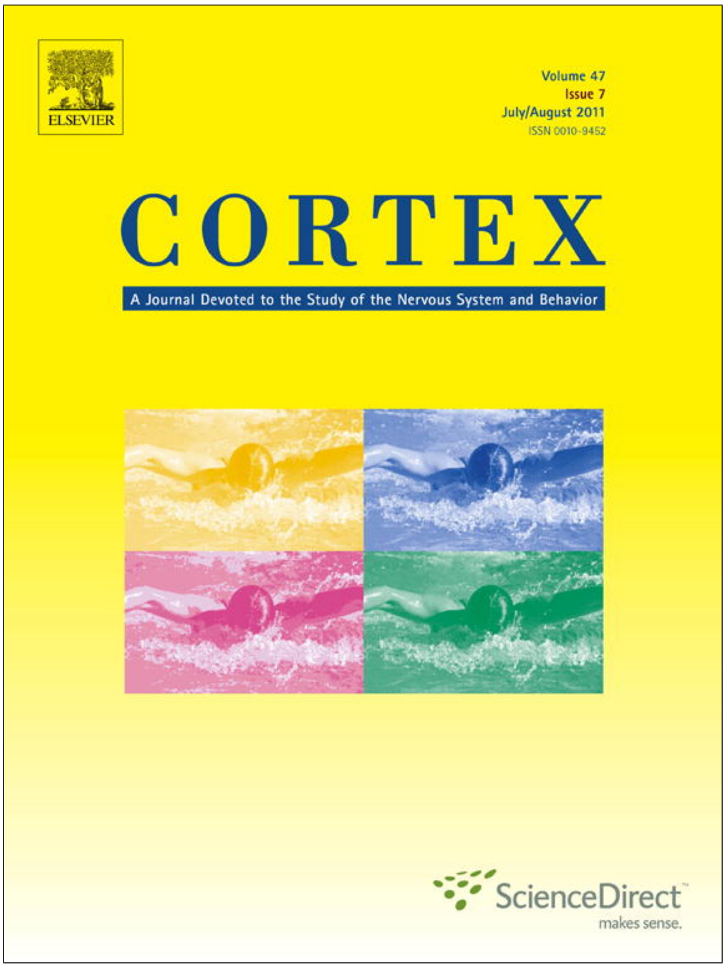
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Note

Swimming-style synesthesia

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ABSTRACT

The traditional and predominant understanding of synesthesia is that a sensory input in one modality (inducer) elicits sensory experiences in another modality (concurrent). Recent evidence suggests an important role of semantic representations of inducers. We report here the cases of two synesthetes, experienced swimmers, for whom each swimming style evokes another synesthetic color. Importantly, synesthesia is evoked also in the absence of direct sensory stimulation, i.e., the proprioceptive inputs during swimming. To evoke synesthetic colors, it is sufficient to evoke the concept of a given swimming style e.g., by showing a photograph of a swimming person. A color-consistency test and a Stroop-type test indicated that the synesthesia is genuine. These findings imply that synesthetic inducers do not operate at a sensory level but instead, at the semantic level at which concepts are evoked. Hence, the inducers are not defined by the modality-dependent sensations but by the "ideas" activated by these sensations.

1. Introduction

Some individuals report that when seeing an alphanumeric symbol (e.g., an "A"), they experience also color sensations (e.g., red). Others may perceive colored patterns when hearing a music piece. Those people are called synesthetes. Synesthesia is traditionally understood as a perceptual phenomenon, such that a sensory stimulus, presented within one modality, triggers an additional perception in the same or a different modality (e.g., Baron-Cohen and Harrison, 1997; Mattingley et al., 2001; Ramachandran and Hubbard, 2001; Cytowic, 2002).

However, recently, a possibility of a different perspective on synesthesia emerged. Grossenbacher and Lovelace (2001) introduced the term "synesthetic conception" to account for the properties of synesthesia that did not match the classical descriptions of this phenomenon. The authors noted that either the inducer or the concurrent can operate at a conceptual rather than perceptual level, as for many types of synesthesia no obvious perceptual basis exists. One example is time-unit-space synesthesia (e.g., Smilek et al., 2007; Jarick et al., 2008; Mann et al., 2009), where individuals experience units of time—mostly hours, days and months—being placed

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at specific locations in space relative to their body. Other evidence about a strong semantic component in synesthesia (Dixon et al., 2000, 2006; Rich and Mattingley, 2003; Ward et al., 2006; Simner and Ward, 2006) and about an ability to transcend sensory modalities by imagining or just thinking of a stimulus (Grossenbacher, 1997; Frith and Paulesu, 1997; Ramachandran and Hubbard, 2001; Cytowic, 2002; Rich et al., 2005) has been collected meanwhile. Even a substitution of old graphemes with new ones, never seen before, can result in a transfer of synesthesia in less than 10 min of such experiences (Mroczko et al., 2009). Thus, synesthesia seems to depend strongly on the interpretation of the stimuli and the meaning that they have for the subject, rather than being caused by low-level pre-wired connections between sensory representations (Nikolić, 2009).

If an activation of the underlying concept alone elicits synesthetic concurrents, evidence is provided that low-level perceptual processes—i.e., modality-dependent processes—are not necessary to evoke synesthetic experiences (e.g., Dixon et al., 2000). We report here a novel form of synesthesia in which the concurrent can be easily elicited without a specific sensory stimulation. Two synesthetes report perceiving colors while swimming—each swimming style (e.g., breaststroke or butterfly) being associated with a different color. This newly discovered form of the phenomenon, which we named *swimming-style synesthesia*, had the interesting property of allowing us to segregate the direct sensory inputs—i.e., proprioceptive inputs during the act of swimming—from those that evoke conceptual representations—i.e., pictures or words associated with this sport. Thus, if synesthesia occurs while direct sensory inputs are absent and only indirect ones exist, a conclusion follows on the conceptual nature of the phenomenon.

2. Methods

2.1. *Subjects*

Two synesthete subjects H.T. and U.J., male and female, both 24 years old, participated in the study. Both are active in swimming, which is an important aspect of their lives. They began swimming in early childhood and practice on a weekly basis. U.J. was competing at a communal level until the age of 13 and continues to swim regularly for leisure purposes until today. H.T. began competing at the age of 6, and won his first championship in butterfly style at the age of 8. He was the national champion of Syria for several years until he stopped competing at the age of 16, but has also continued swimming for leisure until today.

Both subjects have also other forms of synesthesia. H.T. reports having number–color synesthesia (but not letter–color), and U.J. has complete grapheme-color synesthesia (i.e., numbers and letters), ordinal linguistic personifications, and time-units-space synesthesia, among others. For the color-consistency test, three other swimmers were recruited as control subjects, two who matched H.T. (H.P. and D.R.) for gender, age and swimming experience and one who matched U.J. (F.M). For the swimming styles breaststroke, butterfly, backstroke and front crawl, subject H.T. had associated colors: medium blue, deep red, light yellow, and white, and subject U.J. had colors: red-brown, sky-blue, purple-blue, and yellow, respectively.

For the Stroop-type test we recruited additional two non-synesthete subjects, matched by gender, age (24 and 27 years old) and education (A.M.L. and P.L.W.). These subjects were not active swimmers but were familiar with all four swimming styles.

2.2. *Experimental procedures*

The synesthetes were subjected to a consistency test of the colors associated with four main swimming styles (breaststroke, butterfly, backstroke and front crawl). Also a Stroop-type test was performed (e.g., Schneider and Kaernbach, 2001; Odgaard et al., 1999; Nikolić et al., 2007; Mroczko et al., 2009). In the consistency test, the subjects were presented with a sheet of paper with four black-and-white close-up photographs of single swimmers engaging in one of the four main swimming styles. The photographs were never seen before by the subjects. The task was to find in a book containing more than 5500 shades of colors (Küppers, 2003) the one that matched best the synesthetic color associated to that swimming style. All procedures were conducted in a laboratory in a sitting position and did not involve any motor activities associated with swimming. Subjects were not aware that they would be required to complete the same color selection procedure once again several weeks later. For each swimming style, the color was reported once for test and once for retest. The test–retest interval was longer for synesthetes (four weeks for H.T. and three weeks for U.J.) than for non-synesthete control subjects (two weeks in all cases). U.J. is one of the authors of this study but was originally fully naïve about the study and the purpose of the color selection procedure and was, at the time of the first selection, unaware that a second one would follow. For each swimming style, subjects were asked only once at test and once at retest to give the best-matching color. The control subjects were given the same tasks but were asked to choose the color that, according to their opinion, suited the individual swimming styles best.

To quantify color consistency, the chosen colors were first calculated in red-green-blue (RGB)-space using a custom-made computer program. For each participant and each swimming style, the Euclidian distance was calculated in RGB-space for the colors reported at the two occasions, and these distances were used as a measure of the difference in the chosen colors (a test–retest error). The RGB-values 0–255 were first normalized to the range 0–1. Hence, theoretically, the maximal possible distance between a pair of colors was $\sqrt{3} = 1.73$ RGB-units. A pair of randomly chosen colors would on average have a distance of .67 RGB-units (Schneider and Kaernbach, 2001).

In the Stroop-type test, the synesthetes were presented with the same four photographs used for the consistency test but on a computer screen with a colored tone. Instead of being black-and-white, photographs were painted with another ink such as red or yellow. The hue was chosen to be either the same as the synesthetic color associated to that swimming style (congruent) or to be different (incongruent). The incongruent colors were chosen as the opponent color and one of the two possible orthogonal colors in a color wheel. Thus, for each congruent picture two incongruent ones were presented, leading to twice as many incongruent than congruent trials. The used color wheel was close to the psychological color wheel and, to find easily opponent colors, implemented in a program farbwert.exe, a freeware Windows application downloadable from http://www.AnnaVis.de. All pictures were shown on a black background.

The subjects' task was to name the presented color as fast as possible and the vocal response time was measured. The methods were similar to those in Nikolić et al. (2007) and Mroczko et al. (2009). The images are presented in the center of the screen without a fixation cross. All trials were presented within one block (i.e., without a break and with a 1-sec inter-trial interval). The entire procedure lasted about 25 min. Each stimulus—i.e., a swimming style in a given color—was presented 20 times, leading to a total of 240 trials (20 presentations $\times$ 4 styles $\times$ 3 colors). The responses to two types of incongruent stimuli were averaged prior to the analysis. The expectations for the directions of all differences tested by t-tests were defined prior to the analyses and hence, all estimates of significances were made with one-tailed distributions. For subject H.T. four data points were taken out of the analysis as outliers because vocal responses were not loud enough to reach the threshold needed to determine response times. The error rates (i.e., incorrectly named colors) were very low. They were always $\leq$1.25% (i.e., at most one or two errors per stimulation conditions), and were about equally likely to occur for congruent and incongruent colors. Hence, it was unlikely that any changes in naming times could be explained by a trade off between speed and accuracy.

3. Results

Both synesthete subjects reported experiencing distinct colors for each of the four main swimming styles whenever they practice swimming, but also when they think about practicing or even when they think about the concept of the given swimming style. They had these experiences for as long as they could remember and the colors seem to have stayed constant throughout their lifetimes.

The test–retest distances between the reported nuances of colors are shown in Table 1 for all subjects and for all swimming styles. The synesthetes and controls differed markedly as groups. Synesthetes had about eight times smaller test–retest error than controls, which was a statistically significant difference [t-test, $t(18) = 3.47$; $p < .002$]. Also, individually, each synesthete had smaller average test–retest error than any of his/her controls (at least 4.8$\times$ smaller). Thus, synesthetes showed considerably higher consistency in reported colors than did control subjects, despite the fact that the former group was tested over a much longer time interval than the latter one. The poor test–retest reliability of controls indicates that, in this task, color choices cannot be precisely memorized over the period of several weeks. Instead, to report reliably the same color nuance, one needs to have on both test occasions the same internal reference for comparison—which was available only to synesthetes, presumably through their synesthetic concurrents.

Example stimuli used in the Stroop-type task are shown in Fig. 1a. The times needed to name the ink color of the presented photographs of swimmers were analyzed separately for each synesthete such that the data were pooled for all four swimming styles. Both subjects showed Stroop-type effects. Subject U.J. was about 101 msec slower in naming incongruent colors than congruent ones (Fig. 1b). This difference was significant [$t(79) = 3.24$; $p < .001$] and its magnitude was consistent with the results typically obtained by applying a similar Stroop-type task for testing grapheme-color synesthesia (Dixon et al., 2000; Mattingley et al., 2001; Cohen Kadosh and Henik, 2006; Nikolić et al., 2007; Mroczko et al., 2009). Subject H.T. exhibited only about one-third of the magnitude of this effect, the average difference in the naming times between congruent and incongruent conditions being 33 msec (Fig. 1). This difference was also significant [$t(76) = 1.95$; $p = .027$]. Therefore, in both cases, color naming is slower in incongruent than in congruent condition.

This was not the case for the two control subjects, who showed a different trend: the congruent conditions had the tendency to be slower than the incongruent ones (i.e., opposite than the results obtained for synesthetes) but these differences were not significant [both $t(77) \leq 1.05$; $p \geq .15$] (Fig. 1c).

4. Discussion

Both of our attempts to provide evidence for the existence of swimming-style synesthesia were successful. Synesthete subjects reported much more consistent colors than non-synesthetes and the naming times slowed down when the color of the paint was incongruent with the synesthetic color of the swimming style. In combination with all the other descriptions that the subjects provided about this phenomenon, we can conclude that these two individuals have true synesthesia for swimming styles. Thus, swimming-style synesthesia is not a result of imagination but is a form of synesthesia similar to many other more common types of the phenomenon, such as for example grapheme-color synesthesia.

These experiments were made in a laboratory and did not require the measurements to be performed in a swimming

Table 1 – Norms of the distance vectors. The italic values in parentheses are standard deviations.

		Breaststroke	Butterfly	Backstroke	Front crawl	Mean	
Synesthetes	U.J.	.021	.012	.000	.006	.009 (*.01*)	.050 (*.06*)
	H.T.	.313	.024	.027	.000	.091 (*.15*)	
Controls	F.M. (U.J.)	.586	.518	.005	.383	.373 (*.26*)	.423 (*.05*)
	H.P. (H.T.)	.234	.228	.872	.398	.433 (*.30*)	
	D.R. (H.T.)	.877	.635	.327	.016	.464 (*.37*)	

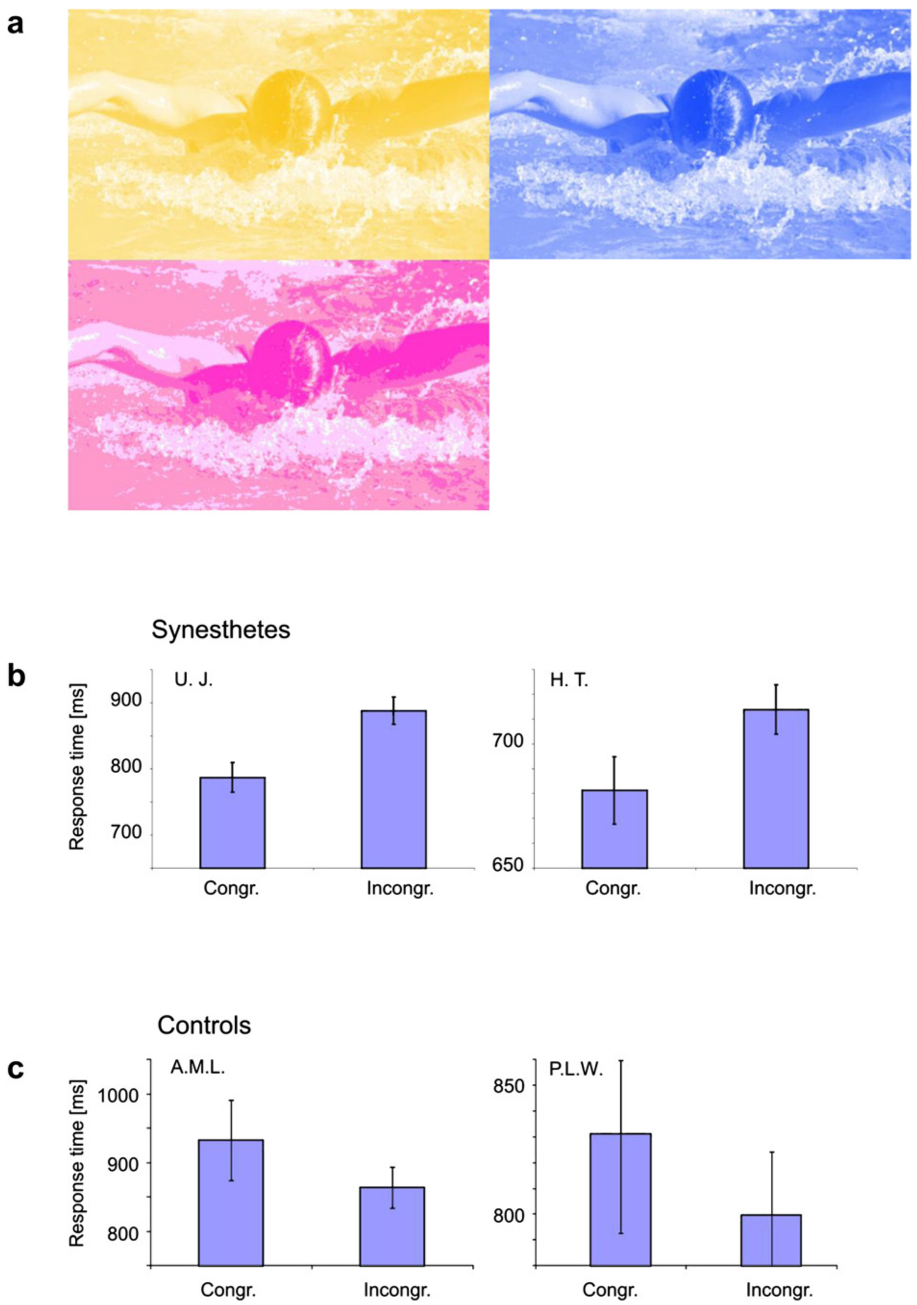

Fig. 1 – Stimuli and results. (a) Example pictures of a swimmer performing butterfly stroke painted either in a U.J.'s synesthetic color (upper left) or in one of her two non-synesthetic colors. (b) Average response times in a Stroop-type task for two synesthetes. Congr.: Photographs presented in the colors same as the synesthetic colors (congruent). Incongr.: Photographs shown in colors different from synesthetic ones (incongruent). Vertical bars: Standard error of the mean. (c) The same as in (b) but for two non-synesthete subjects matched by gender, age and education.

pool. The classical understanding of synesthesia, as a form of cross-wiring between senses, would suggest that a phenomenon such as swimming-style synesthesia could be evoked and hence studied only by producing corresponding proprioceptive inputs. However, as we find, no direct proprioceptive stimulation is necessary. To demonstrate behaviors characteristic of synesthesia by objective methods it was sufficient to simply activate the respective concepts by showing photographs of other people swimming. Hence, we can conclude that a mere thought about a given swimming style elicits the perception of color already in the absence of any muscular activation and even without an explicit instruction to imagine the respective movement. This result generalizes the findings reported for imagination of graphemes in grapheme-color synesthesia (Frith and Paulesu, 1997; Ramachandran and Hubbard, 2001) also to swimming-style synesthesia: As our results indicate, the concept of the inducer evokes concurrent perceptions of colors, much like the original sensory input itself. This in turn suggests that the original proprioceptive input is not necessary to induce synesthesia but that the conceptual representation is sufficient. However, our experiments, per se, cannot rule out the possibility that the visual processing of the pictures elicits colors directly without an involvement of higher conceptual processes. Nevertheless, and in line with our reasoning, much evidence has accumulated suggesting a role of "high-level" conceptual processes in synesthesia (Dixon et al., 2000, 2006; Rich and Mattingley, 2003; Ward et al., 2006; Zahn et al., 2007; Simner, 2007). In contrast, the hypothesis that inducers operate at "low" sensory levels often failed to receive empirical support (Edquist et al., 2006; Sagiv et al., 2006; Rothen and Meier, 2009; Ward et al., 2009). Hence, if the present results are integrated with other available evidence, a possibility opens that synesthesia is exclusively a semantic phenomenon and thus, that low-level synesthesia either does not exist at all or exists as a completely different and unrelated set of perceptual experiences. Maybe only the concurrents can (but do not have to, e.g., Simner, 2007) operate at the sensory level. Inducers may operate exclusive at the semantic level. Hence, the original name of the presently investigated phenomenon *syn+aesthesia* (Greek for *union of senses*) may turn out misleading in respect to its true nature. The term *ideaesthesia* (Greek for *sensing concepts*) may describe then the phenomenon much more accurately (Nikolić, 2009).

If the activation of the concept of the inducer is a sufficient condition for the elicitation of the concurrent, other, currently unknown, cases of synesthesia may be discovered in which particular bodily movements may serve as inducers, such as e.g., "tennis-strike" or "dancing-style" synesthesia. For example, a synesthete may be discovered for whom a backhand strike evokes a color experience different than that of a forehand strike. Likewise, a waltz may have a different flavor or smell than a tango. In either case, one would predict that the concurrents should be evoked also by mere activation of the concepts and no actual dancing or tennis playing would be necessary.

The unique properties of swimming-style synesthesia can help us understand also why, in synesthetes, only some types of concepts (i.e., "modalities") produce synesthesia but not others. Both of our synesthetes have been active swimmers since childhood and, during this period, swimming has played a central role in their lives. This supports the hypothesis that in childhood, when synesthesiae are known to develop (Baron-Cohen et al., 1987; Harrison and Baron-Cohen, 1997), the categories of concepts that are especially prone toward acquiring synesthesia are those that play an important role for the child at that time. Synesthesia may develop most easily for the concepts that these children spend most time with and that are the predominant cognitive contents during learning and play. Therefore, no a-priori reason may exist to exclude any concept from being a possible inducer of synesthetic experiences. The main factor may be the frequency with which this concept is being used. Typically, inducers are cultural artefacts, that is, stimuli such as numerals, letters and words that are acquired after extensive experience. In contrast, concurrents represent more natural categories that are "just there" in the outside world and which can be comprehended without cultural education (cf., Rothen et al., 2010). However, it is unclear whether a "critical" period exists during which, for example, a child may be most prone for acquiring synesthetic associations and which may explain the high occurrence of grapheme-color synesthesia in synesthetic population (Cytowic and Wood, 1982; Sagiv and Ward, 2006; Rich et al., 2005). The time at which children are intensively busy with learning to write may coincide well with the time at which they are most susceptible toward developing synesthetic associations. Also, reports of acquiring synesthesia in adult age are rare. However, contrary to this hypothesis, we have shown recently that adult synesthetes can transfer synesthetic associations to novel inducers (Mroczko et al., 2009), suggesting that synesthesia is not fixed and, with an appropriate set of experiences, can be affected also in adult age. Moreover, adult non-synesthetes can be trained to acquire at least the behavioral consequences of synesthesia–although not necessarily the experiential ones (Meier and Rothen, 2009).

These results suggest that the induction of synesthetic experiences may be mediated by the activation of the conceptual representations of the perceived events. This implies that, in synesthesia, no principal difference may exist between observations of various forms of activities and them being enacted, be it a simple touch or a more complex activity such as swimming. In either case, the respective concepts may be activated first, the corresponding sensation being then recalled from memory. Our cognitive apparatus, in which semantic operations play a central role (Mausfeld, 2002), should have the full capacity of activating and manipulating synesthesia-inducing concepts much like it does for any other concepts. Such synesthesia founded on conceptual processing, that is, *ideaesthesia*, should exhibit in principle an unlimited flexibility in the choice of the potential inducers. Under particular circumstances any set of concepts may become inducers, no matter how specific or unusual they may seem from the perspective of the "low-level" (i.e., sensory) hypothesis of the nature of synesthesia. For the "high-level" hypothesis a sound or a smell is as much legitimate as an inducer as is swimming style, mirror-touch, or any other even more abstract concept (e.g., freedom, quark, or travel-to-the-moon) as long as it has been used and experienced by these individuals in the right way and at the right time.

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