0.142	0.49	-0.31 – 1.28	0.228	0.66	-0.14 – 1.47	0.105	0.54	-0.26 – 1.34	0.183
Age				-0.73	-1.54 – 0.07	0.074						
Sex: female							1.48	0.48 – 2.48	**0.004**			
Device: laptop										2.64	0.22 – 5.06	**0.032**
Device: tablet										1.60	-1.69 – 4.89	0.341
Device: smartphone										0.86	-0.86 – 2.59	0.326
ICC	0.81			0.81			0.78			0.80		
Observations	2104			2104			2104			2104		
AICc	2073.751			2072.572			2067.017			2074.480		

Table S3. Summaries of models predicting illusion susceptibility from anomalous perception.
Std Beta: fully standardized coefficients; CI: 95% confidence intervals; ICC: Intraclass correlation coefficient reflecting the ratio of between-person and total variance in the dependent variable; AICc: corrected Akaike Information Criterion

Predictors	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*
Angle: 30°	-0.81	-1.21 – -0.42	<**0.001**	-0.81	-1.21 – -0.42	<**0.001**	-0.81	-1.21 – -0.42	<**0.001**	-0.81	-1.21 – -0.42	<**0.001**
Angle: 45°	-1.06	-1.46 – -0.67	<**0.001**	-1.06	-1.46 – -0.67	<**0.001**	-1.06	-1.46 – -0.67	<**0.001**	-1.06	-1.46 – -0.67	<**0.001**
Angle: 60°	-0.89	-1.28 – -0.50	<**0.001**	-0.89	-1.28 – -0.50	<**0.001**	-0.89	-1.28 – -0.50	<**0.001**	-0.89	-1.28 – -0.50	<**0.001**
Ratio: 120%	1.06	0.44 – 1.68	**0.001**	1.06	0.44 – 1.68	**0.001**	0.92	0.35 – 1.50	**0.002**	1.00	0.40 – 1.61	**0.001**
MSS-B: Disorganized schizotypy	-0.06	-0.87 – 0.76	0.894	-0.21	-1.03 – 0.62	0.625	-0.16	-1.00 – 0.67	0.699	-0.14	-0.96 – 0.69	0.742
Age				-0.84	-1.65 – -0.03	**0.043**						
Sex: female							1.47	0.45 – 2.48	**0.004**			
Device: laptop										2.82	0.39 – 5.25	**0.023**
Device: tablet										1.80	-1.50 – 5.10	0.285
Device: smartphone										1.02	-0.70 – 2.74	0.246
ICC	0.81			0.81			0.78			0.79		
Observations	2104			2104			2104			2104		
AICc	2075.897			2073.790			2069.500			2076.145		

Table S4. Summaries of models predicting illusion susceptibility from disorganizedschizotypy.
Std Beta: fully standardized coefficients; CI: 95% confidence intervals; ICC: Intraclass correlation coefficient reflecting the ratio of between-person and total variance in the dependent variable; AICc: corrected Akaike Information Criterion

Predictors	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*
Angle: 30°	-0.81	-1.21 – -0.42	**<0.001**	-0.81	-1.21 – -0.42	**<0.001**	-0.81	-1.21 – -0.42	**<0.001**	-0.81	-1.21 – -0.42	**<0.001**
Angle: 45°	-1.06	-1.46 – -0.67	**<0.001**	-1.06	-1.46 – -0.67	**<0.001**	-1.06	-1.46 – -0.67	**<0.001**	-1.06	-1.46 – -0.67	**<0.001**
Angle: 60°	-0.89	-1.28 – -0.50	**<0.001**	-0.89	-1.28 – -0.50	**<0.001**	-0.89	-1.28 – -0.50	**<0.001**	-0.89	-1.28 – -0.50	**<0.001**
Ratio: 120%	1.07	0.45 – 1.69	**0.001**	1.08	0.45 – 1.70	**0.001**	0.94	0.35 – 1.52	**0.002**	1.01	0.41 – 1.62	**0.001**
MSS-B: Negative schizotypy	0.04	-0.76 – 0.85	0.913	0.05	-0.75 – 0.85	0.910	0.14	-0.68 – 0.97	0.734	0.07	-0.74 – 0.89	0.862
Age				-0.80	-1.60 – -0.00	**0.049**						
Sex: female							1.46	0.45 – 2.47	**0.005**			
Device: laptop										2.79	0.37 – 5.22	**0.024**
Device: tablet										1.76	-1.55 – 5.07	0.298
Device: smartphone										1.01	-0.71 – 2.73	0.250
ICC	0.81			0.81			0.79			0.80		
Observations	2104			2104			2104			2104		
AICc	2075.903			2074.016			2069.535			2076.222		

Table S5. Summaries of models predicting illusion susceptibility from negative schizotypy.
Std Beta: fully standardized coefficients; CI: 95% confidence intervals; ICC: Intraclass correlation coefficient reflecting the ratio of between-person and total variance in the dependent variable; AICc: corrected Akaike Information Criterion

Predictors	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*	*Std Beta*	*CI*	*p*
Angle: 30°	-0.81	-1.21 – -0.42	**<0.001**	-0.81	-1.21 – -0.42	**<0.001**	-0.81	-1.21 – -0.42	**<0.001**	-0.81	-1.21 – -0.42	**<0.001**
Angle: 45°	-1.06	-1.46 – -0.67	**<0.001**	-1.06	-1.46 – -0.67	**<0.001**	-1.06	-1.46 – -0.67	**<0.001**	-1.06	-1.46 – -0.67	**<0.001**
Angle: 60°	-0.89	-1.29 – -0.50	**<0.001**	-0.89	-1.29 – -0.50	**<0.001**	-0.89	-1.28 – -0.50	**<0.001**	-0.89	-1.28 – -0.50	**<0.001**
Ratio: 120%	1.08	0.46 – 1.71	**0.001**	1.09	0.46 – 1.72	**0.001**	0.95	0.37 – 1.54	**0.001**	1.03	0.42 – 1.64	**0.001**
MSS-B: Overall schizotypy	0.45	-0.35 – 1.24	0.272	0.39	-0.40 – 1.18	0.338	0.47	-0.34 – 1.28	0.256	0.45	-0.35 – 1.25	0.273
Age				-0.77	-1.57 – 0.03	0.058						
Sex: female							1.45	0.45 – 2.46	**0.005**			
Device: laptop										2.76	0.35 – 5.17	**0.025**
Device: tablet										1.64	-1.64 – 4.92	0.328
Device: smartphone										0.95	-0.76 – 2.67	0.274
ICC	0.81			0.81			0.79			0.80		
Observations	2104			2104			2104			2104		
AICc	2074.710			2073.111			2068.362			2075.053		

Table S6. Summaries of models predicting illusion susceptibility from overall schizotypy.
Std Beta: fully standardized coefficients; CI: 95% confidence intervals; ICC: Intraclass correlation coefficient reflecting the ratio of between-person and total variance in the dependent variable; AICc: corrected Akaike Information Criterion

D.) Bootstrapping

To estimate the uncertainty of the model averaged coefficients (Figure 3A), we performed bootstrapping (Burnham & Anderson, 2002). We drew 1000 bootstrap samples, resampling at the level of participants, and constructed 95% confidence intervals (percentile method), and we also visualized the bootstrapped distributions (which can be interpreted as an approximation of a noninformative nonparametric posterior probability distribution; Hastie, Tibshirani& Friedman, 2009).

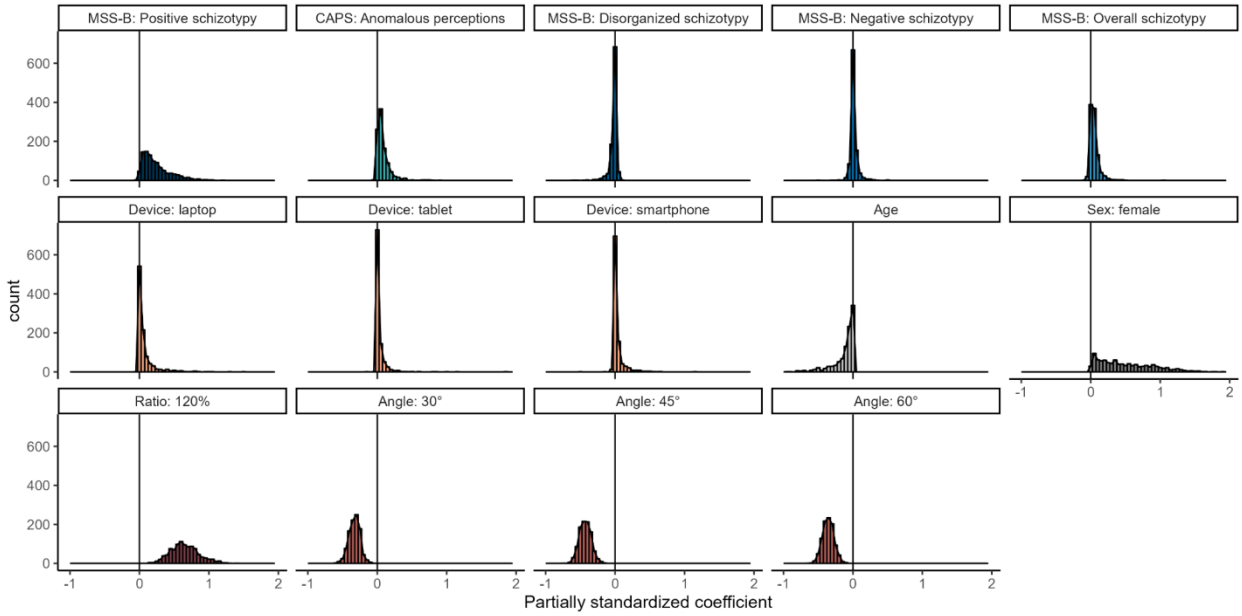

Fig. S1. Bootstrapped distributions of the model averaged coefficients.

predictor	CI_low	CI_high
MSS-B: Positive schizotypy	**0.013**	**0.756**
CAPS: Anomalous perceptions	-0.004	0.365
MSS-B: Disorganized schizotypy	-0.175	0.039
MSS-B: Negative schizotypy	-0.064	0.150
MSS-B: Overall schizotypy	-0.020	0.233
Device: laptop	**0.000**	**0.542**
Device: tablet	-0.003	0.236
Device: smartphone	-0.012	0.298
Age	-0.610	0.000
Sex: female	**0.022**	**1.387**
Ratio: 120%	**0.292**	**1.099**
Angle: 30°	**-0.488**	**-0.175**
Angle: 45°	**-0.600**	**-0.263**
Angle: 60°	**-0.511**	**-0.191**

Table S7. Confidence intervals (95%) of the model averaged coefficients, calculated by the 2.5% - 97.5% percentiles.

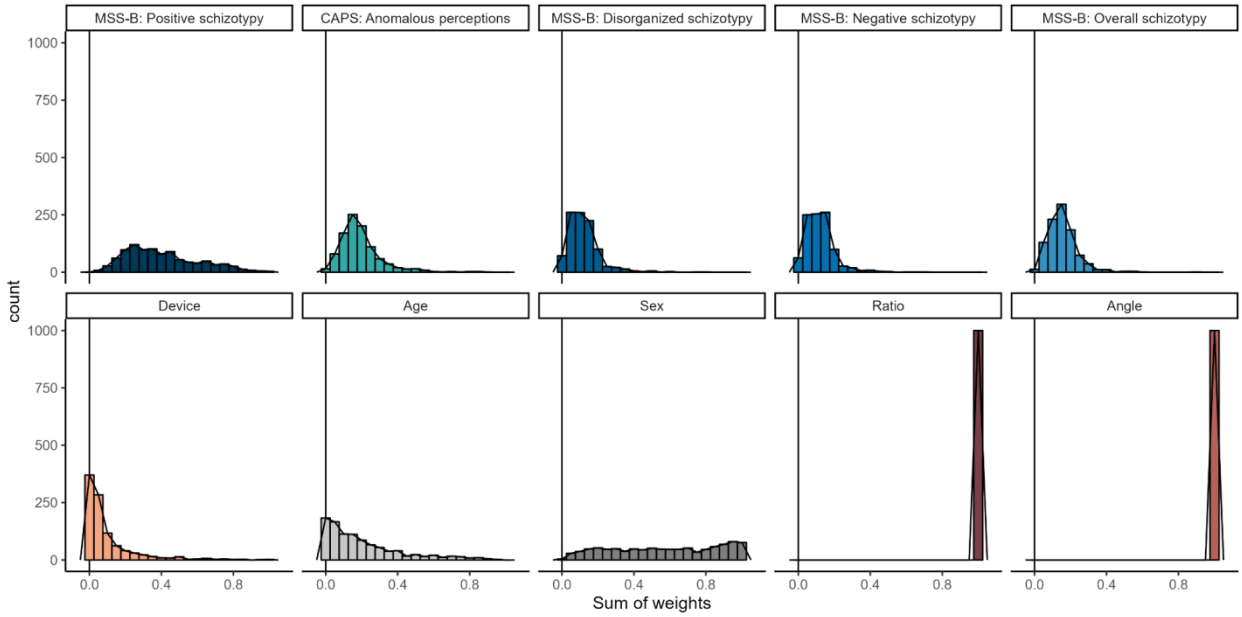

Fig. S2. Bootstrapped distributions of the sums of model weights.*Note that ratio and angle were entered into every model by default; they are only included for completeness.*

predictor	CI_low	CI_high
MSS-B: Positive schizotypy	0.114	0.847
CAPS: Anomalous perceptions	0.035	0.522
MSS-B: Disorganized schizotypy	0.011	0.352
MSS-B: Negative schizotypy	0.012	0.329
MSS-B: Overall schizotypy	0.035	0.358
Device	0.001	0.577
Age	0.001	0.772
Sex	0.062	0.997
Ratio	1.000	1.000
Angle	1.000	1.000

Table S8. Confidence intervals (95%) of the sums of model weights, calculated by the 2.5% - 97.5% percentiles. *Note that ratio and angle were entered into every model by default; they are only included for completeness.*

Supplementary References

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