**Supplementary Material**

**Perceptual phenotypes: Perceptual gains and losses in synesthesia and schizophrenia**

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**Supplementary Figure 1. Trial sequence and decreasing sensory evidence results**

(A) Time course of one trial within a sequence.A trial began with an inter-trial interval of random duration (1-1.5 secs), during which a fixation cross was presented. Next, the stimulus was displayed for 0.5 secs, followed by a question mark prompting participants to indicate the visibility of the stimuli according to the PA Scale ([Overgaard *et al.*, 2006](#_ENREF_7)). (B and C) Thresholds of perception for all three groups during decreasing sensory evidence trials, for synesthesia-inducing (B) and neutral (C) stimulus conditions. While an explicit prior aids perception in all groups (Fig. 1E of main paper), thresholds for perception (see insets in B and C) are nonetheless higher in schizophrenia patients as compared to the other groups despite the presence of an explicit prior, especially for the neutral condition (synesthetes vs schizophrenics: 2.35 vs 2.93, *t*(36)= -3.00, p<.01; controls vs schizophrenics: 2.45 vs 2.93, *t*(39)= -3.13, p<.01). In synesthetes, threshold for synesthesia inducing stimuli remains lower than for the other two groups (synesthetes vs schizophrenics: 1.62 vs 2.11, *t*(36)= -2.40, p<.05; synesthetes vs controls: 1.62 vs 1.95, *t*(30.12)= -2.13, p<.05 (df adjusted for inequality of variance). Pointing arrows correspond to the perceptual threshold, colored differently for each group. Error bars depict standard error of the mean.

**Supplementary Material and Methods**

**Participants**

*Synesthete recruitment and inclusion*

Synesthetes were recruited by advertisement of the study via email to students in Frankfurt am Main and surrounding cities, by advertisement on the internet, and from earlier studies. Prior to inclusion in the study, developmental grapheme-color synesthesia was established by means of a synesthesia questionnaire (e.g. ‘‘How long have you experienced synesthesia?’’) ([van Leeuwen *et al.*, 2010](#_ENREF_14)) and by on line completion of the standardized grapheme-color subtest of the Synesthesia Battery, which evaluates the consistency of synesthetic experiences ([Eagleman *et al.*, 2007](#_ENREF_2)). Consistency is a defining characteristic of the condition ([Ward, 2013](#_ENREF_15)) (but see also ([Niccolai *et al.*, 2012](#_ENREF_6); [Simner, 2012](#_ENREF_10))). In the Synesthesia Battery, subjects are presented with all 26 letters of the alphabet and digits 0-9 three times in random order, and requested to choose from a color palette, the color (on a red, green, blue [RGB] scale) that best matches their specific synesthetic experience. Differences in RGB value between the three instances of each grapheme are used to compute a difference score. Difference score values below 1.0 are considered to signal consistent synesthetic color experiences in which variation between the three instances of the color is low ([Eagleman *et al.*, 2007](#_ENREF_2)) (but see ([Rothen *et al.*, 2013](#_ENREF_8)) for argumentation that a more lenient cut-off score of 1.43 also suffices). All twenty synesthetes except one scored below 1.0, the average score was 0.70±0.28. One synesthete reported multiple simultaneous colors for several graphemes, therefore exhibiting less consistency during the Battery test (score of 1.48), but was still included in the study on the basis of her subjective reports in the synesthesia questionnaire.

*Control recruitment and inclusion*

Healthy control participants were recruited locally in Frankfurt am Main via online advertisement and word of mouth. In addition to the standard (medical) screening, controls were interviewed about synesthetic experiences and completed the grapheme-color test of the Synesthesia Battery on line prior to participation to exclude synesthesia. All controls were well above the 1.0 threshold for synesthesia and scored, on average, 2.24±0.69 on the Synesthesia Battery. No difference in the synesthesia battery scores were found between controls and schizophrenia patients (*t*(35) = 0.937, p=.36).

*Schizophrenia patient synesthesia characteristics*

Schizophrenia patients were additionally interviewed about possible synesthetic experiences and completed the grapheme-color test of the Synesthesia Battery when arriving at the laboratory, prior to participation in the main experiment, to exclude synesthesia. In this case the Synesthesia Battery was run in the offline Matlab version of the toolbox. On average, patients scored 2.03±0.62 on the Synesthesia Battery. One patient scored within the synesthetic range for numbers and vowels only (score of 0.56).

**Stimulus selection and presentation**

Ten letter/digit stimuli eliciting strong synesthetic experiences, with maximum synesthetic color variety, and sufficient variety in visual shape were selected separately for each synesthete on the basis of their synesthetic color experiences and used for the synesthesia condition. Additionally, ten non-synesthesia inducing symbols were chosen for each synesthete and used for the neutral condition. Prior to the experiment, synesthetes selected their individual synesthetic colors for the ten letters/digits on the experimental computer to ensure proper matching of the stimulus colors to the actual synesthetic color of the stimuli. Stimuli were then generated separately for each synesthete using custom code in Matlab (Mathworks, http://mathworks.com).

A total of 1260 trials were presented in 180 sequences of 7 trials. Ninety sequences belonged to the synesthetic-inducing condition (9 sequences per letter) and ninety sequences to the neutral condition (9 sequences per symbol). Subjects performed four blocks of 45 sequences each, with self-paced breaks between blocks. The experiment took approximately 80 minutes to complete. Each trial (Supplementary Fig. 1) started with a random inter-trial interval (1.0-1.5 secs) during which a black fixation cross on a grey background was displayed. The stimulus was then shown for 0.5 secs immediately followed by a question mark presented until the subject’s response. After the subject response, the next trial began immediately.

Stimuli were presented in pseudo-randomized order using Presentation (Neurobehavioral Systems, https://www.neurobs.com/). Two consecutive sequences did not display stimuli either of the same color, or the same token. A maximum of 5 consecutive sequences from the same condition was permitted (synesthetic inducing or neutral), and two different font sizes per stimuli were used to avoid adaptation and/or perceptual learning. Stimuli of the same font size repeated maximally 5 times in a row.

Controls (N=26) and schizophrenia patients (N=20) received one of the 20 unique stimulus lists previously generated for each of the 20 synesthetes (conserving the same stimuli and stimulus order). This was done since unique stimuli had to be used for each synesthete, introducing variability in stimulus shape for each participant in addition to varying degrees of discriminability due to the different background colors (e.g. visibility against a dark blue or bright yellow background, see also Fig. 1B). Matching the stimulus lists between the groups removed these confounds from our dataset. Since there were more controls than synesthetes, several stimulus lists were used twice for the control group.

Magnetoencephalography (MEG) data were collected during the study, hence participants performed the experiment while being seated in an electrically shielded and sound attenuated room. Stimuli were presented on a transparent screen with a grey background located 51 cm in front of the subjects. An LCD projector (60 Hz refresh rate) located outside the magnetically shielded room was used to project the stimuli onto a screen inside the MEG cabin via 2 front-silvered mirrors. The grey background (Figure S1) measured 29.1 x 37.9 degrees of visual angle and the stimulus display measured 22.6 x 30.2 degrees of visual angle. Grapheme stimuli themselves were created using the same font and measured maximally 3.9 x 3.6 degrees of visual angle depending on the exact letter/digit/symbol shape.

**Learning of the stimulus set**

To evaluate possible learning across the stimulus set during the experiment we analyzed visibility scores and reaction times (RTs) for the first three instances of each stimulus separately for synesthetes (N=20) and their matched controls (N=20). RTs below or above 2.5 SD from the mean for each participant and condition were removed prior to analysis. Visibility scores and RTs were subjected to a mixed repeated measures ANOVA with the between-subject factor Group (synesthetes/controls) and the within-subject factors Stimulus condition (synesthesia inducing/neutral), Phase (sensory evidence increase/sensory evidence decrease), Repetition (first, second, and third occurrence of the stimuli) and Stimulus level (1,2,3). For results see main text.

**Supplementary Results**

*Verifying that psychophysical thresholds are not modulated by the spatial location of synesthetic experience.*

Synesthetes differ in the spatial location where they experience synesthesia, and have been classified as projectors or associators based on these differences. ‘Projector’ synesthetes tend to experience their synesthetic colors in the outside world, often located at the place where the inducer is located. ‘Associator’ synesthetes experience their synesthesia as strong associations, e.g. ‘in the mind’s eye’. Projector and associator synesthetes differ in various behavioral and physiological measures and projector-associator status may influence experimental outcomes ([Dixon *et al.*, 2004](#_ENREF_1); [van Leeuwen *et al.*, 2011](#_ENREF_13); [van Leeuwen, 2013](#_ENREF_12)). We therefore verified that our main findings were not restricted to only projector or only associator synesthetes.

We assessed the projector-associator status of our population of synesthetes by means of two questionnaires: the Projector-Associator questionnaire (PAQ) ([Rouw and Scholte, 2007](#_ENREF_9); [van Leeuwen *et al.*, 2010](#_ENREF_14)), consisting of ten statements related to the synesthetic experience for which participants indicated to which extent they agreed to the statement on a 5-point Likert scale; and the Illustrated Synesthetic Experience Questionnaire (ISEQ) which makes use of visual illustrations of what the synesthetic experience could be like ([Skelton *et al.*, 2009](#_ENREF_11)). Based on the responses to these questionnaires, which correlated strongly (r=0.873, p<.001), we classified 8 subjects as projectors and 11 as associators; for one person the status could not be determined with certainty. We correlated the PAQ-score with the consistency of the synesthetic experiences, and with the perceptual thresholds in all four experimental conditions (synesthesia inducing sensory evidence increasing, synesthesia inducing sensory evidence decreasing, neutral sensory evidence increasing, neutral sensory evidence decreasing) to investigate whether projector-associator status affected any of the experimental outcomes. No significant effects were found (all p>.37), indicating that the location of the experienced synesthetic colors did not influence task performance.

*Reaction times for synesthesia inducing stimuli upon the first encounter of the stimulus*

To further evaluate whether synesthetes make explicit use of the color priors to aid grapheme recognition, we also evaluated whether synesthetes recognize synesthesia inducing stimuli faster than neutral stimuli upon the first encounter. We evaluated differences in RT between conditions for synesthetes and their matched controls (N=20 in both groups) in a mixed repeated measures ANOVA with the between-subject factor Group (synesthetes/controls) and the within-subject factors Stimulus condition (synesthesia inducing/neutral), Phase (sensory evidence increase/sensory evidence decrease), Repetition (first, second, and third occurrence of the stimuli) and Stimulus level (1,2,3). When collapsing across all stimulus levels (1-3, leading to different degrees of visibility), we found comparable RTs for synesthesia inducing and for neutral stimuli (levels 1-3, *F*(1,38)=2.92, p=.104). However, when we investigated the effect separately per stimulus level, we observed that for stimulus level 2, at the visibility threshold, RTs for synesthesia inducing stimuli were slower than for the neutral condition, 1201 ms and 997 ms respectively (*F*(1,19)=7.46, p=.013). While for level 1 and 3, for which subjects either do not perceive the stimuli due to the strong noise level or perceive them clearly due to low noise level, there was no difference in the RT (p=.42 and p=.49). Altogether, these results indicate that synesthetes do not make strategic use of the color cue to anticipate synesthetic inducing stimuli upon the first encounter of a stimulus. If anything, synesthesia inducing stimuli are recognized later than neutral stimuli. This RT difference for stimulus level 2 concurs with previous electrophysiological findings using the same paradigm reporting that synesthetes exhibited a delayed visual P200 peak response, exclusively for synesthesia inducing stimuli ([Leugner *et al.*, 2010](#_ENREF_3)). The P200 is an ERP component related to conscious visual processing ([Luck, 2005](#_ENREF_4); [Melloni *et al.*, 2011](#_ENREF_5)). The slowing of the EEG P200 component and the RTs in our experiment at level 2 for synesthesia inducing stimuli only may then reflect the extra processing time needed to bind the inducer to the synesthetic color, a process which is not needed for neutral stimuli which do not elicit synesthesia. As synesthetes recognized almost 40% of synesthesia inducing stimuli at threshold (level 2), this extra binding process could explain the slower RTs in our study.

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