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Creativity and involvement in art in different types of synaesthesia

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The aim of the present study was to test the relationship between different types of synaesthesia and their involvement in art, creative, and visual abilities. We tested 20 grapheme-colour, 18 sound-colour, 19 grapheme-colour-and-sound-colour, 20 sequence-space synaesthetes, and the same number of controls matched by age, gender, and education. We assessed the number of artistic professions, involvement in art, and the performance in psychometric tests of divergent and convergent creativity, as well as visual and visuo-spatial abilities. Results show a higher prevalence of artists among synaesthetes, especially sound-colour synaesthetes. Sound-colour synaesthetes also showed a higher involvement in artistic activities overall while sequence-space synaesthetes showed higher involvement in visual art. Only grapheme-colour-and-sound-colour synaesthetes showed significantly higher divergent creativity compared to matched controls. Additionally, overall, synaesthetes scored higher in visuo-spatial abilities (i.e., mental rotation). For synaesthetes and controls, visuo-spatial abilities correlated with divergent creativity. We discuss that synaesthetes' higher involvement in art is not necessarily reflected in their basic creative abilities.

What Kandinsky, Klee, and Lady Gaga have in common is their synaesthetic world of experience, but it is unclear whether this is the source of their creative ideation and artistic achievement. Synaesthesia is a diverse phenomenon in which ordinary stimuli like digits, music, or days of the week (called the inducer) elicit extraordinary experiences like colours, tastes, or spatial representations (called the concurrent). As there are many famous artists who are also synaesthetes, synaesthesia has been assumed to benefit creativity. Although there is, in fact, a higher prevalence of grapheme-colour synaesthesia among art students, and synaesthetes are more likely to be involved in artistic professions or activities, group studies did not find a consistent benefit in psychometric tests of creativity (Chun & Hupé, 2016; Domino, 1989; Niccolai, Jennes, Stoerig, & Van Leeuwen, 2012; Rich, Bradshaw, & Mattingley, 2005; Rothen & Meier, 2010; Ward, Thompson-Lake, Ely, & Kaminski, 2008). However, previous studies did not differentiate between different types of synaesthesia although it is known that different types of synaesthesia vary in cognitive style and creativity patterns (Chun & Hupé, 2016; Meier & Rothen, 2013a; Ward, Thompson-Lake *et al.*, 2008). Therefore, the aim of this study was to systematically

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compare creativity and visuo-spatial abilities in four different types of synaesthesia and matched controls.

Creativity can be separated into convergent and divergent creativity. Divergent thinking is defined as the ability to generate many new and adaptive ideas or products. Convergent thinking is characterized by finding the only one correct solution for a problem (Goff & Torrance, 2002; Mednick & Mednick, 1971; Sternberg & Lubart, 1999; Takeuchi *et al.*, 2011). High creativity has been associated with a broader, more flexible, and widely ramified semantic network and with a higher degree of mental imagery and visuo-spatial abilities (Kenett, Anaki, & Faust, 2014; Kozhevnikov, Kozhevnikov, Yu, & Blazhenkova, 2013; Paivio, 1970; Shindell, 1983). High divergent verbal creativity has also been connected to higher performance in working memory (Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014; Lunke & Meier, 2016). In general, synaesthesia provides for a broader semantic network through automatically spreading activations and a richer world of experiences (cf. Meier, 2013; Ramachandran & Hubbard, 2001). There is evidence that synaesthetes outperform control participants in abilities related to creativity such as visuo-spatial tasks. Sequence-space synaesthetes have shown higher performance in visual and visuo-spatial tasks of perception and working memory (Kozhevnikov *et al.*, 2013; Simner, Mayo, & Spiller, 2009). A mixed group of different types of synaesthesia have shown higher accuracy in detecting embedded figures (Ward, Brown, Sherwood, & Simner, 2017). Synaesthetes with multiple types of synaesthesia such as both grapheme-colour-and-sound-colour synaesthesia have shown more vivid imagery (Meier & Rothen, 2013a; Shindell, 1983). Moreover, synaesthetes have an advantage in memory performance and this may also affect creativity (Lunke & Meier, 2018; Meier & Rothen, 2013b; Rothen, Meier, & Ward, 2012). In general, the question whether synaesthetes are more involved in creative activities as a consequence of these cognitive differences or whether they are more involved as a direct consequence of their synaesthetic experiences, independent of cognitive differences, is still not settled (Mulvenna, 2013).

Regarding artistic creativity, prevalence studies have shown a higher amount of synaesthetes in art students. Domino (1989) interviewed 358 fine art students and found that 23% reported to have synaesthesia (as categorized through the Synesthesia Questionnaire developed by Jones 1976, as cited in Domino, 1989; Shindell, 1983). Using a consistency test, Rothen and Meier (2010) found a prevalence of 7% of grapheme-colour synaesthetes in art students compared to 2% in the control sample. Rich *et al.* (2005) also found a higher amount of artistic professionals among synaesthetes. In a sample of more than 150 mainly grapheme-colour synaesthetes, 24% pursued an artistic occupation compared to one single person in a sample of 50 non-synaesthetes and also compared to 2% of the general Australian population. The synaesthete group was significantly more involved in visual art, but not in music or crafts. Ward, Thompson-Lake *et al.* (2008) found similar results in a sample of 82 synaesthetes of various types and 119 controls regarding professions and how much time they spent producing visual art or playing music. Synaesthetes were more likely to pursue a creative occupation and produced significantly more art, but they did not play more music than controls. In another study which included 63 synaesthetes of various types, 9% were artistic professionals and 68% were active in art (Niccolai *et al.*, 2012). Seventy-eight percent indicated synaesthesia helped them in their creative jobs. Shindell (1983) compared 56 sound-colour synaesthetes with matched controls regarding questionnaires of creative personality and mental imagery and found significantly higher scores for synaesthetes. In sum, these studies suggest that synaesthetes are more involved in creativity and art and are more often occupied in professions related to creativity.

To date, only few studies have compared synaesthetes and non-synaesthetes in psychometric tests of creativity. Domino (1989) tested 61 self-referred synaesthetes and matched control participants. For the creativity assessment, participants completed the Barron-Welsh Revised Art Scale (Barron & Welsh, 1952) in which they rated the pleasantness of visual art pieces. Additionally, as a divergent figural task, the Obscure Figures Test (McReynolds, 1968, as cited in Domino, 1989), and as a divergent verbal task, the Similes Test (Schaefer, 1958, as cited in Domino, 1989) were used. Synaesthetes scored significantly higher in all tests. Domino (1989) concluded that a clear relationship between synaesthesia and creativity exists, one which might rely on cognitive styles that facilitate creativity. However, as in this study the classification of synaesthesia was based on self-report only, the generality of the results may be questioned.

In Ward, Thompson-Lake *et al.'s* (2008) study in which synaesthesia was affirmed by a consistency test, the presence of multiple synaesthesias correlated with higher scores in the convergent verbal creative Remote Associates Test (Mednick & Mednick, 1967) that directly relates to each one of the three (Mednick & Mednick, 1967). However, synaesthetes did not show higher fluency in the divergent verbal creative Alternative Uses Task (Guilford, Merrifield, & Wilson, 1978). In contrast to Domino (1989), Ward, Thompson-Lake *et al.* (2008) concluded that synaesthetes might be more involved in art, but do not show a general advantage in creativity. Still, they found that multiple synaesthetes might have an advantage, at least in convergent verbal creativity. This result indicates that different types of synaesthesia may differ in their creativity profile. Notably, both studies used verbal tests of divergent creativity only; that is, they did not include any measure of figural creativity. Moreover, they focused on creativity and did not include any measurement of related cognitive functions such as visuo-spatial abilities.

In a more recent study, Chun and Hupé (2016) compared the performance in convergent and divergent creativity tasks and related cognitive functions among 29 synaesthetes of various types and 36 control subjects. They used the Torrance Test of Creative Thinking (TTCT; Torrance, Ball, & Safter, 1966), the Alternative Uses Task (Guilford *et al.*, 1978), and the Animal Naming Task (Read, 1987; as cited in Chun & Hupé, 2016) as verbal divergent creativity tests. As verbal convergent creativity task, they used the Remote Associates Test and constructed a visual adaption (the Visual Associates Test). Additionally, they included the Wechsler-Adult-Intelligence-Scale III (WAIS-3; Wechsler, Coalson, & Raiford, 1997) tasks for verbal comprehension, working memory, processing speed, and perceptual organization. They found that synaesthetes scored significantly higher in the convergent figural Visual Associates Test, and in the divergent verbal Alternative Uses Task, as well as in verbal comprehension and mental imagery. However, they did not obtain a higher score in the TTCT overall or the Remote Associates Test. Synaesthetes did also not score higher in the WAIS-3 tests regarding working memory, processing speed, and perceptual organization. In line with Ward, Thompson-Lake *et al.* (2008), Chun and Hupé (2016) concluded that synaesthesia is not directly related to enhanced creativity.

So far, results of psychometric creativity tests do not consistently support an advantage of synaesthesia for creativity. While Domino (1989) found an advantage for synaesthetes in divergent creativity tasks, Ward, Thompson-Lake *et al.* (2008), and Chun and Hupé (2016) included different numbers of various types of synaesthetes in their samples and found mixed results. These inconsistencies might reflect differences in types of synaesthesia. For example, Ward, Thompson-Lake *et al.* (2008) found a relationship between the benefit in convergent creativity and the number of types of synaesthesia experienced. Differences in types of synaesthesia as a source of different effects would be in line with findings by Hale, Thompson, Morgan, Cappelletti, and Kadosh (2014), Lunke and Meier (2018), Meier and Rothen (2013a), Simner *et al.* (2009), Ward, Hovard, Jones, and Rothen (2013) and Ward *et al.* (2017) who found differences in cognitive performance and cognitive style for different types of synaesthesia.

In general, both theory and studies suggest that different types of synaesthesia relate to different creative abilities. In the present study, we aim to systematically compare four types of synaesthesia with respective groups of control participants with different inducer-concurrent pairings, including self-reported involvement in art as well as divergent verbal and figural production. Additionally, we examine visuo-spatial abilities as related cognitive functions. As types with a different inducer but similar concurrent, we investigate grapheme-colour and sound-colour synaesthetes. As a type without a coloured concurrent, we investigate sequence-space synaesthetes. As a type with multiple synaesthesias, we include grapheme-colour-and-sound-colour synaesthetes. This way, we are able to test for a general advantage of synaesthesia overall and for synaesthesia-type specific benefits compared to matched controls. We hypothesized a generally higher involvement in art for all types of synaesthesia. For creativity and visuo-spatial abilities, we anticipate a distinct pattern for the different types of synaesthesia. For grapheme-colour-and-sound-colour synaesthetes, we expected the highest benefit in creativity as advantages have been found for multiple synaesthesias (Chun & Hupé, 2016; Ward, Thompson-Lake *et al.,* 2008). For sequence-space synaesthetes, we expected higher figural creative abilities (cf., Paivio, 1970; Simner *et al.*, 2009).

Method

Participants

We recruited 80 synaesthetes via the Synaesthesia-Check of the University of Bern (www.synaesthesie.unibe.ch) and 80 healthy control participants (cf. Meier, Rothen, & Walter, 2014). The Synaesthesia-Check is a short questionnaire used to establish contact with the general public interested in our research. It involves questions about potential forms of synaesthesia, the nature of synaesthetic experiences, and it provides the opportunity to leave contact information for those willing to take part in future studies. The groups were matched for age, gender, and education. The study was approved by the local ethics committee, and participants were compensated.

One control participant knew the creativity tasks and was thus excluded (together with her matched synaesthete). One synaesthete was sent home after half of the study because she felt sick and was excluded for all tasks (together with her matched control participant). One synaesthete refused to complete the visuo-spatial tasks and was excluded (together with her matched control participant). Of the remaining 154 participants, seven synaesthetes and six control participants were left handed. Of the synaesthetes, 20 were grapheme-colour synaesthetes (M_{ageSyn} = 45.00, SD_{ageSyn} = 16.82, $M_{ageCont}$ = 46.25, $SD_{ageCont}$ = 16.91, 17 female and three male each), 18 were sound-colour- synaesthetes (M_{ageSyn} = 34.61, SD_{ageSyn} = 19.68, $M_{ageCont}$ = 34.78, $SD_{ageCont}$ = 21.10, twelve female and six male each), 19 were grapheme-colour-and-sound-colour synaesthetes (M_{ageSyn} = 31.68, SD_{ageSyn} = 12.28, $M_{ageCont}$ = 32.42, $SD_{ageCont}$ = 13.84, 16 female and three male each), and 20 were sequence-space synaesthetes (M_{ageSyn} = 32.55, SD_{ageSyn} = 13.25, $M_{ageCont}$ = 32.25, $SD_{ageCont}$ = 13.85, all female).

Before participation in the laboratory, participants with colour experiences for graphemes completed an online measurement of consistency. They were presented with

36 black-on-white graphemes (A–Z, 0–9) in a random order and instructed to choose a colour out of 13 (black, dark blue, brown, dark green, grey, pink, purple orange, red, white, light blue, light green, yellow) or indicate *no colour* (Rothen & Meier, 2010; Simner *et al.*, 2006). In this task, the mean number of consistent digits and letters was $M = 25.34$ ($SD = 6.88$) which is above the cut-off of 20 used by Simner *et al.* (2006) and Rothen and Meier (2010).

Participants who experienced spatial representations for sequences had participated in another study in which they were asked to draw their spatial representations. In the present study, they were asked again to draw them. The drawings were categorized by an independent rater regarding consistency and complexity to confirm synaesthesia (cf. Rothen, Jünemann, Mealor, Burckhardt, & Ward, 2016).

For sound-colour synaesthesia, we originally considered using the Eagleman battery (Eagleman, Kagan, Nelson, Sagaram, & Sarma, 2007). However, we noticed that in this battery, using a simple strategy (low tones/big instrument -> dark colours; high tones/small instruments -> bright colours) leads to a high consistency score (passing synaesthesia criterion). Moreover, sound-colour synaesthesia is a very heterogeneous phenomenon in which for some people pitch relates to colours, for others timbre relates to colours, for others tone intervals relate to colours, etc.. . ... Thus, we decided to rely on the subjective self-reported experiences.

At the beginning of the laboratory session, both synaesthetes and control participants were first asked whether they experienced any kind of synaesthesia. If additional synaesthetic experiences were reported to those described before in the Synaesthesia-Check questionnaire, participants were tested for consistency and reassigned. If several types of synaesthesia were present, participants were asked which form they experience as the main type. Of the grapheme-colour synaesthetes, eight reported having additional types of synaesthesia (sequence-space, other: person-smell and situation-smell). One grapheme-colour synaesthete was recategorized as grapheme-colour-and-sound-colour synaesthete. One control participant was recategorized as grapheme-colour synaesthete. Of the sound-colour synaesthetes, twelve reported additional types of synaesthesia (sequence-space, grapheme-colour, other: ticker-tape, touch-colour, smell-form, person/memory-colour, taste-colour/pictures). Three grapheme-colour-and-sound-colour synaesthetes were recategorized as sound-colour synaesthetes. Moreover, one control participant was recategorized as sound-colour synaesthete. Of the grapheme-colour-and-sound-colour synaesthetes, sixteen reported additional types of synaesthesia in the laboratory (sequence-space, other: ticker-tape, daytime-feeling, feeling-colour, pain-colour, scene-taste/smell person-colour). One reported not to have sound-colour synaesthesia but then again to have colour experiences for digits. Three grapheme-colour synaesthetes were recategorized as grapheme-colour-and-sound-colour synaesthetes. Of the sequence-space synaesthetes, three reported additional types of synaesthesia in the laboratory (one grapheme-colour, two sound-colour, one grapheme-colour-and-sound-colour, one person/experience colour). One grapheme-colour-and-sound-colour synaesthete was recategorized as sequence-space synaesthetes. Four control participants were recategorized as sequence-space synaesthetes.

Materials

Creative self-evaluation

The questions about creative occupations and creative involvement by Ward, Thompson-Lake *et al.* (2008) were translated into German. A question about the frequency of music enjoyment was also included. The questions were as follows: (1) *What profession do you have?* (2) *How often do you paint or sketch?* (3) *How often do you play a musical instrument?* (4) *Do you like visual arts?* (5) *Do you like music?* For the last four questions, participants were asked to indicate on a 6-point Likert scale how frequently they pursued these actions (from 'daily' to 'never').

Divergent thinking

Divergent thinking was assessed with the German adaption of the *Abbreviated Torrance Test for Adults* (ATTA; Goff & Torrance, 2002; cf. Lunke & Meier, 2016). This is a short and valid measurement of divergent thinking (c.f. Althuizen, Wierenga, & Rossiter, 2010; Torrance, 1972). It consists of one verbal and two figural tasks. As a second verbal divergent thinking task, the *Sentence Construction* subtest of the German *Analyse des Schlussfolgernden und Kreativen Denkens* (ASK, Schuler & Hell, 2005; cf. Lunke & Meier, 2016) was used in order to complement the assessment with a second verbal divergent task. The norms of the ASK allowed us to use comparable standardized values.

Visual and visuo-spatial abilities

The *Mental Rotation Test* by Shepard and Metzler (1971) and the *Group Embedded Figures Test* with Gottschaldt figures (G-EFT; Gottschaldt, 1929; Oltman, Raskin, & Witkin, 1971) were used as short tasks to measure visual and visuo-spatial abilities. Both tasks are time-limited and highly demanding which allows to have a component of processing speed covered without having to measure reaction time. The Mental Rotation Test consists of black and white two-dimensional pictures of three-dimensional figures. To create a three-dimensional appearance, all figures were constructed of 10 little cuboids each. The test consists altogether of 25 target figures, 25 target figures in different positions, and 50 distractor figures; that is, there was one target figure with two distractors in each trial. The G-EFT consists of four simple black and white target line figures, and 20 complex test figures, which include one of the four targets each in the same position.

Procedure

Onsite, participants were tested under controlled light conditions with an 851 ux/watt lamp with 6,400 calvin colour temperature and two standard interior lamps. They were informed about the purpose of the study and were asked to sign consent. All tasks were performed with a fine black pen on paper. First, the creativity self-evaluation was administered. Then, divergent thinking tasks were conducted. In the first one, the verbal test of the ATTA, participants were presented with the fictive situation that they are able to fly, without a plane or any external aid. They were instructed to write down as many problems this situation could cause as possible. They had 3 min for this task. In the second and third figural tasks, participants received sheets with incomplete figures and were instructed to paint interesting drawings from them and to give each drawing a title. They had 3 min to complete each of the two figural tasks. Next, the verbal divergent thinking task, called ASK, was administered. In two trials, the participants received a sheet with four different letters each. They were instructed to invent as many four-word-sentences as possible with these four letters as capital letters. For each trial, they had 3 min of time.

After approximately 30 min of unrelated tasks, the G-EFT was conducted. Participants received a sheet with two small and simple black-on-white line target figures, and the instruction to detect these target figures inside of ten bigger, more complex figures. They were instructed that when they found one, they should mark it. The test consisted of two trials on two sheets, each including the search of two target figures in ten complex figures and participants had 2 min for each trial. The total score was 20. Afterwards, a mental rotation test was administered. Participants were presented with a Tetris-kind-Figure which was presented rotated together with similar Figures in a test display. They were instructed to pick the target figure and to mark it. The test consisted of 25 trials distributed across five pages. Participants had 5 min to complete this test. The total score was 25.

Statistical analyses

Alpha was set at .05 for all analyses. If homogeneity of variances was violated, Greenhouse–Geisser corrected values are reported. In order to be able to interpret non-significant effects between synaesthetes and controls, Bayesian statistics was calculated using JASP (Wagenmakers *et al.*, 2017).

A two-way ANOVA with *synaesthesia* (yes/no) and *type of synaesthesia* as between-subject variables and *age* as dependent variable revealed a main effect of *type of synaesthesia,* $F(3, 146) = 6.21$, $MSE = 260.96$, $p = .001$, $\eta_p^2 = .11$, and *age* was thus included as covariate. It was significant in the analyses of *divergent figural* creativity, *verbal fluency* measured by the ASK, the Mental Rotation Test, and the G-EFT when all the different *types of synaesthesia* were included in one analysis, all $p < .001$.

Four independent raters, blind regarding participant groups, rated half of the samples of verbal and figural ATTA responses by following the criteria specified by Goff and Torrance (2002). All three tasks were rated regarding fluency and originality. The figural tasks were rated also regarding elaboration. One of the two figural tasks was additionally rated regarding flexibility. The verbal task was rated regarding richness and colourfulness of imagery, emotions/feelings, future orientation, humour, and provocative questions. The two figural tasks were rated regarding openness, unusual visualization/different perspective, movement or sound, abstractness of titles, articulateness in telling stories, combination/synthesis of two or more figures, internal visual perspective, expression of feelings and emotion and fantasy. After a first round of ratings, the two resulting scores were compared for each participant. One rater reviewed all ratings and made necessary adjustments where errors had occurred (miscalculations) or rerated the scores if necessary. Interrater reliability as measured by Pearson correlation was high ($r = .88$). A mean of all ratings was calculated. Then, a *figural divergent score* was computed as the sum of all figural subscales of the ATTA. A *verbal divergent score* was computed as the sum of all verbal subscales of the ATTA. Finally, sentence construction of the ASK was scored as a *verbal fluency* score of all correct responses and transformed into scaled scores as given by the manual. For the G-EFT and the Mental Rotation Test, sum scores of correct answers were computed. For the questionnaire about artistic involvement adapted from Ward, Thompson-Lake *et al.* (2008), the following professions were categorized as creative: decorator, florist, landscape gardener, piano teacher, art and communication specialist, painter, musician, artist, music therapist, dancer, actor, colour designer, advertiser, graphic illustrator, radio journalist, dance therapist, theatre tailor. Correlations were compared using Fisher's z.

Results

Self-evaluation of creativity

With 16 out of 77 (20.78%) creative professions among synaesthetes and three out of 77 (3.90%) among controls, synaesthetes were overall significantly more likely to be involved in a creative profession, χ^2 (1) = 9.79, p = .001. Comparisons per *type of synaesthesia* showed that sound-colour synaesthetes were significantly more likely to work in creative professions than their controls with six out of 18 (33.33%) compared to zero out of 18 (0.00%) creative professions, χ^2 (1) = 6.48, p = .006. Of the grapheme-colour synaesthetes, four out of 20 (20.00%), compared to one out of 20 (5.00%), had a creative profession, χ^2 (1) = 2.25, p = .067. For the grapheme-colour-and-sound-colour synaesthetes, four out of 19 (21.05%) compared to two out of 19 (10.53%), χ^2 (1) = 0.79, p = .187 had a creative profession. For the sequence-space synaesthetes, two out of 20 (10.00%) compared to zero out of 20 (0.00%) had a creative profession, χ^2 (1) = 2.00, p = .079.

Regarding involvement in creative activities, the questions about how often they painted, played music (active involvement), enjoyed visual arts, enjoyed music (passive involvement) were analysed (see Table 1). To test for a general as well as a synaesthesia-type specific benefit, a repeated-measures ANCOVA was calculated. This ANCOVA with the between-subject factors *synaesthesia* (yes/no) and *type of synaesthesia,* the within-subject factors *active–passive* and *visual–musical,* and the covariate *age* gave main effects of *synaesthesia* (yes/no), $F(1, 144) = 14.85$, $MSE = 2.12$, $p < .001$, $\eta_p^2 = .09$, and *type of synaesthesia,* $F(3, 144) = 3.20$, $MSE = 2.12$, $p = .025$, $\eta_p^2 = .06$, and an interaction between *active–passive* and *visual–musical,* $F(1, 144) = 35.05$, $MSE = 1.47$, $p < .001$, $\eta_p^2 = .20$. Critically, the interaction between *synaesthesia* (yes/no) and *type of synaesthesia* was not significant, $F(3, 144) = 1.39$, $MSE = 2.12$, $p = .248$, $\eta_p^2 = .03$. However, due to the theoretical and practical relevance, we calculated planned contrasts (see Table 1). Sound-colour synaesthetes reported they played a musical instrument significantly more frequently and consumed significantly more music and visual art than their matched controls. Sequence-space synaesthetes reported they consumed significantly more visual art than their matched controls. *Bayesian t*-tests were performed to analyse whether non-significant results show true null-results (see also Table 1). For grapheme-colour synaesthetes, evidence for the null occurred regarding painting and playing a musical instrument compared to controls. Results were inconclusive regarding consumption of visual art and consumption of music. For sound-colour synaesthetes, results were inconclusive regarding painting. For grapheme-colour-and-sound-colour synaesthetes, all results regarding active and passive involvement in art were inconclusive. For sequence-space synaesthetes, there was evidence for the null regarding playing a musical instrument. Results regarding painting and consuming music were inconclusive. The pattern of effect sizes (Table 1) revealed that many of the comparisons suggested substantial effects.

Figural divergent creativity

The results for figural divergent creativity are presented in Figure 1a. An ANCOVA with the *figural divergent* score as dependent variable and *synaesthesia* (yes/no) and *type of synaesthesia* as between-subject factors and the covariate *age* gave no significant main effect, with *synaesthesia* (yes/no), $F(1, 145) = 0.52$, $MSE = 133.12$, $p = .474$, $\eta_p^2 < .01$, and *type of synaesthesia,* $F(3, 145) = 1.88$, $MSE = 133.12$, $p = .136$, $\eta_p^2 = .04$, but a marginal interaction, $F(3, 145) = 2.31$, $MSE = 133.12$, $p = .079$, $\eta_p^2 = .05$. Planned

Table 1. Creative activities: Means, standard errors, *t*-values of planned contrasts, Bayes factors, and Cohen's *d* for the differences between synaesthetes and controls

	Type of synaesthesia	*M* (*SE*)	*t*	*p*	BF_{10}	*d*
Active painting	GC	2.70 (.39)	−0.23	.409	0.31	.07
	Controls	2.60 (.28)				
	SC	3.33 (.33)	1.46	.073	0.91	.55
	Controls	2.67 (.23)				
	GCSC	3.00 (.37)	1.40	.081	0.69	.46
	Controls	2.37 (.26)				
	SS	3.05 (.33)	1.50	.068	0.76	.48
	Controls	2.40 (.28)				
Active playing	GC	2.55 (.43)	−0.26	.400	0.32	.08
	Controls	2.40 (.38)				
	SC	4.28 (.47)	2.87	.003	4.61	.89
	Controls	2.56 (.44)				
	GCSC	3.11 (.45)	0.63	.264	0.37	.21
	Controls	2.74 (.38)				
	SS	2.45 (.39)	0.35	.363	0.33	.12
	Controls	2.25 (.35)				
Passive art	GC	3.10 (.22)	−0.92	.179	0.53	.37
	Controls	2.80 (.14)				
	SC	3.33 (.29)	1.95	.027	1.11	.60
	Controls	2.67 (.23)				
	GCSC	3.28 (.31)	1.45	.076	0.64	.44
	Controls	2.79 (.20)				
	SS	3.40 (.28)	1.69	.047	0.87	.52
	Controls	2.85 (.20)				
Passive music	GC	5.20 (.24)	−0.91	.184	0.43	.29
	Controls	4.85 (.30)				
	SC	5.94 (.06)	2.22	.019	2.06	.74
	Controls	5.56 (.17)				
	GCSC	5.17 (.33)	−0.52	.302	0.36	−.17
	Controls	5.37 (.21)				
	SS	5.40 (.21)	0.82	.209	0.40	.26
	Controls	5.15 (.22)				

Note. BF_{10} = Bayes factor; GC = grapheme-colour; GCSC = grapheme-colour-and-sound-colour; SC = sound-colour; SS = sequence-space.

contrasts showed a significant advantage for grapheme-colour-and-sound-colour synaesthetes compared to their matched controls (Table 2). No other *type of synaesthesia* showed a significant difference. Bayesian *t*-tests showed inconclusive results for grapheme-colour synaesthetes, sound-colour synaesthetes, and sequence-space synaesthetes (Table 2).

Verbal divergent creativity

The results for verbal divergent creativity are presented in Figure 1b. First, we conducted a univariate ANCOVA for the *verbal divergent* scores from the ATTA as dependent

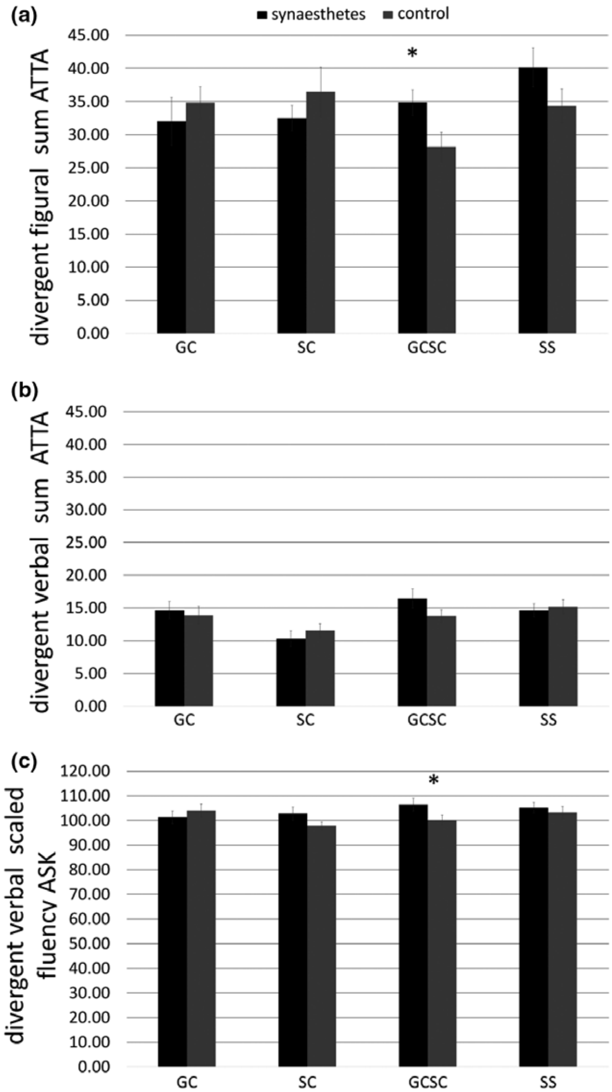

Figure 1. Mean sum scores for (a) divergent figural creativity and for (b) divergent verbal creativity as measured by the Abbreviated Torrance Test for Adults (ATTA). (c) Divergent verbal sum scores as scaled fluency score in sentence construction (ASK). GC = grapheme-colour; GCSC = grapheme-colour-and-sound-colour; SC = sound-colour; SS = sequence-space. Error bars display standard errors. $^*p < .05$.

variable with *synaesthesia* (yes/no) and *type of synaesthesia* as between-subject factors, and with the covariate *age*. We found a significant main effect with *type of synaesthesia,* $F(3, 145) = 5.03$, $MSE = 27.53$, $p = .002$, $\eta_p^2 = .09$ but not with *synaesthesia* (yes/no), $F(1, 145) = 0.24$, $MSE = 27.53$, $p = .625$, $\eta_p^2 < .01$. Critically no interaction occurred, $F(3, 145) = 0.99$, $MSE = 27.53$, $p = .401$, $\eta_p^2 = .02$. However, due to the theoretical and practical relevance we calculated planned contrasts as we expected that some types of synaesthesia would differ from their matched controls in a direct comparison (Table 3). These showed no significant advantage for any of the *types of synaesthesia* compared to

Table 2. Figural divergent creativity: *t*-values of planned contrasts, Bayes factors, and Cohen's *d* for the differences compared between synaesthetes and controls

Type of synaesthesia vs. controls	*t*	*p*	BF_{10}	*d*
GC	0.74	.230	0.37	−.21
SC	−0.99	.163	0.46	−.31
GCSC	1.71	.045	4.80	.75
SS	1.53	.064	0.74	.47

Note. BF_{10} = Bayes factor; GC = grapheme-colour; GCSC = grapheme-colour-and-sound-colour; SC = sound-colour; SS = sequence-space.

Table 3. Verbal divergent creativity: *t*-values of planned contrasts, Bayes factors, and Cohen's *d* for the differences compared between synaesthetes and controls in ATTA ad ASK

	Type of synaesthesia vs. controls	*t*	*p*	BF_{10}	*d*
ATTA	GC	−0.47	.320	0.33	.13
	SC	−0.70	.243	0.41	−.26
	GCSC	1.57	.060	0.75	.49
	SS	−0.32	.376	0.33	−.11
ASK	GC	0.81	.211	0.38	−.23
	SC	1.40	.082	0.87	.54
	GCSC	1.82	.036	1.18	.60
	SS	0.60	.276	0.35	.19

Note. ASK = Analyse Schlussfolgernden und Kreativen Denkens; ATTA = Abbreviated Torrance Test for AdultsGC = grapheme-colour; GCSC = grapheme-colour-and-sound-colour; SC = sound-colour; SS = sequence-space.

their matched controls. Bayesian *t*-tests showed evidence for the null for grapheme-colour and sequence-space synaesthetes. Results were inconclusive for sound-colour and grapheme-colour-and-sound-colour synaesthetes (Table 3).

Next, we conducted a similar ANCOVA for the scaled *verbal fluency* score of the ASK (see Figure 1b). We found no main effect with *synaesthesia* (yes/no), $F(1, 145) = 2.42$, $MSE = 101.42$, $p = .122$, $\eta_p^2 = .02$, *type of synaesthesia,* $F(3, 145) = 1.39$, $MSE = 101.42$, $p = .247$, $\eta_p^2 = .03$, and no interaction, $F(3, 145) = 1.57$, $MSE = 101.42$, $p = .200$, $\eta_p^2 = .03$. However, as above, due to the theoretical and practical relevance we calculated planned contrasts (Table 3). Planned contrasts showed a significant advantage for grapheme-colour-and-sound-colour synaesthetes compared to their matched controls. Bayesian *t*-tests showed inconclusive results for all other types of synaesthesia (Table 3).

Visual and visuo-spatial abilities

The results for visual and visuo-spatial abilities are presented in Figure 2. For the embedded figures test (G-EFT), a univariate ANCOVA was conducted with *synaesthesia* (yes/no) and *type of synaesthesia* as between-subject factors, and with the covariate *age* gave no effect of *synaesthesia* (yes/no), $F(1, 145) = 0.87$, $MSE = 18.60$, $p = .352$, $\eta_p^2 = .01$, or *type of synaesthesia,* $F(3, 145) = 0.20$, $MSE = 18.60$, $p = .898$, $\eta_p^2 < .01$ and

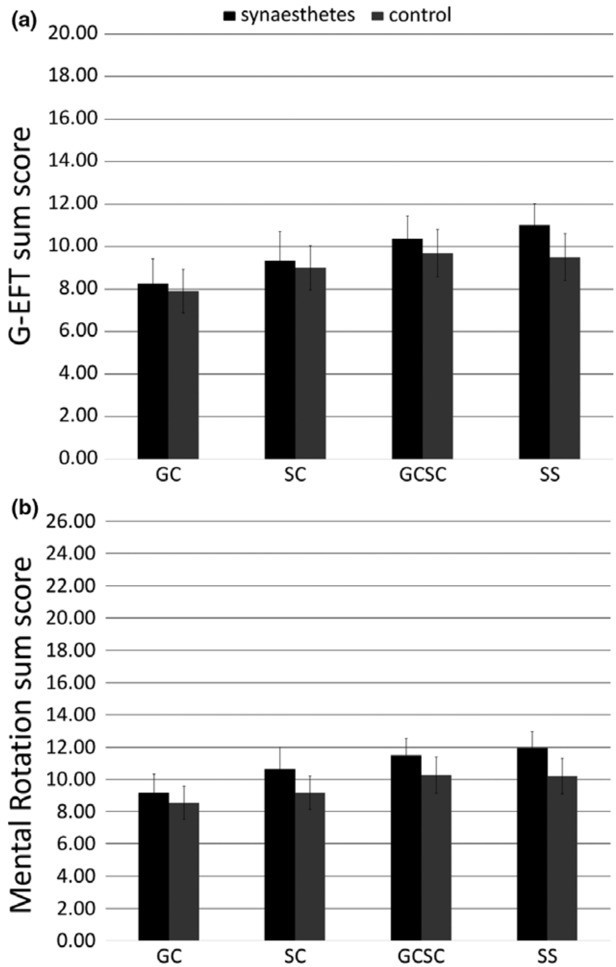

Figure 2. Mean of correct answers in (a) the Group Embedded Figures Task (G-EFT) and (b) the Mental Rotation test. GC = grapheme-colour; GCSC = grapheme-colour-and-sound-colour; SC = sound-colour; SS = sequence-space. Error bars display standard errors.

no interaction, $F(3,\ 145) = 0.20$, $MSE = 18.60$, $p = .893$, $\eta_p^2 < .01$ (depicted in Figure 2a). However, we expected that sequence-space synaesthetes would show an advantage compared to their matched controls and calculated planned contrasts (Table 4). However, no significant advantage occurred for any of the *types of synaesthesia* compared to their matched controls (Table 4). Bayesian *t*-tests showed evidence for the null for grapheme-colour and for sound-colour synaesthetes. Results were inconclusive for grapheme-colour-and-sound-colour synaesthetes and sequence-space synaesthetes (Table 4).

For the Mental Rotation Test (depicted in Figure 2b), the same ANCOVA gave a marginal main effect of *synaesthesia* (yes/no), $F(1,\ 145) = 3.80$, $MSE = 14.25$, $p = .053$, $\eta_p^2 = .03$. There was no main effect of *type of synaesthesia,* $F(3,\ 145) = 0.35$, $MSE = 14.25$, $p = .792$, $\eta_p^2 < .01$ and no interaction, $F(3,\ 145) = 0.23$, $MSE = 14.25$, $p = .873$, $\eta_p^2 = .01$. However, due to the theoretical and practical relevance, we calculated planned contrasts (Table 4). Planned contrasts were performed as we expected at least sequence-space synaesthetes to have a significant advantage compared to their matched controls. However, no significant advantage occurred for any of the *types of synaesthesia* compared to their matched control (Table 4). Bayesian *t*-tests showed evidence for the null for grapheme-colour synaesthetes and were inconclusive for all other *types of synaesthesia* (Table 4).

To explore the relationship between visuo-spatial abilities, artistic involvement and divergent creativity, correlational analyses were conducted, separately for synaesthetes and controls (Table 5). For synaesthetes, figural divergent creativity correlated significantly with visuo-spatial abilities in the G-EFT but not the mental rotations and it correlated significantly with the frequency to paint but not with playing a musical instrument. Verbal divergent creativity did not correlate with any of the visuo-spatial abilities, painting or playing a musical instrument. For controls, figural divergent creativity correlated significantly with visuo-spatial abilities in the G-EFT and the mental rotations. It did not correlate with the frequency to paint or to play a musical instrument. Verbal divergent creativity correlated with the visuo-spatial abilities in the G-EFT but not in the

Table 4. Visuo-spatial abilities: *t*-values of planned contrasts, Bayes factors, and Cohen's *d* for the differences compared between synaesthetes and controls

	Type of synaesthesia vs. controls	t	p	BF_{10}	d
G-EFT	GC	−0.23	.411	0.32	.07
	SC	0.20	.419	0.33	.06
	GCSC	0.43	.334	0.34	.14
	SS	0.97	.167	0.46	.32
Mental rotation	GC	−0.43	.333	0.33	.12
	SC	0.99	.162	0.52	.37
	GCSC	0.85	.198	0.42	.27
	SS	1.26	.105	0.60	.41

Note. GC = grapheme-colour; GCSC = grapheme-colour-and-sound-colour; SC = sound-colour; SS = sequence-space.

Table 5. Correlation coefficients *r* between figural and verbal divergent scores, visuo-spatial abilities, and active involvement in art

	Synaesthetes			Controls		
	Figural divergent	Verbal divergent ATTA	Verbal divergent ASK	Figural divergent	Verbal divergent ATTA	Verbal divergent ASK
G-EFT	.34**	−.04	.40**	.32**	.24*	.40**
Mental rotation	.16	−.03	.15	.32**	.05	.19
Active painting	.27*	.16	.08	.16	.02	.09
Active playing	−.14	−.19	.02	.06	−.12	−.02

Notes. ASK = Analyse Schlussfolgernden und Kreativen Denkens; ATTA = Abbreviated Torrance Test for Adults; G-EFT = Group Embedded Figures Task.
*$p < .05$; **$p < .001$.

mental rotations and did also not correlate with the frequency to paint or to play a musical instrument. We compared each of the correlations between synaesthetes and controls. No difference was significant, all ps > .08.

Discussion

The goal of the present study was to systematically investigate the relationship between different types of synaesthesia (grapheme-colour, sound-colour, grapheme-colour-and-sound-colour, sequence-space), their involvement in art, figural and verbal divergent creativity, and visuo-spatial abilities as measured by embedded figures and mental rotations. Additionally, the relationship between performance in divergent creativity and self-reported involvement in art as well as visuo-spatial abilities was investigated. Results showed an advantage for grapheme-colour-and-sound-colour synaesthetes in *figural divergent creativity* and one *divergent verbal creativity* task. No advantage was found for sound-colour, grapheme-colour or for sequence-space synaesthetes. Sound-colour synaesthetes scored highest in self-reported involvement in art. Synaesthetes showed slightly enhanced visuo-spatial abilities in the mental rotation task.

Self-reported involvement in art

Significantly more synaesthetes pursued a creative occupation. In particular, among sound-colour synaesthetes, there was a high ratio of creative professionals. Moreover, this group was significantly more involved in artistic activities, active as well as passive. Grapheme-colour-and-sound-colour synaesthetes did not differ from their matched controls in artistic involvement. These results are similar to those from studies that found a higher amount of artistic professionals among synaesthetes and a higher amount of synaesthetes among artists (e.g., Domino, 1989; Rich *et al.*, 2005; Rothen & Meier, 2010; Ward, Thompson-Lake *et al.,* 2008). However, the fact that predominantly one out of four types of synaesthesia had a significantly higher involvement in art, namely sound-colour synaesthetes, supports the hypothesis that there are profound differences between the types of synaesthesia. This is confirmed further by the results of the divergent creativity tasks.

Divergent creativity

Here, only grapheme-colour-and-sound-colour synaesthetes showed an advantage in figural and verbal divergent creativity. The fact that the multiple type of synaesthesia scored highest is in line with the findings of Ward, Thompson-Lake *et al.* (2008), who found a correlation between convergent verbal creativity and the amount of multiple types of synaesthesia and with Ward *et al.* (2017). The finding that sound-colour synaesthetes are specifically more involved in art, but do not score significantly higher in divergent creativity, is also in line with Ward, Thompson-Lake *et al.* (2008) and Chun and Hupé (2016). They proposed that involvement in art, as shown by synaesthetes, is not reflected by their basic divergent abilities. Moreover, our results inform the discussion about whether art produced by synaesthetes is merely an expression of synaesthetic experiences or an expression of divergent creative abilities. The fact that sound-colour synaesthetes are most involved in visual art, but score lower in divergent figural tasks, appears to support the former interpretation (Mulvenna, 2013; Ward, Moore, Thompson-

Lake, Salih, & Beck, 2008). However, the results may reflect the fact that divergent creativity is not the basis for distinct artistic abilities. In a previous study, we separated four artistic domains and 18 subdomains and correlated these with divergent verbal and figural creativity (Lunke & Meier, 2016). The results showed a distinctive pattern of correlations for each subdomain. Therefore, psychometric tests of divergent creativity appear not to reflect artistic creativity neither in synaesthetes nor in non-synaesthetes.

Visual and visuo-spatial abilities

The results showed a limited advantage for synaesthetes in the mental rotations task. However, sequence-space synaesthetes showed no significant advantage compared to their matched controls, which is not in line with the findings of enhanced visuo-spatial abilities in sequence-space synaesthetes reported by Simner *et al.* (2009).

The relationship between visuo-spatial abilities art and divergent creativity

For both synaesthetes and controls, visuo-spatial abilities correlated similarly with divergent figural creativity. For synaesthetes, the frequency of painting also correlated with divergent figural creativity. This result supports the idea that the ability to hold and manipulate visual representations is beneficial for divergent creativity (Kenett *et al.*, 2014; Kozhevnikov *et al.*, 2013). However, as there were no significant differences between synaesthetes and controls and as the correlations were rather small, synaesthetes do not appear to enjoy a performance advantage from their visuo-spatial abilities.

Conclusion

Our results support that synaesthetes' involvement in art is not specifically reflected in divergent creative abilities. They also indicate that people with different types of synaesthesia score differently in different cognitive abilities, and that those with multiple synaesthesia types are most likely to show enhanced divergent creativity. It is thus important to differentiate between different types of synaesthesia. Further, the results show that a higher involvement in art is not necessarily reflected in higher divergent creativity as measured with psychometric tests. Last but not least, the results indicate that visuo-spatial abilities support divergent creativity but only in a limited way and this holds for both synaesthetes and non-synaesthetes. To conclude, further studies should disentangle the relationship between different types of synaesthesia and specific types of creativity such as, for instance, artistic creativity by including various domains and subdomains.

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