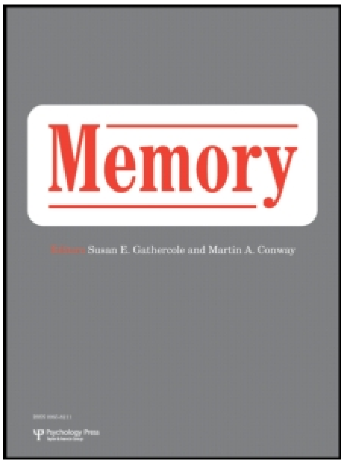

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Grapheme-colour synaesthesia yields an ordinary rather than extraordinary memory advantage: Evidence from a group study

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Grapheme–colour synaesthesia yields an ordinary rather than extraordinary memory advantage: Evidence from a group study

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In synaesthesia, the input of one sensory modality automatically triggers an additional experience, not normally triggered by the input of that modality. Therefore, compared to non-synaesthetes, additional experiences exist and these may be used as retrieval cues when memory is tested. Previous case studies have suggested that synaesthesia may yield even extraordinary memory abilities. However, group studies found either a task-specific memory advantage or no performance advantage at all. The aim of the present study was to test whether grapheme–colour synaesthesia gives rise to a general memory benefit using a standardised memory test (Wechsler Memory Scale). The synaesthetes showed a performance advantage in episodic memory tests, but not in short-term memory tests. However, performance was still within the ordinary range. The results support the hypothesis that synaesthesia provides for a richer world of experience and as a consequence additional retrieval cues may be available and beneficial but not to the point of extraordinary memory ability.

Keywords: Synaesthesia; Episodic memory; Case studies; Wechsler Memory Scale.

Synaesthesia is a condition in which the input of one sensory modality triggers an additional sensory experience. For example, in grapheme–colour synaesthesia a letter printed in black on white paper elicits a red colour experience. Two core features of synaesthetic experiences are their consistency over time and their automatic occurrence (Grossenbacher & Lovelace, 2001). These consistent and automatic experiences may function as additional memory cues in synaesthetes when compared to non-synaesthetes. Previous case studies have shown that synaesthesia can contribute to extraordinary memory performance (Luria, 1968; Mills, Innis, Westendorf, Owsianiecki, & McDonald, 2006; Smilek, Dixon, Cudahy, & Merikle, 2002). In contrast, group studies have shown that synaesthetes had just a slight performance advantage or even no performance advantage at all (Rothen & Meier, 2009; Yaro & Ward, 2007). Therefore it seems uncertain whether synaesthesia per se promotes a memory advantage. The aim of the present study was to investigate whether a performance advantage can be found in a standardised memory test using a large sample of grapheme–colour synaesthetes.

First we will examine the previous studies on memory performance in synaesthesia in more detail. Probably the most striking case of a synaesthete with extraordinary memory performance was the famous mnemonist Shereshevskii (“S”; Luria, 1968). Among other things, he could remember complex figures and matrices of 50

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digits after studying them for only a few minutes. Moreover, he was able to recall these matrices years later. Luria (1968) suggested that his extraordinary memory performance was at least in part caused by his multiple synaesthesias (but see Ericsson & Chase, 1982).

A more recent report of exceptional memory was digit–colour synaesthete C (Smilek et al., 2002). She was tested with a matrix test similar to that which Luria (1968) used with S. One matrix consisted of black digits, another of digits congruent with C's synaesthetic colours, and a third of digits incongruent with her synaesthetic colours. When tested immediately after learning a matrix, C showed excellent performance for the black and the congruent matrix. However, her recall for the incongruent matrix was very poor. When tested again after 48 hours with the black matrix, there was no decline in performance. In the control group there was no performance difference between the black, the congruent, and the incongruent matrices, and the control group showed a significant decrease when tested again after 48 hours. Smilek et al. (2002) suggested that synaesthetic colours provided additional memory cues and therefore played an essential role in C's memory abilities.

MLS, an individual with grapheme–colour synaesthesia, reported that synaesthesia helped her to remember names and verbal material (Mills et al., 2006). She and a matched control group were tested with a paired-associates test of fictitious first and last names. In addition, three standardised memory tests were administered, two visual tests, the Benton Visual Retention Test – Revised (BVRT-R) and the Rey Complex Figure Test (RCFT), and one verbal test, the Rey Auditory-Verbal Learning Test (RAVLT). Compared to the control group, MLS scored higher in the verbal tests, but did not differ in the visual tests. These results suggest that MLS was able to use her synaesthesia to remember verbal materials, but she did not show a general memory performance benefit.

Another single case with exceptional abilities in numerical memory and mathematical calculations is the savant DT (Azoulai, Hubbard, & Ramachandran, 2005; Baron-Cohen et al., 2007; Bor, Billington, & Baron-Cohen, 2007). Besides being a savant, DT has an elaborate form of synaesthesia for visually presented digits and it is likely that the use of synaesthetic experiences contributed to his extraordinary memory abilities.

As far as we know, there are only two studies in which memory was tested in a group of synaesthetes, rather than in single cases. Yaro and Ward (2007) investigated a sample of 46 grapheme–colour synaesthetes and 46 non-synaesthetes. The synaesthetes themselves considered that they had better than average memory abilities and they reported more frequent use of visual strategies to aid memory compared to a control group. A subgroup of 16 synaesthetes and 16 controls was further tested with the matrix test (congruent vs incongruent coloured digits and coloured squares), the RAVLT, the Farnsworth-Munsell Colour Test, and the RCFT. Compared to the control group, the synaesthetes showed better memory performance for colours and for words eliciting synaesthetic colours. This advantage was more pronounced after a delay in the colour matrix test and by trend in the RAVLT. In the other tests, however, there were no performance differences between the synaesthetes and the control group. Furthermore, in contrast to previous findings, the performance advantage of synaesthetes for the congruent digit matrix was not replicated. Yaro and Ward (2007) suggested that the performance benefit of synaesthetes in memory tests is related to an enhanced retention of colour in both synaesthetic and non-synaesthetic situations.

In a recent study we investigated a group of 13 grapheme–colour synaesthetes and 13 yoked controls (Rothen & Meier, 2009). We used two matrices, one consisting of incongruently coloured digits and one consisting of black digits. Memory was tested immediately after learning each matrix, after a delay of 30 minutes, and after a delay of 2–3 weeks. The results showed no performance benefit for the group of synaesthetes compared to the controls, either in immediate or in delayed recall, thereby replicating the results of Yaro and Ward (2007). In addition, there was no advantage for memorising the matrix with black digits over the matrix with incongruently coloured digits. The results suggest that synaesthesia per se does not seem to lead to a memory performance advantage.

To summarise, the studies in which extraordinary memory for synaesthetes was found were case reports. These case studies have been conducted to demonstrate that some individuals show exceptional memory performance and the synaesthetes were included because of their special performance in the first place. S (Luria, 1968), C (Smilek et al., 2002), and MLS (Mills et al., 2006) all attracted the researchers' attention because of their extraordinary memory. It is obvious that this approach limits the generalisation of the results. The few studies in which groups of synaesthetes were tested do not suggest that synaesthesia per se provides a general performance benefit. Therefore, it is timely to address the question as to whether synaesthetes perform differently from non-synaesthetes on memory tests. To do this, a simple study is necessary: comparing synaesthetes and a matched control group with a standardised memory test (cf. Baron-Cohen et al., 2007). Towards this goal we tested 44 grapheme–colour synaesthetes with the German version of the revised Wechsler Memory Scale (WMS-R; Härting et al., 2000).

METHOD

Participants

A total of 44 grapheme–colour synaesthetes (40 female and 4 male; $M = 32.9$ years, $SD = 10.2$; $M = 16.8$ years of education, $SD = 3.3$) were recruited via the synaesthesia website of the University of Bern (www.synaesthesie.unibe.ch). They gave informed consent prior to participation. A test of consistency was administered in the original test session and in a second session about 6 months later. Synaesthetes were required to map their synaesthetic colours for letters and digits according to a continuous colour space displayed on the computer. Mean consistency was $r = .82$ for hue, $r = .85$ for saturation, and $r = .80$ for value (i.e., brightness). All consistency measures were statistically different from zero, with $ts(42) > 7.3$, $ps < .001$. They were also statistically different from the highest value ($r = .26$) of a control group tested in a previous study (cf. Meier & Rothen, 2007), with $ts(42) > 5.7$, all $ps < .001$. One synaesthete moved abroad and was not available for the second session. Therefore, we asked her to use the Synesthesia Battery (www.synesthete.org), which revealed a consistency score of 0.56 for grapheme–colour associations, a value in the typical range for grapheme–colour synaesthesia (Eagleman, Kagan, Nelson, Sagaram, & Sarma, 2007).

Material and procedure

To test memory we used the German version of the WMS-R (Härting et al., 2000). The normative sample of the WMS-R consists of seven age groups with 30 participants in each. To be representative, the normative sample is gender- and education-weighted according the data of the statistical yearbook of the Federal Republic of Germany (1995). The WMS-R provides standardised indices for immediate memory performance (which can be further subdivided into a verbal and a visual memory score), delayed memory performance, and short-term memory performance. Each of these indices consists of several subtests.

Figural Memory examines the ability to recognise briefly presented figures from an array. *Logical Memory* examines the ability to recall the ideas from two orally presented stories. In *Visual Paired Associate Learning* the participant has to remember the specific colour associated with line drawings, which were paired with different colours. In *Verbal Paired Associate Learning* the participant is orally presented with word pairs, and then has to recall the second word of each pair when presented with the first. There are up to six trials to learn the pairs. In *Visual Reproduction* the participant is briefly presented with abstract figures on paper and then has to reproduce them by pencil and paper drawing. *Digit Span Forward* examines the ability to immediately recall a digit-string of increasing length in forward order. *Digit Span Backward* examines the ability to immediately recall a digit-string of increasing length in backward order. In *Visual Memory Span Forward* the experimenter taps out sequences of increasing length on a board comprising little blocks set out in a grid. The participant has to immediately reproduce the sequences in forward order. In *Visual Memory Backward* the participant has to immediately reproduce the sequences in the backward order. Following the administration of the tests, a *Delayed Recall for Logical Memory, Visual Paired Associate Learning, Verbal Paired Associate Learning, and Visual Reproduction* is conducted. Importantly, there is a retention interval of at least 30 minutes between immediate and delayed recall for each specific test. All participants were tested individually in a single session according to the instructions of the WMS-R manual (Härting et al., 2000).

Analysis

For all statistical analyses, alpha was set at .05. First, each subtest was analysed separately. To enable a comparison to the reference sample, individual test scores were standardised according to the age matched reference sample (Härting et al., 2000). Z-scores were calculated by subtracting each individual test value from the corresponding mean and dividing by the corresponding standard deviation. Values within one standard deviation of the reference sample (i.e., between $M = 0$ and $SD = \pm 1$) were regarded as ordinary performance. Values above one standard deviation were regarded as extraordinary (i.e., beyond the average range).

Second, the indices provided by the WMS-R were analysed (i.e., immediate recall, immediate verbal memory, immediate visual memory, delayed memory). Values within one standard deviation of the reference sample (i.e., between $M = 100$ and $SD = \pm 15$) were regarded as ordinary performance. Values above one standard deviation were regarded as extraordinary.

RESULTS

The results for each subtest are presented in Figure 1 and the corresponding frequency distributions are presented in Table 1. To compare the mean performance of the synaesthetes to the reference sample, we conducted one sample t-tests against a test value of zero, which is the mean of the reference sample for each specific subtest. Compared to the reference sample (Härting et al., 2000), there was no performance advantage for synaesthetes in most of the short-term memory subtests—Digit Span Forward, $t(43) = -0.86$, $p > .05$; Digit Span Backward, $t(43) = -0.41$, $p > .05$; Visual Memory Span Forward, $t(43) = 0.45$, $p > .05$—with the only exception of the Visual Memory Span Backward, $t(43) = 2.20$, $p < .05$. In contrast, there was a consistent advantage in the verbal memory subtests: Logical Memory Immediate, $t(43) = 2.08$, $p < .05$; Logical Memory Delayed, $t(43) = 2.46$, $p < .05$; Verbal Paired Associate Learning Immediate, $t(43) = 9.76$, $p < .001$; Verbal Paired Associate Learning Delayed, $t(43) = 8.59$, $p < .001$. In addition, there was a consistent advantage in the visual memory subtests: Visual Reproduction Immediate, $t(43) = 3.75$, $p < .001$; Visual Reproduction Delayed, $t(43) = 5.94$, $p < .001$; Visual Paired Associate Learning Immediate, $t(43) = 16.70$, $p < .001$; Visual Paired Associate Learning Immediate, $t(43) = 32.49$, $p < .001$; Figural Memory, $t(43) = 4.81$, $p < .001$. However, with the exception of immediate Visual Paired Associate Learning, the means of all subtests lay within one standard deviation of the reference sample, that is, within the ordinary range.

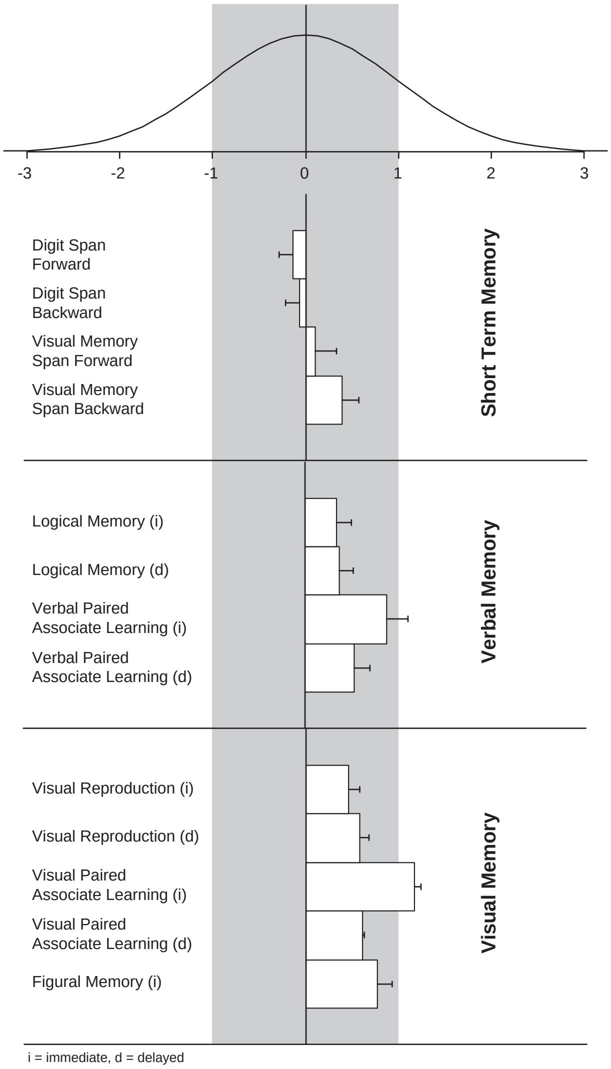

Figure 1. Mean z-scores for each subtest of the WMS-R: The schematic normal curve represents the normative sample. The average range lies between ± 1 standard deviation indicated by a grey-shaded background. Error bars represent standard errors.

The analyses of the composite indices showed a similar pattern. To compare the mean performance of the synaesthetes to the reference sample, we again conducted one sample t-tests

TABLE 1
Number of synaesthetes who performed below average, in the ordinary range, or above average (extraordinary), for each subtest of the WMS-R

Subtest	*Below average*	*Ordinary*	*Extraordinary*
Digit Span Forward (s)	8	31	5
Digit Span Backward (s)	4	34	6
Visual Memory Span Forward (s)	11	20	13
Visual Memory Span Backward (s)	7	24	13
Logical Memory (i)	6	27	11
Logical Memory (d)	6	27	11
Verbal Paired Associate Learning (i)	1	20	23
Verbal Paired Associate Learning (d)	2	42	0
Visual Reproduction (i)	1	36	7
Visual Reproduction (d)	2	33	9
Visual Paired Associate Learning (i)	0	13	31
Visual Paired Associate Learning (d)	0	44	0
Figural Memory (i)	5	17	22

s = short-term memory, i = immediate recall, d = delayed recall.

against a test value of 100, which is the mean of the reference sample. The verbal memory index of the synaesthetes, $M = 106.3$ ($SD = 15.7$), was statistically different from the reference sample, with $t(43) = 2.68$, $p < .05$. The visual memory index, $M = 113.6$ ($SD = 8.9$), was also significant, $t(43) = 10.14$, $p < .001$. However, again the mean indices of the synaesthetes lay in the ordinary range, that is, within one standard deviation of the norms. A paired-samples *t*-test showed that the scores on the visual index were significantly higher, $t(43) = -3.06$, $p < .01$. On the verbal index, five synaesthetes performed below average, 27 performed in the ordinary range, and only 12 showed extraordinary performance. However, on the visual index, no synaesthete was below average, 20 synaesthetes showed ordinary performance, and 24 showed extraordinary performance. Thus synaesthetes showed a memory benefit particularly for visual memory. Moreover, the immediate recall index, $M = 110.4$ ($SD = 13.9$) and the delayed recall index, $M = 110.7$ ($SD = 11.1$) were also statistically different from the reference sample. But again, the mean indices lay within the ordinary range.

Finally, during the recruitment via our synaesthesia website it was established whether synaesthetes think that their synaesthesia helps them "to remember things". A total of 74% responded that synaesthesia helps their memory. The synaesthetes who indicated that synaesthesia helps their memory did not differ from the rest of the synaesthetes in the immediate recall index (109.5 vs 112.0), the delayed recall index (110.7 vs 110.5), the verbal memory index (105.4 vs 108.0), or the visual memory index (113.4 vs 114.0), all ts$(43) < -.58$ and all ps $> .56$.

DISCUSSION

The first aim of this study was to examine whether grapheme–colour synaesthetes have a general memory advantage using a standardised memory test. Our results indicate that overall, synaesthetes scored above average in episodic memory tests compared to the reference sample. However, the mean scores of the synaesthetes in these tests were still within the ordinary range for most of the tests. Only in immediate Visual Paired Associate Learning was performance extraordinary, being defined as more than one standard deviation above the average range of the reference sample. In addition, performance in three out of four short-term memory subtests did not differ from the reference sample.

Overall, there was a performance benefit in visual compared to verbal episodic memory. While only one of the visual subtests is related to colour information, all verbal episodic subtests may potentially elicit synaesthetic colour experiences. Thus, it is unlikely that colour information is the main reason for a performance benefit in visual episodic memory relative to verbal episodic memory (cf. Yaro & Ward, 2007). Our findings rather suggest that grapheme–colour synaesthetes profit from the experiences in the domain of the synaesthetic concurrent, that is, the visual modality for grapheme–colour synaesthesia. A similar result has been presented recently in the domain of sequence-space synaesthesia (Simner, Mayo, & Spiller, 2009). In addition, this interpretation is supported by two studies in which evidence is presented that grapheme–colour synaesthetes have superior visual imagery abilities (Barnett & Newell, 2008; Spiller & Jansari, 2008). Grapheme–colour synaesthetes have also consistently reported relying more on visual strategies than have non-synaesthetes (Yaro & Ward, 2007).

At first glance, two other studies in which no visual memory performance benefit was found for grapheme–colour synaesthetes seem to conflict with this interpretation (Mills et al., 2006; Yaro & Ward, 2007). However these studies used the Rey Complex Figure, which contains more abstract materials than the figures of the Visual Reproduction subtest of the WMS-R. Thus a performance benefit of synaesthetes in recalling abstract figures may be a question of complexity of the specific figures.

Another interesting result of our study is the absence of a short-term memory performance benefit in three of four short-term memory subtests, irrespective of whether the task was visually or verbally related. In short-term memory tasks the material has to be held actively in memory, therefore one would not necessarily expect an advantage due to the availability of additional *retrieval* cues. Thus the absence of a short-term memory advantage supports the hypothesis that synaesthesia generates additional retrieval cues. Consistent with our results, Bor et al. (2007) also failed to find an advantage for their single case DT in a digit span task.

In this study we focused on grapheme–colour synaesthesia and we found a general advantage for episodic memory. However, there is evidence that even grapheme–colour synaesthesia is not beneficial for all kinds of materials (cf. Baron-Cohen et al., 2007; Bor et al., 2007; Yaro & Ward, 2007; see also Smilek et al., 2002 with incongruent matrices), suggesting that synaesthesia may lead to ''islands of ability''. Such an interpretation would be consistent with the frequency distributions of Verbal Paired Associate Learning Immediate, Visual Paired Associate Learning Immediate, and Figural Memory, which may be interpreted as extraordinary abilities in these memory sub-domains.

From the present study we cannot generalise to other forms of synaesthesia. It is possible that other forms of synaesthesia have a more or less beneficial effect on episodic memory. For example, in time-space synaesthesia Simner et al. (2009) found a benefit for both visual short-term and episodic memory. Since sequence–space synaesthesia is a relatively common feature of grapheme–colour synaesthesia (Sagiv, Simner, Collins, Butterworth, & Ward, 2006), it is possible that some of our grapheme–colour synaesthetes also had sequence–space synaesthesia, and that some of the performance advantages we found can be attributed to the benefits associated with sequence–space synaesthesia. It remains a question for further research to what extent different forms of synaesthesia specifically influence different memory abilities.

To conclude, the present study provides evidence for an ordinary, but not an extraordinary, performance advantage for grapheme–colour synaesthetes in episodic memory. We reason that this advantage is related to their synaesthetic experiences.

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REFERENCES

Azoulai, S., Hubbard, E. M., & Ramachandran, V. S. (2005). *Does synaesthesia contribute to mathematical savant skills?* Poster presented at the Proceedings of the Cognitive Neuroscience Society, New York.

Barnett, K. J., & Newell, F. N. (2008). Synaesthesia is associated with enhanced, self-rated visual imagery. *Consciousness and Cognition*, *17*, 1032–1039.

Baron-Cohen, S., Bor, D., Billington, J., Asher, J. E., Wheelwright, S., & Ashwin, C. (2007). Savant memory in a man with colour form–number synaesthesia and Asperger syndrome. *Journal of Consciousness Studies*, *14*, 237–251.

Bor, D., Billington, J., & Baron-Cohen, S. (2007). Savant memory for digits in a case of synaesthesia and Asperger syndrome is related to hyperactivity in the lateral prefrontal cortex. *Neurocase: Case Studies in Neuropsychology, Neuropsychiatry, and Behavioural Neurology*, *13*, 311–319.

Eagleman, D. M., Kagan, A. D., Nelson, S. S., Sagaram, D., & Sarma, A. K. (2007). A standardised test battery for the study of synesthesia. *Journal of Neuroscience Methods*, *159*, 139–145.

Ericsson, K. A., & Chase, W. G. (1982). Exceptional memory. *American Scientist*, *70*, 607–615.

Grossenbacher, P. G., & Lovelace, C. T. (2001). Mechanisms of synesthesia: Cognitive and physiological constraints. *Trends in Cognitive Sciences*, *5*, 36–41.

Härting, C., Markowitsch, H. J., Neufeld, H., Calabrese, P., Deisinger, K., & Kessler, J. (2000). *Wechsler Gedächtnistest-Revidierte Fassung (WMS-R), Testmanual, deutsche Adaptation der revidierten Fassung* *der Wechsler Memory Scale von David Wechsler*. Bern: Hans Huber.

Luria, A. R. (1968). *The mind of a mnemonist: A little book about a vast memory*. Cambridge, MA: Harvard University Press.

Meier, B., & Rothen, N. (2007). When conditioned responses ''fire back'': Bidirectional cross-activation creates learning opportunities in synesthesia. *Neuroscience*, *147*, 569–572.

Mills, C. B., Innis, J., Westendorf, T., Owsianiecki, L., & McDonald, A. (2006). Effect of a synesthete's photisms on name recall. *Cortex*, *42*, 155–163.

Rothen, N., & Meier, B. (2009). Do synesthetes have a general advantage in visual search and episodic memory? A case for group studies. *PLoS ONE*, *4*, e5037.

Sagiv, N., Simner, J., Collins, J., Butterworth, B., & Ward, J. (2006). What is the relationship between synaesthesia and visuo-spatial number forms? *Cognition*, *101*, 114–128.

Simner, J., Mayo, N., & Spiller, M. J. (2009). A foundation for savantism? Visuo-spatial synaesthetes present with cognitive benefits. *Cortex*, *45*, 1246–1260.

Smilek, D., Dixon, M. J., Cudahy, C., & Merikle, P. M. (2002). Synesthetic color experiences influence memory. *Psychological Science*, *13*, 548–552.

Spiller, M. J., & Jansari, A. S. (2008). Mental imagery and synaesthesia: Is synaesthesia from internally-generated stimuli possible? *Cognition*, *109*, 143–151.

Yaro, C., & Ward, J. (2007). Searching for Shereshevskii: What is superior about the memory of synaesthetes? *Quarterly Journal of Experimental Psychology*, *60*, 681–695.