**Patrolling the boundaries of synaesthesia: A critical appraisal of transient and artificially-acquired forms of synaesthetic experiences[[1]](#footnote-1)**

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**Abstract**

Synaesthesiais a neurological condition in which people make unusual associations between various sensations. In recent years, a number of non-developmental cases, including posthypnotic suggestion, drug-use, flavor perception, and use of sensory substitution devices have been linked or directly associated to the emergence of particular types of synaesthetic experiences. Our aim in this chapter is to investigate the extent to which the abovementioned borderline cases can be counted as genuine synesthetic experiences. To do so, we first discuss a number of criteria (i.e., inducer-concurrent pairing, idiosyncrasy, consistency over time, and automaticity of the process) that has been taken as definitional aspects of the condition. We subsequently investigate whether those non-developmental cases fulfill these criteria. Drawing on the lessons learned from the analysis of the borderline cases; we finally highlight the implications of their inclusion on the unity or plurality of the condition.

**1. Synaesthesia: An introduction**

The first documented case of synaesthesia dates back to 1812 when Georg Sachs, an Austrian doctor, submitted within his doctoral dissertation an account of himself as synaesthete, giving detailed explanations of color perception for both numbers and letters (for an English translation of Sachs’ report, see Jewanski et al., 2009). After Sachs’ pioneering account, it took synaesthesia almost 70 years to enter mainstream science, and to be recognized as a genuine phenomenon of scientific relevance (Chabalier, 1864; Galton, 1880; Nussbaumer, 1873). By the end of the 1890s synaesthesia had nevertheless achieved a fully-fledged scientific status, and its study had acquired a strong medical character (see Jewanski et al., 2011; Ward, 2013, for an in-depth historical analysis of synaesthesia).

The beginning of the twentieth century however took the study of synaesthesia far away from its earlier scientific tradition. With the emergence of expressionism and abstract art (Kandinsky and his synaesthetic paintings), dodecaphony in music (Vladimir Rossine, 1916), and futurism in literature (Marinetti, 1911) the term gradually but progressively became to be associated with these artistic movements. Consequently, synaesthesia began to be studied more as a cultural metaphor for the expression of intersensory correspondence than as a biological, psychological, and medical phenomenon deeply and profoundly rooted in scientific practice. With the emergence of behaviorism in psychology (e.g., Skinner, 1938; Watson, 1930), the fate of research on synaesthesia changed again. Synaesthesia lost its surrealistic aura, its magical appeal, and ceased to puzzle psychologists, who started seeing it as nothing more than a learned association (see Howells, 1944), a rather trivial phenomenon of dubious scientific importance.

In recent decades however (especially since the late eighties), with the advent of cognitive neuroscience, synaesthesia has experienced a tremendous resurgence of interest (e.g., Baron-Cohen, 1997; Steven & Blakemore, 2004; Hubbard & Ramachandran, 2005; Rouw et al., 2011; Ward, 2013). This major modern revival has provided a new platform for a broad range of interdisciplinary collaborations (between neuroscientists, psychologists, and philosophers), that are now trying to better understand the neurological and psychological mechanisms underlying this peculiar form of experiencing the world. Even though this resurgence of interest has triggered important improvements in our general understanding of the phenomenon, bringing to light many new important findings, we still know very little about the neurological causes of synaesthesia and about the way it develops and progresses.

Synaesthesiais a condition in which people make unusual associations between various sensations. The stimulus triggering the unusual association can be sensory (such as a printed 2, e.g., see Grossenbacher & Lovelace, 2001), conceptual (such as the result of an arithmetic operation, e.g., see Dixon et al., 2000) or emotional (e.g., Ward, 2004). Such stimuli give rise to so-called canonical or developmental forms of synaesthesia, which are either innate or developed early in infancy (e.g., Baron-Cohen, 1996; Maurer, 1993) and remain constant throughout the lifetime. In recent years however, a number of non-developmental cases, including posthypnotic suggestion (e.g., Cohen Kadosh et al., 2009), drug habits (e.g., Friedrichs, 2009; Shanon, 2002), flavor perception (e.g., Stevenson & Boakes, 2004), and use of sensory substitution devices (e.g., Farina, 2013; Proulx & Stoerig, 2006; Ward & Meijer, 2010), have been linked or directly associated to the emergence of particular types of synaesthetic experiences. These borderline cases have been associated with cases of proper synaesthesia because they either induce some form of conscious, concurrent experience or show patterns of cross-modal interference that characterize canonical cases of synaesthesia (such as the Stroop interference effect, e.g. Mills et al., 1999; see Eagleman et al., 2007, for a review of the existing tests). Our purpose in this chapter is to investigate conceptually whether it is possible to count the abovementioned borderline cases as genuine synesthetic experiences.

In section 2, we provide a number of definitions of synaesthesia in terms of its core definitional aspects (e.g., inducer-concurrent pairing, idiosyncrasy, consistency over time, and automaticity). The analysis of these criteria helps us in setting the benchmark for what it ought to be counted as proper synaesthesia and therefore allows us to explore theoretically the question of whether borderline cases can be explained in light of these definitions. Having introduced such criteria, we then turn, in section 3, to the empirical analysis of two temporary forms of synaesthesia: those induced by post-hypnotic suggestion and drug-use. We review evidence for these cases and discuss whether it is appropriate to treat them as genuine forms of the condition. In section 4, we analyze two alleged forms of learned synaesthesia. We first address the case of flavor perception, where certain odor-taste interactions have been claimed to correspond to a learned synaesthesia that would be common to us all (e.g., Stevenson & Boakes, 2004). We then turn to sensory substitution, tackling the idea of artificially-acquired synaesthesia. We report preliminary evidence for this claim (Proulx & Stoerig, 2006; Ward & Meijer, 2010, Farina, 2013; Ward & Wright, 2013) and then critically discuss it. In section 5, drawing on the lessons learned from the analysis of transient and acquired cases of synaesthesia, we highlight the implications of their inclusion on the unity or plurality of the condition (e.g., Terhune & Cohen Kadosh, 2012). Counting such a wide range of phenomena as genuine synaesthetic experiences does indeed raise the question of whether it still makes sense to describe synaesthesia as a unitary event or whether we should interpret it as an umbrella term that encompasses several different domains with independent probabilities of expression.

**2. Definitions of synaesthesia**

Synaesthesia is a condition in which “stimulation in one sensory or cognitive stream leads to associated experiences in a second, unstimulated stream” (Hubbard, 2007, p. 193; see also Cytowic, 2003). Synaesthesia is thus normally described as a “startling sensory blending” (Cytowic, 1997, p. 17) “not experienced by most people under comparable conditions” (Grossenbacher & Lovelace, 2001, p. 36). In synaesthesia, in fact, sensory experiences (such as tastes) or concepts (such as numbers) automatically evoke additional percepts, such as colors” (Cohen Kadosh & Walsh, 2006, p. R963). For example, a grapheme-color synaesthete can experience color when reading a digit or a letter. Analogously, a hearing-color synaesthete can see colors when she hears particular sounds (Baron-Cohen et al., 1987), and a lexical-gustatory synaesthete can experience tastes when she hears or reads certain words (Ward & Simner, 2003). Thus, synaesthetic occurrences can be elicited by the visual appearance of a printed item, or by certain sounds, when spoken aloud. In other cases, just thinking about a particular letter, digit, or word can induce color experiences (Dixon et al., 2000; Smilek et al. 2001) and someone can have a synaesthetic experience through the imagination of the meaning of certain words (Rich et al., 2005).

To date, more than 65 different types of synaesthesia have been reported (Day, 2009; see<http://www.daysyn.com/Types-of-Syn.html> for a complete list) each with its own set of triggering stimuli and its correlated synaesthetic occurrences. Because of the intrinsic diversity and complexity of the phenomenon, a comprehensive and universally accepted definition of synaesthesia is yet to be formulated. The broad range of occurrences usually classified as synaesthetic presents a challenge for any researcher who wants to arrive at a shared understanding. Yet, there are four criteria that can be used to get started. We would like to note here that none of these criteria should be taken as being individually necessary. We will argue instead that they are jointly-sufficient, i.e., their joint-combination allows us to distinguish between synesthesia and other related phenomena. This point will be further detailed in the discussion.

First, synaesthesia is characterized by the existence of what Grossenbacher and Lovelace (2001) have called, an inducer-concurrent pairing. The term “inducer”, on their account, refers to the experience of the triggering stimulus that causes the correlated synaesthetic experience to emerge. The term “concurrent” denotes the associations being experienced by the synaesthete. Since this distinction was established in the literature at the onset of the 2000s, every type of synaesthesia is now minimally described in terms of this pairing (see Auvray & Deroy, forthcoming, for an in-depth discussion). This helpful distinction certainly provides a good starting point for a characterization of genuine forms of synaesthesia. However, there is an aspect of the concurrent that seems crucial in addition to its being paired with an inducer: this is the fact that the inducer is always consciously experienced. This requirement is central in many definitions that emphasize that synaesthesia is “a conscious experience of systematically induced sensory attributes” (Grossenbacher & Lovelace, 2001, p. 36). As Deroy and Spence (in press) have recently noted, there are, among others, two related differences between synaesthesia and crossmodal correspondences. First, in the former, the concurrent is necessarily conscious, whereas in the later the crossmodal matching is not. Second, in synaesthesia the concurrent is determined in an *absolute* way (i.e., a particular sound associated to a shape), in cross-modal correspondences it functions in a *relative* way (a higher-pitched sound associated to a higher position in space, e.g., see Marks, 1987; Pedley & Harper, 1959). These two differences are directly linked as we are more conscious of absolute experiences than of relative ones. Thus, the first criterion to define synaesthesia must be the existence of a pairing between an inducer and a *conscious* concurrent.

A second important characteristic of synaesthesia is its relative idiosyncrasy. It has often been emphasized that in synaesthesia, the induced sensory attributes “are *not experienced* by most people under comparable conditions” (Grossenbacher & Lovelace, 2001, p. 36). In addition, there is not always a one to one correspondence between one type of concurrent and one type of inducer. For instance D. reports having the experience of a “pretty yellow green” when she hears a B2 and of a “dirty yellow-green” when hearing a D# (Ortmann, 1933). Another synesthete can nevertheless experience the contrary without anyone being entitled to question his synaesthetic associations. The possibility of generalization has also been investigated with letters; where As tend to be mainly seen as red and Bs as blue (Simner et al., 2005). Yet, genuine synaesthetes can have very different associations (such as seeing a green A). Thus, even if certain regularities or tendencies can be observed, the inducer-concurrent pairing cannot be reduced to a learned association between regularities to which people have been exposed (Hubbard & Ramachandran, 2003). Rather, the set of observed concurrent pairings is broad and varies, even within a same family and between twins (Barnett et al., 2008). The atypical character of synaesthetic experiences thus seems to be another important aspect of synaesthetic occurrences.

A third important feature of synaesthetic experiences is their automaticity, i.e. the fact that the concurrent is experienced as an inevitable and involuntary consequence of the synaesthete coming across a specific inducer. The automaticity criterion has been extensively used in experimental tests (such as with a variant of the Stroop task, e.g., Dixon et al., 2000). For example, a person with grapheme-color synaesthesia should be able to determine unequivocally and automatically what color certain letters trigger in her mind. If the person needs mental effort or extra time to recall the colors she previously attributed to those letters, then she is most likely not a synaesthete and she is probably associating the two experiences at another level (e.g., semantic associations). It should be noted that in synesthesia, the automaticity at stake is not pre-attentional. It is only after the inducer has been attended that the concurrent is elicited (e.g., see Sagiv et al., 2006; Deroy & Spence, 2013a). Nonetheless, the concurrent is elicited without voluntary control, and it cannot be recalled or dismissed at will. In recent years, a number of functional neuroimaging studies have further highlighted the automaticity of synaesthesia (MacLeod & Dunbar 1988; Nunn et al., 2002) and its crucial role in processes of attention, saliency, perceptual judgment, and awareness (for an interesting discussion of this topic see Mattingley, 2009). For all these reasons, the automaticity criterion has become increasingly important in the characterization of synaesthetic experiences and we include it in ours.

A fourth crucial condition is consistency, which refers to the fact that the same inducer always triggers the same concurrent. To give an example, if the letter ‘b’ is perceived by the synaesthete as green, that letter should be consistently perceived as green even if the synaesthete is asked about it on multiple occasions over the course of her lifetime. In many articles in the contemporary literature, consistency has been described as the most fundamental characteristic of synaesthesia (Brang & Ramachandran, 2010; Ward et al., 2010) and the test of consistency has come to be referred as the behavioral ‘gold standard’ for determining the authenticity of the condition (Rich et al., 2005). Synaesthetes are in fact normally included in empirical studies only after having passed the consistency test (Baron-Cohen et al., 1987), in which they first have to provide a set of their synaesthetic associations and then, after a considerably long period of time (e.g., after 6 months; Ward and Simner, 2003), they are given a surprise retest. The consistency between their initial and re-tested scores is compared to a control group of non-synaesthetes. This control group is requested to invent analogous associations and recall them by memory alone in a shorter period of time (e.g., 2 weeks, Ward and Simner, 2003). Only those synaesthetes who clearly outperform control participants are considered as genuine synesthetes, and therefore assessed by means of further studies (Ward & Simner, 2003). Typically, only one in six people who initially report synaesthesia are ultimately classified as synaesthetes (Simner, Glover, et al., 2006; Simner, Mulvenna, et al., 2006). While this rigorous approach seems to be effective to identify genuine cases of synaesthesia, it has been recently questioned for its circularity and somewhat biased nature (for more details see Proulx and Stoerig, 2006; Rich & Mattingley, forthcoming; Simner, 2012).

What should we make of those people who fail the consistency test but still report having synaesthetic experiences? There are, at least, two possibilities here; the first one is to consider that those persons are intentionally misreporting or inventing experiences they do not have. The second possibility is to acknowledge that they could also be genuine synaesthetes, and that they possess a type of synaesthesia that is not fully captured by the consistency requirement. If we accept the second possibility, we must consider “whether synaesthesia is truly consistent over time as a definitional criterion, or whether, instead, consistency over time merely characterizes a subset of synaesthetes only” (Simner 2012, p.7). To date there is no hard evidence available to settle this question. If anything the opposite is true and many researchers have begun investigating the relevance of consistency, highlighting its potential circularity (Eagleman, 2009; Rich & Mattingley, forthcoming; Simner 2012). They pointed out that almost all synaesthetes reported in the literature are synaesthetes who display consistency, but this is due to the fact that these synaesthetes have been recruited for empirical studies on the basis of the consistency criterion. This was the test used for defining what ought to be counted as proper synaesthesia. Thus, there is theoretical room for arguing that the consistency criterion ends up being circular. Given this possibility, rather than seeing the requirement of consistency as a gold standard to assess the significance of any synaesthetic experience, we would like to call for a more careful and prudent assessment of its role in defining synaesthesia. Consequently, while we believe that consistency (when complemented by inducer-concurrent pairing, idiosyncrasy and automaticity) can offer a pretty reliable tool for singling out proper forms of synaesthesia; our characterization of the condition is not bounded to it, and rather envisages the need to complement consistency with other hallmark traits.

It is worth mentioning here that there are several other features that have been considered as definitional aspects of synaesthesia, but we have not included them as jointly-sufficient requirements, either because they can be considered as consequences of other criteria or because they do not seem to be applicable to the vast majority of the standard cases. In what follows we briefly discuss spatial extension and affect. Some researchers (e.g., Eagleman & Cytowic, 2009) have argued that spatial extension qualifies as a defining aspect of synaesthesia. According to these authors the synaesthetic occurrence experienced by the synaesthete is perceived as being localized in the world. This requirement however remains highly controversial as certain synaesthetes do experience the concurrent as being external; however, others experience it in an internal space (for an in-depth analysis of the divide between associators and projectors, see Dixon et al., 2004). Note that the argument of spatial extension would not hold for the inducer either as it need not always be spatially extended for the synaesthetic percept to arise. Indeed some people do have synaesthetic experiences by simply imagining the meaning of words. We therefore believe that the requirement of spatial extension is not a defining character of any synaesthetic occurrence. Cytowic (1997) has also argued that synaesthesia is always affect laden. We believe that not all forms of synaesthesia manifest this feature. For instance, it is unlikely that spatial sequence synaesthesia - where people see all numerical sequences they come across as points in space - is necessarily affect laden. Hence, we believe that the requirement of being affect laden is not strictly necessary for genuine forms of synaesthesia and therefore we did not take it as a definitional aspect of the condition.

In summary, there are four fundamental criteria that we believe are jointly sufficient for individuating genuine forms of synaesthesia. These are: 1. the existence of pairing between an inducer and a conscious concurrent; 2. the relative idiosyncrasy of the pairings; 3. the automaticity of the process; 4. the consistency of the occurrence over time. In recent years, a number of researchers have hypothesized that synaesthesia can also be experienced in a more or less intermittent way and that it can be acquired. It has indeed been suggested that synaesthesia-like experiences can be induced by post-hypnotic suggestions (e.g., Kadosh et al., 2009), drug-use (e.g., Friedrichs, 2009; Shanon, 2002), flavor perception (e.g., Stevenson and Boakes, 2004), and extensive training with sensory substitution devices (e.g., Farina, 2013; Proulx & Stoerig, 2006; Ward & Wright, 2013; Ward & Meijer, 2010). In the next two sections we turn to these cases and assess whether they count as examples of synaesthesia in the light of the conditions we have just identified.

**3. Transient forms of synesthetic experiences: post-hypnotic suggestion and drugs-use
3.1. Synesthetic experiences triggered by post-hypnotic suggestion**

Post-hypnotic suggestion has been used to trigger synaesthetic-type experiences. During post-hypnotic suggestion, the experimenter administers suggestions to their participants which consist in verbal statements that are intended to trigger various kinds of responses, i.e., affective, cognitive, or motor. It is worth noting here that this method works well only with highly suggestible persons, which comprise approximately 10-15 % of the total population tested (see Laurence, Beaulieu-Prévost, & du Chéné, 2008; see also Terhune et al. this volume). Consequently, only this subset of people was involved in the studies described below.

In one study by Cohen Kadosh et al. (2009), four highly suggestible non-synaesthetes were hypnotized and instructed to associate six digit-colors pairs. These participants were subsequently presented with black inked digits on a colored background and asked to detect the grapheme presented. The background could be in a color that is congruent with the one associated with the grapheme (e.g., if the N is perceived as yellow, a black N on a yellow background) or it could be inconsistent with it (e.g., a black N on a blue background). The participants displayed the same pattern of responses as congenital synaesthetes (as reported in Smilek et al., 2001, for instance); that is, they made more errors in the congruent condition than in the incongruent one. There was no such difference in the control group. These results suggest a form of automaticity in the associations. But did the participants show consistency? Only two participants in the study were re-tested; immediately after the experiment took place and then again one week after it. These two participants, unlike two control ones, displayed a consistency effect in the sense that they made more errors in the congruent condition than in the incongruent one.

[Terhune and Cohen Kadosh (2012)](#_ENREF_93) investigated whether a post-hypnotically induced synesthesia would display, as with its congenital counterpart, a divide between projectors (the concurrent is experienced as being located externally) and associators (the concurrent is experienced mentally, i.e., as being located in the mind’s eyes). Terhune and Cohen Kadosh first differenciated the participants who were responsive to hypnotic suggestions for either associator or projector grapheme-color synaesthesia. They subsequently administered posthypnotic suggestions to associate four numbers with four colors and to experience the colors as either being spatially co-localized with graphemes (for the subgroup of projectors) or as mental images (for the subgroup of associators). The participants then underwent two versions of the Stroop color-naming task. One in which they had to name the colors *of* the digits and one in which they had to name the color *associated* with the digit. Researchers found similar results to those previously obtained with congenital synaesthetes (e.g., Dixon et al., 2004): projectors had larger congruency effects (i.e, faster responses for graphemes in the same color as that used for this pairing during the post-hypnotic suggestion than for graphemes in a different color) than associators in the first experimental conditions and there was no difference between the two in the second condition. Phenomenologically, participants reported an involuntary and vivid character of the induced color during the Stroop task, as congenital synaesthetes do.

It should be mentioned that, so far, there are no studies conducted on the neural mechanisms underlying post-hypnotically induced synaesthesia. Terhune (this volume) argues that the very possibility of inducing synaesthesia with post-hypnotic suggestion is at odds with the theory of greater anatomical connectivity. Indeed, it is highly unlikely that a corresponding hyper connectivity could be induced in such a short amount of time, i.e., the few minutes of hypnotic suggestions. Post-hypnotic suggestion does seem sufficient to elicit similar behavioral and phenomenological markers as are found in congenital synaesthesia. More precisely, it appears to be sufficient to produce a pairing between an inducer and a concurrent. It should however be noted that a much debated question in the literature concerns the extent to which a conscious status can be achieved in cases of post-hypnotic suggestion (Cohen Kadosh et al., 2009). In addition, in the current state of data, it can be equally argued that, rather than having the experience of synaesthetic concurrents, the participants engage in a vivid form of mental imagery (see Deroy & Spence, 2013a, see also Spence & Deroy, 2013b for an analysis of the difference between mental imagery and synesthesia). Thus, further empirical investigation is needed to confirm the possibility of post-hypnotically elicited conscious concurrents. With respect to the second criterion of our characterization, the obtained pairing seems relatively idiosyncratic, as reflected by individual differences. Behavioral tests also suggest a high degree of automaticity in the process. The consistency criterion needs further empirical testing, as only two participants in Cohen Kadosh, et al.’s (2009) showed a positive result.

**3.2. Drug-induced synaesthesia**

Administration of pharmacological agents has long been used to induce abnormal crossmodal experiences that can be thought of as resembling synaesthetic experiences. Notable cases involve the use of mescaline (Ellis, 1898), LSD (Hofmann, 1983), and psilocybin (Luke et al., 2012; Wasson, 1978). It is hypothesized that these pharmacological agents trigger synaesthetic experiences over short periods of time and can potentially work with a great number of people (around 60% see Luke, et al., 2012; Tart, 1975), as opposed to post-hypnotic suggestion that is effective only with highly suggestible individuals.

Despite these potentialities, only a few early studies (Hartman & Hollister, 1963; Simpson & McKellar, 1955) investigated the possibility of triggering synaesthetic experiences through drug use, mostly because this kind of research started to be prohibited in the sixties. In one of these studies two congenital synaesthetes and two controls, (the two authors of the article) reported their synaesthetic impressions after ingestion of mescaline when presented with a range of possible inducers (Simpson & McKellar, 1955). The participants reported eight different types of synaesthetic experiences that for the synaesthetes were not the variant they previously possessed. This study therefore suggests the possibility of inducing synaesthetic experiences in non-synaesthetes and of triggering novel synaesthetic experiences in synaesthetes. In a similar vein, another early study by Hartman and Hollister (1963) showed that, when the 18 participants involved in the experiment were presented with different sounds, they experienced more visual concurrents (colors, brightening of the visual field, and other visual effects) when they were under the influence of LSD and mescaline than when they were not.

Other studies have used questionnaires and surveys to ascertain the possibility of drug-induced synaesthesia. Most of these surveys and questionnaires were however part of other studies investigating different topics and were only subsequently used for understanding the phenomenon of drug-induced synaesthesia. These surveys nevertheless revealed that synaesthetic experiences can be obtained with a broad set of different substances (that will not be further described here; the interested reader can consult Luke et al., 2012, for a review) and that they elicited a broad range of inducer-concurrent associations, with a greater variability in the inducer than in the concurrent. With regard to the former, although sounds are the most frequently reported, tactile, gustatory, olfactory, and pain also act as inducers (Leuner, 1962; Shanon, 2002). As for the latter, the most common concurrents are visual and can consist in abstract geometric imagery or more complex scenes (Friedrichs, 2009; Grof, 1975; Leuner, 1962; Siegel, 1975).

From the results mentioned above it seems possible to produce an inducer-concurrent pairing through drug use. These pairings can be consciously reported, although - as was noted by Hubbard and Ramachandran (2003) - there is a difficulty in identifying experiences that are produced by drug use. With respect to the pairing itself, Sinke et al. (2012), building on previous results by Mayer-Gross (1931), notice that the inducer and concurrents are experienced as an integrated unified entity. The experience can be so confusing in certain individuals that some people might even find it difficult to describe the modalities in which the stimuli occur. Thus, the inducer and concurrent seems to be experienced as less demarcated than in congenital synaesthesia. In addition, it should be mentioned that no studies conducted so far has investigated whether or not the experience is genuinely perceptual as opposed to a mere vivid association (Aghajanian & Marek, 1999).

The studies we have revealed found variability among the inducer-concurrent pairing across people, satisfying the idiosyncrasy criterion. However, so far, no work has yet investigated systematically and experimentally automaticity in drug usage (see also Terhune, this volume). Sinke et al. (2012) suggest, based on previous verbal reports, that the experience of a synesthetic concurrent is not necessarily triggered, which raises doubts on the fact that the automaticity criterion can be fulfilled. Indeed, sometimes, under drugs, one inducer can elicit a synaesthetic concurrent; however, in other occasions, the same inducer does not elicit anything (Studerus, Kometer, Hasler, & Vollenweider, 2010). Furthermore, even in cases of experienced synaesthesia, a stimulus does not always elicit its expected concurrent (Delay, Gérad, & Racamier, 1951; Leuner, 1962; Masters & Houston, 1966). For example, when a synaesthete perceives a letter (e.g., A), she always experience it with the same colour (e.g., red). In drug induced synaesthesia, one person can sometimes experience one letter (an A) as red and sometimes perceive the same letter with no color.

Consistency is also very problematic: preliminary research by Brang and Ramachandran (2008) suggested that pairings obtained through drugs could be consistent. Using a texture segregation test, Brang and Ramachandran in fact showed that one grapheme-colour synaesthetic experience could be consistent. On the other hand, Sinke et al. (2012), referring to an old study by Beringer (1927) investigating mescaline-induced synaesthetic experiences, claims that experience was not consistent. According to Sinke et al. (2012), there are no consistent inducer-concurrent couplings. For instance, the same tone might be red, but when repeated, it may be experienced as another color, and it can even be translated into another sensory modality. The authors nonetheless emphasize the possibility that some stimuli that are considered to be more associative may produce more consistent pairings. In this case they would display lower intra-personal and inter-personal variance; in our terminology, they would better satisfy the consistency criterion while counting as weaker cases of idiosyncrasy. In summary, there is no wide agreement on whether the synaesthetic experiences obtained through pharmacological agents satisfy the consistency and automaticity criteria.

**4. Acquired synaesthesia: flavor perception and use of sensory substitution**

We now turn to forms of synaesthesia that are induced less intermittently, i.e. the case of acquired synaesthesia. We first address the case of flavor perception and then turn to sensory substitution.

**4.1. Flavor perception**

Recent psychophysical research on flavor perception has investigated the possibility of odors eliciting changes in the perceived sweetness (i.e., taste) of liquid solutions (e.g., Stevenson, Prescott, & Boakes, 1999). This phenomenon, known as sweetness enhancement, led Stevenson and Boakes (2004; see also Stevenson & Tomiczek, 2007) to suggest that odors can induce a synaesthetic experience of taste that is common to us all.

Sweetness enhancement consists in adding ‘sweet’ odors, which have no taste (they cannot be detected by the taste receptors) as flavorings to solutions. When participants have to taste such solutions, they perceive them as being sweeter than the same solution deprived of the added odors (Cliff & Noble,1990; Frank & Byram, 1988; Frank, Shaffer, & Smith, 1991; Schifferstein& Verlegh, 1996). For example, when caramel odor is added to a sucrose solution, the taste of the resulting mixture is perceived as being sweeter than the pure sucrose solution if tasted alone. It should be mentioned that the odors that typically induce sweet tastes appear to be related to previous instances of co-exposure with a sweet taste, such as might naturally occur during eating (e.g., Prescott, 2004; Stevenson & Boakes, 1995; Stevenson, Boakes, & Prescott, 1998). For example, the odors of vanilla, caramel, strawberry, and mint induce sweetness enhancement in western countries where people often experience those odors with sucrose. On the other hand, non-western participants do not describe some of these odors as sweet, probably due to a less frequent pairing of these odors with sweetness in their food culture (Nguyen, Valentin, Ly, Chrea, & Sauvageot, 2002). The modifications of the attribution of taste qualities to odors can also be obtained in laboratory settings, thanks to the repeated pairing of novel odors with a particular tastant. For example, novel odors (such as lychee or water chestnut) repeatedly paired with sucrose are later reported to be sweeter than their initial ratings (Stevenson et al., 1995, 1998; Yeomans & Mobini, 2006; Yeomans et al., 2006). Similarly, novel odors are reported to be sourer than their initial ratings if they are repeatedly paired with citric acid (Stevenson, Boakes, & Wilson, 2000a, 2000b), or more bitter, if paired with bitter tastes such as sucrose octa-acetate (Yeomans et al., 2006; for the difficulty of distinguishing between tastes and flavors, see Spence et al., forthcoming).

The idea that odors can induce a synaesthetic experience of taste that is common to us all (Stevenson & Boakes, 2004; Stevenson & Tomiczek, 2007) could be central to the field of synaesthesia. Indeed, if it was possible to acquire synaesthetic experiences through repeated co-exposure to stimuli, this would provide an excellent model system for the study of synaesthesia, as every one of us experiences flavor. We believe however that two main arguments question the appropriateness of considering flavor perception as a ubiquitous example of synaesthetic experience between the senses of smell and taste. First, sweetness enhancement does not fulfill the second criterion, idiosyncrasy, as the addition of the same flavorants give rise to the same effect within a given culture (e.g., mint increases the perception of sweetness in all Westerners) or, in laboratory settings, through the same repeated pairings.

In addition, there are reasons to believe that sweetness enhancement does not satisfy our first criterion either, i.e., the existence of distinct inducer and consciously perceived concurrent. In particular, it has been shown that the results depend on the task given to the participants: the adoption of an analytic versus synthetic approach to the perception of flavor strongly influences the extent to which odor-taste integration is observed. Indeed, on the one hand, when the participants are encouraged to adopt a strategy of analyzing the individual elementsin the mixtures, this results in a decrease in sweetness enhancement (Prescott, Johnstone, & Francis, 2004). On the other hand, it is when the participants are encouraged to adopt a synthetic approach, by being required to attend only to the overall flavor intensity, that a sweetness enhancement effect is obtained. However, it can then be argued that, in this later case, attending only to the overall percept does not allow disentangling the relative contributions of the senses of taste and smell to the overall flavor. In other words, it encourages the blurring of the senses of taste and smell. In summary, in this case the stimuli in the two sensory modalities are not both consciously perceived at the same time (rather it is the synthesis of the two that is attended to); thus this does not count as inducer-concurrent pairings. In addition, a study by Frank, van der Klaauw, and Schifferstein (1993) has shown that sweetness enhancement crucially depends on the responses allowed to participants. Their study revealed that the sweetness enhancement of a sucrose solution that can be elicited by adding strawberry odor only occurs when the participants are asked to rate sweetness, and nothing else. However, when they are also asked to judge other qualities, such as sweetness, saltiness, sourness, and bitterness, the sweetness enhancement effect disappears. In summary, if the occurrence of sweetness enhancement is a function of the task requirements, this would undermine the very idea of a learned synaesthesia between the senses of taste and smell.

It should be mentioned that the same line of reasoning applies to other cases in the field of flavor where other types of interactions could be, at a first glance, similarly interpreted as a synaesthetic experience. But it will turn out that mostly, what is obtained is not an additional and distinct perceptual experience, but rather the replacement of one sensory experience by another. For example, in a study by Davidson and colleagues (1999), participants had to continuously rate the perceived intensity of flavor in their mouths while chewing a piece of mint-flavored gum. The taste of the mint-flavored gum comes from the sugar contained in it, while the menthol gives rise to the olfactory and trigeminal components. The perceived intensity of the menthol odor was shown to increase very rapidly when people initially started to chew the gum. Then, while the actual intensity of the menthol odor stayed fairly constant over the course of 4-5 minutes of chewing, its perceived intensity declined rapidly (tracking the decline in the sugar taste in the mouth), and could only be brought back up again by the release of additional sugar (i.e., by the addition of a tastant which has no smell). Davidson et al.’s results therefore show that people’s perception of the intensity of the menthol flavor was actually being driven by the release of sugar in their mouths (and detected on their tongues). But in this case, the participants should not be considered as having a synaesthetic experience either because what they perceived was not the original sensory impression (that of sweetness) plus the individuated sensory impression of menthol odor, but instead one sensory impression replaced the other. In other words, in this case, the sensory impression of sweetness was replaced by the sensory impression of the menthol odor and not added to it.

To conclude, sweetness enhancement (along with other phenomena in the field of flavor) surely is, once acquired, consistent over time, thus fulfilling our fourth criterion. The third one, automaticity of the process, however, remains controversial. Furthermore, sweetness enhancement does not satisfy the first one criterion (i.e., inducer-concurrent pairing) in that it does not involve distinct concurrents and inducers that are consciously perceived at the same time. In addition, it does not involve idiosyncrasy, at least intra-culturally.

**4.2. Sensory substitution**

Sensory substitution devices (SSDs) aim at replacing the functions of an impaired sensory modality (e.g. sight) by providing the environmental information normally gathered by another sensory modality (e.g. touch or audition). To do so, these systems typically convert visual images, obtained through a video camera, into patterns of either auditory (e.g., the vOICe see Meijer, 1992; Vibe see Hanneton et al., 2010) or tactile (e.g., the Tongue Display Unit, see Bach-y-Rita & Kercel, 2003) stimulation. The translation code for visual-to-tactile devices is analogical; for instance a visual circle is translated into a circular pattern of tactile stimuli. The code used in visual-to-auditory devices translates several dimensions of the visual signal into dimensions of the auditory signal. For instance, the vOICe translates vertical position into frequency, horizontal position into time scanning, and visual brightness into auditory loudness. Through training with sensory substitution devices, users gradually develop the ability to perform localization tasks (e.g., Levy-Tzedek et al., 2012; Proulx et al., 2008; Renier et al., 2005) and simple form, as well as complex shapes recognition (e.g., Arno et al., 2001; Auvray et al., 2007; Pollok et al., 2005; see also Auvray & Myin, 2008; Kiverstein et al., forthcoming, for reviews).

Proulx and Stoerig (2006) speculated that the long-term use of sensory substitution devices may induce, in practiced users, the emergence of forms of synaesthesia (for an analogous claim see also Farina, 2013; Proulx, 2010, Renier & De Volder, 2013; Ward & Wright, 2013). Ward & Meijer (2010) defended this view based on the phenomenological reports gathered on two persons who became blind later in life and have been using the vOICe for more than 10 years. One of these practiced users (PF) describes her experiences as analogous to a form of:

*“*Monochrome artificially induced synaesthesia only in certain frequencies of sound. It is almost as if you had a computer with two monitors running simultaneously different pictures, one was a very grey blurred version of the real world, and the other was a pure grey background with a big semi-circular light grey arc on it, and sometimes you switched your attention between both” (Ward & Meijer, 2010, pp. 497-498).

PF also affirms that the sounds generated by the device elicited visual experiences, caused forms of depth perception to emerge and even triggered the experience of colors (Ward & Meijer 2010, p. 497). Another interesting thing that PF reported was that her experiences of images, color or motion when hearing sounds do not change as a function of other parameters such as her mood, the time or environmental factors. This has been taken to suggest a form of consistency of her “synaesthetic percepts” over time (quoted in Ward & Meijer 2010, p. 498).

Is the claim that SSD-use is comparable to the synaesthetic experiences enjoyed by colored-hearing synaesthetes (e.g., Ward & Meijer, 2010; Ward & Wright, 2013) tenable? To answer this question we need to be specific and carefully define the level of users’ experience and the different processes that are involved in SSD-use. This has not been done clearly so far. In SSD-use there is the information that is provided to the users in their intact sensory modality (audition in the case of visual-to-auditory devices), which we label here as the “substituting information”. This information corresponds to the conversion of a signal from another sensory modality (i.e., vision in the case of visual-to-auditory sensory substitution devices), which we define as the “substituted information”. The substituted information can be understood at the level of information processing; that is, it can be inferred from the substituting information and the knowledge of the translation code (e.g., understanding that there is a visual diagonal line from a sound increasing in pitch). Note that this also involves specific knowledge of our movements. For instance the distance of an object, although not given by the translation code, can be deduced from triangulation, i.e., two points of view on the object. Then, there could be a phenomenology associated with the process of perceiving, that we will label “associated phenomenology”. This corresponds to phosphenes or impressions of colors that blind persons reported while using the device, and can be considered as an ‘extra’, an addition to the level of pure information processing. The associated phenomenology thus does not necessarily follow from the translation code but is joined to the sensory occurrence experienced through the coupling with the device.

When researchers argue that SSD-use is a form of acquired synaesthesia, they identify the inducer with the substituting information. The concurrent is linked to either the substituted information or to the associated phenomenology. There is therefore a trap into which one can easily fall by confusing these two levels. In what remains of this section we will disentangle the two claims and will analyze them separately to establish the extent to which each of them fulfills the four criteria for genuine forms of synaesthesia that we listed in section 2[[2]](#footnote-2). Note, a potential difficulty comes from the fact that there are many results gathered at the level of information processing, whereas the claims on the associated phenomenology are based only on the verbal reports from two late blind persons.

The first criterion we discussed for identifying genuine forms of synaesthesia is the existence of a pairing between an inducer and a conscious concurrent. This involves that both the inducer and the concurrent are consciously perceived at the same time; and thereby that it is not the case that, in trained users, access to the substituting information fades away (as was claimed for instance by O’Regan & Noë (2001). Ward and Wright (2013) defend the first alternative while acknowledging that there are actually no data to confirm or disconfirm this point. What can be said for now is that, if the concurrent is the substituted information only additional data will shed light on the question of whether or not, after training, both the inducer and the concurrent are consciously perceived at the same time. Similarly, if the concurrent is the associated phenomenology, more data is clearly needed. Let’s just note here that many of the claims equating SSD-use and synaesthesia re-occurring in the literature mention the verbal report from one of the two participants in Ward and Meijer’s (2010) study who describes her experiences as analogous to a form of “monochrome artificially induced synaesthesia” (see the complete quote at the beginning of the section). However, while she describes her experience as being akin to synaesthesia her report underlines that she switched her attention between the different impressions that the sounds give rise to her, which is at odds with congenital synesthetic experiences.

The second criterion that we listed for characterizing proper forms of synaesthesia is idiosyncrasy. This involves two levels: first that synaesthetes have an experience that is additional to what the rest of the population experiences; second that this additional experience greatly differs among them. While saying that SSD-users have an experience that is not shared with non-users is not problematic; saying that this experience differs among users proves to be far more controversial. Here again, let’s dissociate the substituted information from the associated phenomenology. With respect to the former there is nothing idiosyncratic about the users’ experience. This is obvious from the fact that SSDs are based on a determined translation code, which is the same for each user. Given specific visual information recorded by the camera, this information will be translated into an auditory one in the same way. Thus, for a given visual image every user will obtain the same auditory information. From that information, users are then given the same possibility to have experiences of shapes, size and so on with the device. The extent to which they do reach these abilities then only depends on the amount of training they had. But here there is no qualitative difference between them, only quantitative ones correlated with training. With respect to the associated phenomenology, there is again a crucial lack of data to confirm idiosyncrasy, as only two persons reported some forms of colors and light. One important thing we would like to emphasize is that any supposed idiosyncrasy of associated phenomenology would remain very limited (merely colors and light) and it is hard to imagine it reaching the wide set of pairings occurring in congenital synaesthesia.

With respect to the third criterion, there areactually no data to assess if SSD-use becomes automatic or not. It seems that the argument could be problematic in the case of the substituted information. Several authors, such as O’Regan and Noë (2001) have claimed that after training, SSD-use becomes automatic and that at this moment the device and the sensory processing becomes transparent. Similarly, Farina (2013) hypothesized that “after extensive practice, the device gets increasingly transparent, its boundaries progressively fade away, and the perception experienced through the coupling with it becomes involuntary.” (p.652). However, it should be noted that while the experience of the concurrent becomes automatized, the fact that the inducer remains consciously perceived (first criterion) might be lost correspondingly. It thus might be the case that before training the experience lacks automaticity, whereas after training it lacks conscious attention to the inducer. Of course users could regress to the substituting modality but then this could reflect breaks of transparency (thereby losing the automaticity criterion) or an attentional displacement. The question being, in this case would the user still have access to the substituted information? Note that in opposition to this idea that after experience, while the device becomes transparent the inducing modality is lost, Ward and Wright (2013) have argued that it remains a complicated dual experience. These two opposite views remain purely speculative and any scientific claim about automaticity will have to await further empirical investigation (such as Stroop tests run on expert users).

Finally, with respect to the fourth criterion - the consistency of the occurrence over time -there are similarly no data to confirm or disconfirm this position. With regard to the associated phenomenology, there is only one verbal report (an e-mail from PF) that was quoted at the beginning of this section saying that mood, time, and environmental factors do not change the images, color, motion effects she had. Thus, much more evidence is indeed needed to build a case for consistency. With regard for the substituted information, even in lack of data, the argument to say that it fulfills consistency is not very strong: through the same translation code; the same inducer will give rise to the same concurrent. Along the same lines as the first criterion (the presence of an inducer concurrent pairing), it is not hard to see how the consistency criterion is fulfilled exactly to the extent to which it does not fulfill the idiosyncrasy one. The same inducer might give rise to the same concurrent, but this will also be the same for all of the users in a way that negates idiosyncrasy.

To summarize, the aim of this section was to clarify the debate on SSD-use being akin to synaesthesia, by dissociating the substituted information from the associated phenomenology. When considering the associated phenomenology, the genuine existence of a concurrent that would be different from visual imagery is currently lacking empirical support. In addition, this concurrent would not be absolute (as in synaesthesia) but rather relative (for instance the louder, the brighter). The idiosyncrasy of the pairing, although limited to a narrow set, is still an option, and there is currently no substantial evidence for automaticity and consistency; although these cannot be ruled out either. This suggests that the idea that the associated phenomenology involved in SSD-use is a form of artificially induced synaesthesia is not yet scientifically established. It can be either provisionally endorsed, conditional on further scientific evidence (as Farina 2013, suggests), or rejected as scientifically unfounded (as Auvray & Deroy, 2012, have previously argued). When considering the substituted information, there is no problem in considering that the experience is consistent, and the presence of a concurrent is not questionable either. However, the extent to which both the concurrent and the inducer are consciously perceived remains unclear. The question of automaticity remains open, and there cannot be any idiosyncrasy involved. Thus, anyone defending SSD-use at the level of the substituted information will have to give up this last criterion.

**5. Conclusions**

Summary of the analyses

The aim of this chapter was to examine the extent to which alleged cases of transient and acquired forms of synaesthetic experiences can be considered as genuine cases of synaesthesia.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  Criteria Cases | Inducer-concurrent pairing | Idiosyncrasy | Automaticity of the process | Consistency over time |
| Congenital synaesthesia | Yes | Yes | Yes | Yes |
| Post-hypnotic suggestions | Debated | Yes | Yes | Lack of Data |
| Drug use | Debated | Yes | Lack of Data | Lack of Data |
| Sweetness enhancement | No | No | Debated | Yes |
| SSD: associated phenomenology | Debated | Yes (narrow set) | Lack of Data | Lack of Data |
| SSD: substituted information | Lack of Data | No | Lack of Data | Yes |
| Crossmodal correspondences | No | No | Yes | Yes |

**Table 1.** Summary of the criteria fulfilled by four alleged cases of synaesthetic experiences: post-hypnotic suggestion, drug-use, flavor perception, and use of sensory substitution devices. In the table we also added congenital synaesthesia and crossmodal correspondences. The terms yes and no are used when the claim is not controversial, debated is added when there are existing data, but their interpretation is subject to controversy, lack of data is used when more empirical data are needed.

Table 1 gives an overview of the analyses. To summarize them, in post-hypnotic suggestion, the concurrent is consciously reported during the experiment although the extent to which a conscious status can be achieved in such cases remains highly controversial. There is idiosyncrasy, and automaticity, however the question of consistency remains open to further empirical confirmation (although preliminary results by Cohen Kadosh, et al., 2009, point toward this direction). With respect to drug-use, there is an inducer-concurrent pairing, although the inducer and concurrent seems to be experienced as less demarcated than in congenital synesthesia. As for post-hypnotic suggestions, these pairings can be consciously reported, although there is a difficulty in identifying experiences that are induced while being under drugs, and it still remains unclear whether the concurrent is different from vivid hallucinations. There is idiosyncrasy. However, there are no studies investigating experimentally automaticity. Furthermore there are reports suggesting that it’s unlikely to be the case as under drugs someone can report a pairing one time and not the other. Consistency remains also controversial with preliminary studies pointing to different directions.

With regard to sweetness enhancement, the inducer and concurrent are not both consciously perceived at the same time, as the phenomenon occurs when the participants adopt a synthetic strategy and when they are not provided with the scales that allow them to disentangle their perception from different sensory modalities. There is no idiosyncrasy (at least intra-culturally), the automaticity remains controversial, and there is consistency. With respect to sensory substitution, when the concurrent is considered to be the associated phenomenology there is a crucial lack of empirical data, as the hypothesis arise from only two verbal reports. These preliminary reports suggest that there might be a consciously perceived concurrent (but without certainty of its perceptual status, i.e., differences from added visual imagery). There can be idiosyncrasy, although narrower than congenital synesthesia, and there are no substantial data to know if there can be automaticity and consistency. When the concurrent is considered to be the substituted information, the existence of an inducer concurrent pairing can be acknowledged, however, the extent to which both the concurrent and the inducer are consciously perceived awaits further empirical data. In addition the concurrent is linked to the inducer more in a relative than in an absolute way (which is closer to cross-modal correspondences than synesthesia; see Deroy & Spence, 2013a) and there is no idiosyncrasy. In summary, it appears that none of the alleged cases of synaesthesia we considered can be claimed to match the criteria that we established to single out genuine forms of synaesthesia.

Borderline cases: Closer to crossmodal correspondences than synesthetic experiences?

Table 1 also shows that the alleged cases of transient and acquired synaesthesia are not closer to congenital synaesthesia than they are to crossmodal correspondences. Indeed, two main criteria distinguish synaesthesia from crossmodal correspondences: pairing and idiosyncrasy, whereas they both share automaticity and consistency. We will first discuss the shared criteria and then move on to analyse the non-shared ones. Many of the claims that link borderline cases to synaesthesia emphasize their automaticity and consistency, however these two criteria alone does not allow distinguishing these cases from crossmodal correspondences. Thus, obtaining a Stroop effect or any measure of automaticity allows assessing the strength of an association, but it does not allow assessing if this association occurs at a semantic level or at a perceptual level. The same is true for any measure of consistency. To repeat it again, further empirical data will only confirm that there is a strong association of the pairings. However, in the absence of the two remaining criteria (i.e. pairing and idiosyncrasy), this will not help disentangling whether these associations resemble synaesthesia, crossmodal correspondences, or associations occurring at an even higher level of processing (such as conceptual or semantic associations).

Thus, in order to say that the borderline cases resemble more synaesthesia than crossmodal correspondences the other two criteria must to be fulfilled. Idiosyncrasy is the easiest to discuss as the extent to which each of the borderline cases fulfills it is less subject to debates. This criterion rules out sweetness enhancement and SSD-use with substituted information as concurrent. The first criterion is less straightforward to discuss as it involves taking into account different levels of associations. Many articles discuss the nature of synaesthetic experiences (see Auvray & Deroy, in press, for a review) but there seems to be a consensus on the idea that it has to involve a process close to a perceptual one otherwise there would not be ways to say that synaesthesia is different from hallucination, from visual imagery, and from semantic and conceptual associations. So far, none of the mentioned borderline cases can be affirmed with certainty to be genuinely perceptual. To reiterate, this is not the case of sweetness enhancement and SSD-use with substituted information as concurrent. In the case of SSD-use with associate phenomenology as concurrent, as well as with post-hypnotic suggestions, there is no data so far to distinguish the associated experience from mental imagery. As for drug-use, there is no data either to distinguish the associations that are made from hallucinations.

In light of these considerations we would like to conclude this chapter with an appeal for cautiousness. If anything, these borderline cases crucially show that it is false to think of sensory modalities as being non-overlapping and discrete (see Haigh et al., 2013, for this claim in the context of SSD-use). This claim is already crucial in the fields of psychology and philosophy of perception. Going one step further and linking borderline cases to synaesthesia can be interesting as a working hypothesis, as it gave rise to studies using the experimental methodologies from synaesthesia that in return allow to better document and hence understand these cases. However it can prove highly misleading to go beyond the limits of a working hypothesis and have strong affirmations that do not rest on firm empirical grounds. There are two main reasons for resisting the fashionable phenomenon of synaesthesia and applying this term to any phenomena which would share a vague resemblance (thereby avoiding terminological confusions). First, in order to fully understand different phenomena we have to keep their study separate. It is thus important to bear in mind what these borderline cases do not share with synaesthesia in order to allow research digging into these differences, which might prove to be the specificity of each of these borderline cases. Second, keeping different phenomenon as being distinct is specifically what allows having a unified vision of each of these phenomena. It is by considering as synaesthetic only the cases that were identified as fulfilling the definitions that the study of synaesthesia can preserve a scientific robustness. Furthermore treating such a wide range of phenomena as genuine synaesthetic experiences does threaten an understanding of synaesthesia as a unitary event. It additionally prevents treating synaesthesia as a natural kind of its own. Anyone defending a broad acceptance of the term synaesthesia will have to give an account of why one or several criteria to define synaesthesia can be loosened in some cases without weakening the understanding and definitions given to congenital synaesthesia.

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**References**

Aghajanian, G. K., & Marek, G. J. (1999). Serotonin and hallucinogens. *Neuropsychopharmacology, 21*, 16S-23S.

Auvray, M., & Deroy, O. (in press). How do synaesthetes perceive the world? In M. Matthen (Ed.), *The Oxford Handbook of Philosophy of Perception*. Oxford, UK: Oxford University Press.

Auvray, M., Hanneton, S., O’Regan, J. K. (2007). Learning to perceive with a visuo-auditory substitution system: localization and object recognition with The Voice. *Perception*, *36*, 416-430.

Auvray, M., Myin, E. (2009). Perception with compensatory devices. From sensory substitution to sensorimotor extension. *Cognitive Science,* *33*, 1036-1058.

Auvray, M., & Spence, C. (2008). The multisensory perception of flavor, *Consciousness & Cognition, 17*, 1016-1031.

Bach-y-Rita, P., & Kercel, S.W. (2003). Sensory substitution and the human-machine interface. *Trends in Cognitive Sciences, 7,* 541-546.

Barnett, K. J., Foxe, J. J., Molholm, S., Kelly, S. P., Shalgi, S., Mitchell, K. J., & Newell, F. N. (2008). Differences in early sensory-perceptual processing in synesthesia: A visual evoked potential study. *NeuroImage, 43*, 605-613.

Baron-Cohen, S. (1996). Is there a normal phase of synaesthesia in development? *Psyche*, *2*, 2-27.

Baron-Cohen, S., Wyke, M. A., & Binnie, C. (1987). Hearing words and seeing colours: An experimental investigation of a case of synaesthesia. *Perception,* *16*, 761-767.

Brang, D., Hubbard, E. M., Coulson, S., Huang, M., & Ramachandran, V. S. (2010). Magnetoencephalography reveals early activation of V4 in grapheme-color synesthesia. *NeuroImage, 53*, 268-274.

Chabalier, E. (1864). De la pseudochromesthesie [About pseudochromestesia]. *Journal de Medecine de Lyon,* *1*, 92-102.

Cliff, M., & Noble, A. C. (1990). Time–intensity evaluation of sweetness and fruitiness and their interaction in a model solution. *Journal of Food Science*, *55*, 450-454.

Cohen Kadosh, R, Henik, A., Catena, A., Walsh, V., & Fuentes, L.J. (2009). Induced cross-modal synaesthetic experience without abnormal neuronal connections*. Psychological Science, 20*, 258-265.

Cytowic, R. (2003). *The man who tasted shapes.* Cambridge, MA: MIT Press.

Cytowic, R. (1989). *Synaesthesia: A union of the senses*. New York, USA: Springer.

Cytowic, R. (1997). Synaesthesia: phenomenology and neuropsychology - a review of current knowledge. In S., Baron-Cohen, & E. Harrison (Eds.), *Synaesthesia: Classic and Contemporary Readings* (pp.17-42). Oxford, UK: Oxford Blackwell.

Cytowic, R., & Eagleman, D.M. (2009). *Wednesday is indigo blue: Discovering the brain of synesthesia*. Cambridge, MA: MIT Press.

Day, S. (2009). Types of synesthesia. In Synesthesia. Retrieved from <http://www.daysyn.com/Types-of-Syn.html> [last accessed April 2013].

Delay, J., Gérad, H. P., & Racamier, P. C. (1951). Les synesthésies dans l’intoxication Mescalinique [Synaesthesias with mescalinic intoxication]. *L’Encephale*, *40*, 1-10.

Deroy, O., & Auvray, M. (in press). A crossmodal perspective on sensory substitution. In S. Biggs, M. Matthen, & D. Stokes (Eds.), *The senses*, Oxford: Oxford University Press.

Deroy, O., & Spence, C. (2013a). Why we are not all synesthetes (not even weakly so). *Psychonomic Bulletin & Review*, *20*, 643-664.

Deroy, O., & Spence, C. (2013b). Training, drugs, and hypnosis: Artificial synaesthesia, or artificial paradises? *Frontiers in Psychology, 4*, 660. doi:10.3389/fpsyg.2013.00660.

Deroy, O., & Auvray, M. (2012). Reading the world through the skin and ears: A new perspective on sensory substitution. *Frontiers in Theoretical and Philosophical Psychology*, *3*, 457. doi: 10.3389/fpsyg.2012.00457.

Davidson, J.M., Linforth, R. S. T., Hollowood, T. A., & Taylor, A. J. (1999). Effect of sucrose on the perceived flavor intensity of chewing gum. *Journal of Agriculture and Food Chemistry*, *47*, 4336-4340.

Dixon, M.J., Smilek D, Cudahy, C., & Merikle, P. M. (2000). Five plus two equals yellow. *Nature,* *406*, 365.

Dixon, M.J., Smilek, D., & Merikle, P.M. (2004). Not all synaesthetes are created equal: Projector versus associator synesthetes. *Cognitive, Affective and Behavioral Neuroscience*, *4*, 335-343.

Eagleman, D.M. (2009). The objectification of overlearned sequences: A new view of spatial sequence synesthesia. *Cortex*, *45*, 1266-1267.

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

Ellis, H. (1898). Mescal: A new artificial paradise. *The Contemporary Review, 73*, 130-141.

Farina, M. (2013). Neither touch nor vision: sensory substitution as artificial synaesthesia? *Biology and Philosophy, 28,* 639-655.

Frank, R. A., & Byram, J. (1988). Taste–smell interactions are tastant and odorant dependent. *Chemical Senses*, *13*, 445-455.

Frank, R. A., Shaffer, G., & Smith, D. V. (1991). Taste–odor similarities predict taste enhancement and suppression in taste–odor mixtures. *Chemical Senses*, *16*, 523.

Frank, R. A., van der Klaauw, N. J., & Schifferstein, H. N. J. (1993). Both perceptual and conceptual factors influence taste-odor and taste-taste interactions. *Perception & Psychophysics, 54,* 343-354.

Friedrichs, H. (2009). *Die Psychologie des Meskalinrausches [The Psychology of Mescaline Intoxications]*. Berlin: VWB – Verlag für Wissenschaft und Bildung.

Galton, F. (1880). Visualised numerals. *Nature*, *21*, 252-256.

Grof, S. (1975). *Realms of the human unconsciousness.* New York, USA: Viking Press.

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

Haigh, A., Brown, D.J., Meijer, P., Proulx, M.J. (2013). How well do you see what you hear? The acuity of visual-to-auditory sensory substitution. *Frontiers in Psychology, 4,* 330. doi: 10.3389/fpsyg.2013.00330.

Hanneton, S., Auvray, M., & Durette, B. (2010). The Vibe: A versatile vision-to-audition sensory substitution device. *Applied Bionics and Biomechanics, 7,* 269-276.

Hartman, A.M., & Hollister, L.E. (1963). Effect of mescaline, lysergic acid diethylamide and psilocybin on color perception. *Psychopharmacolgia*, *4*, 441-451.

Hofmann, A. (1983). *LSD my problem child: Reflections on sacred drugs, mysticism, and science*. Los Angeles, USA: Jeremy P. Tarcher.

Howells, T. (1944). The experimental development of color-tone synesthesia. *Journal of Experimental Psychology*, *34*, 87-103.

Hubbard, E.M. (2007). Neurophysiology of synesthesia. *Current Psychiatry Reports*, *9*, 193-199.

Hubbard, E.M., & Ramachandran, V.S. (2005). Neurocognitive mechanisms of synesthesia. *Neuron,* *48*, 509-520.

Jewanski, J., Day, S.A., Simner, J., & Ward, J. (2011). The development of a scientific understanding of synesthesia during the mid-nineteenth century (1849–1873). *Journal of the History of the Neurosciences*, *20*, 284-305.

Jewanski, J., Day, S.A., Ward, J. (2009). A colorful albino: The first documented case of synaesthesia, by Georg Tobias Ludwig Sachs in 1812. *Journal of the History of the Neurosciences*, *18*, 293-303.

Kiverstein, J., Farina, M., & Clark, A. (in press). Substituting the senses. In M. Matthen (Ed). *The Oxford Handbook of Philosophy of Perception*,Oxford, UK: Oxford University Press.

Laurence, J.R., Beaulieu-Prévost, D., & Du Chéné, T. (2008). Measuring and understanding individual differences. In M. Nash, & A. Barnier (Eds.), *The Oxford Handbook of Hypnosis: Theory, Research, and Practice*. (pp 225-253). Oxford, UK: Oxford University Press.

Levy-Tzedek, S., Hanassy, S., Abboud, S., Maidenbaum, S., & Amedi, A. (2012). Fast, accurate reaching movements with a visual-to-auditory sensory substitution device *Restorative Neurology and Neuroscience, 30*, 313-323.

Leuner, H. (1962). *Die experimentelle psychose* *[The experimental psychosis].* Berlin, Germany: Springer.

Loomis, J. M. (2010). Sensory substitution for orientation and mobility: What progress are we making? Sidebar 1.1 (pp. 7-10) to Chapter 1, *Perceiving to Move and Moving to Perceive: Control of Locomotion by Students with Vision Loss* by D. A. Guth, J. J. Rieser, & D. H. Ashmead (pp. 3-44). In: R. William, R. Wiener, R.L.Welsh, & B. B. Blasch (Eds), *Foundations of Orientation and Mobility*, *Third Edition, Volume 1 (History and Theory)*, New York: AFB Press.

Luke, D., Terhune, D. B., & Friday, R. (2012). Psychedelic synaesthesia: Evidence for a serotonergic role in synaesthesia. *Seeing and Perceiving, S1*, 74.

MacLeod, C.M., & Dunbar, K. (1988). Training and Stroop-like interference: evidence for a continuum of automaticity. *Journal of Experimental Psychology: Human Perception and Performance*, *14*, 126-135.

Marinetti, F.T. (1911). *Distruzione: Poema Futurista [Destruction: Futuristic Poem]. Milano*, Italy: Edizioni futuriste di Poesia.

Marks, L. E. (1987). On cross-modal similarity: Auditory–visual interactions in speeded discrimination. *Journal of Experimental Psychology: Human Perception and Performance*, *13*, 384-394.

Masters, R. E. L., & Houston, J. (1966). *The varieties of psychedelic experience*. New York/Chicago: Holt, Rinehart & Winston.

Mattingley, J. B. (2009). Attention, automaticity, and awareness in synesthesia. *Annals of the New York Academy of Sciences, 1156*, 141-167.

Maurer, D., (1993). Neonatal synesthesia: Implications for the processing of speech and faces. In B. de Boysson-Bardies, S. de Schonen, P. Jusczyk, P. McNeilage, & J. Morton (Eds.), *Developmental Neurocognition: Speech and Face Processing in the First Year of Life*, (pp. 109-124), Kluwer Academic: Dordrecht, The Netherlands.

Mayer-Gross, W. (1931). Über synästhesien im meskalinrausch [About synaesthesia in mescaline intoxication]. In: G. Anschütz (Ed.), *Farbe-Ton-Forschungen Bd. III* (pp. 266–277). Hamburg: Psychologischästhetische Forschungsgesellschaft.

Meijer, P.B.L. (1992). An experimental system for auditory image representations. *IEEE Transactions on Biomedical Engineering, 39*, 112-121.

Mills, C. B., Boteler, E. H., Howell, O., Glenda K. (1999). Digit synaesthesia: A case study using a Stroop-type test. *Cognitive Neuropsychology*, *16*, 181-191.

 Nguyen, D. H., Valentin, D., Ly, M. H., Chrea, C., & Sauvageot, F. (2002). When does smell enhance taste? Effect of culture and odorant/tastant relationship. Paper presented at the European Chemoreception Research Organisation conference, Erlangen, Germany.

Nunn, J.A., Gregory, L.J., Brammer, M., Williams, S.C.R., Parslow, D.M., Morgan, M.J., Morris, R.G., Bullmore, E.T., Baron-Cohen, S. & Gray, J.A. (2002). Functional magnetic resonance imaging of synesthesia: Activation of V4/V8 by spoken words. *Nature* *Neuroscience*, *5*, 371-375.

Nussbaumer, F.A. (1873). Über subjektive Farbempfindungen, die durch objektive Gehörempfindungen erzeugt werden [About subjective colour sensations, caused by objective auditory sensations]. *Wiener Medizinishe Wochenschrift*, *1,* 4-7.

O’Regan, J.K., Noë, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences*, *24*, 939-1031.

Ortmann, O. (1933). Theories of synesthesia in the light of a case of colored hearing. *Human Biology*, *5*, 155-211.

Pedley, P. E., & Harper, R. S. (1959). Pitch and the vertical localization of sound. *The American Journal of Psychology*, *72*, 447-449.

Pollok, B., Schnitzler, I., Mierdorf, T., Stoerig, P., & Schnitzler, A. (2005). Image-to-sound conversion: Experience-induced plasticity in auditory cortex of blindfolded adults. *Experimental Brain Research, 167,* 287-291.

Prescott, J. (2004). Psychological processes in flavour perception. In A. J. Taylor, & D. D. Roberts (Eds.), *Flavor Perception* (pp. 257-277). Oxford, UK: Blackwell.

Prescott, J., Johnstone, V., & Francis, J. (2004). Odor-taste interactions: Effects of attentional strategies during exposure. *Chemical Senses, 29,* 331-340.

Proulx, M. J. (2010). Synthetic synaesthesia and sensory substitution. *Consciousness and Cognition, 19,*501-503.

Proulx, M. J., & Stoerig, P. (2006). Seeing sounds and tingling tongues: Qualia in synaesthesia and sensory substitution. *Anthropology & Philosophy, 7*, 135-151.

Proulx, M. J., Stoerig, P., Ludowig, E., & Knoll, I. (2008). Seeing 'where' through the ears: effects of learning-by-doing and long-term sensory deprivation on localization based on image-to-sound substitution. PLoS One, 3(3), e1840.

Renier, L., & De Volder, A. G. (in press). Sensory substitution devices: Creating “artificial synaesthesias”. In: J. Simner, & E. Hubbard (Eds), *The Oxford Handbook of Synaesthesia*, (pp. 853-868), Oxford, UK: Oxford University Press.

Rich, A.N., & Mattingley, J.B. (in press). The role of attention in synaesthesia. In: J. Simner, & E. Hubbard (Eds), *The Oxford Handbook of Synaesthesia*. Oxford, UK: Oxford University Press.

Rich, A.N., Bradshaw, J.L, & Mattingley, J.B. (2005). A systematic, large-scale study of synaesthesia: implications for the role of early experience in lexical colour associations. *Cognition*, *98*, 53-84.

Robertson, L.C., & Sagiv, N. (2005). *Synesthesia: Perspectives from Cognitive Neuroscience.* New York, USA: Oxford University Press.

Rouw, R., Scholte, H.S., & Colizoli, O. (2011). Brain areas involved in synaesthesia: a review. *Journal of Neuropsychology*, *5*, 214-242.

Sachs, G.T.L. (1812). Historiae naturalis duorum leucaetiopum: Auctoris ipsius et sororis eius. *Solisbaci [Natural history of two albinos, the author and his sister]*, Germany: Sumptibus Bibliopoli Seideliani.

Sagiv, N., Heer, J., & Robertson, L. (2006). Does binding of synesthetic color to the evoking grapheme require attention? *Cortex, 42,* 232-242.

Schifferstein, H. N. J., & Verlegh, P. W. J. (1996). The role of congruency and pleasantness in odor-induced taste enhancement. *Acta Psychologica*, *94*, 87-105.

Shanon, B. (2002). Ayahuasca visualizations: A structural typology. *Journal of Consciousness Studies*, *9*, 3-30.

Siegel, R. K. (1975). *Hallucinations – Behavior, Experience, and Theory*. New York, USA: John Wiley & Sons.

Simner, J. (2012). Defining synaesthesia. *British Journal of Psychology, 103*, 1-15.

Simner J., & Ward J. (2008). Synaesthesia, color terms, and color space: Color claims came from color names in Beeli, Esslen, and Jancke. *Psychological Science*, *19*, 412-414.

Simner, J., Glover, L., & Mowat, A. (2006). Linguistic determinants of word colouring in grapheme-colour synaesthesia. *Cortex*, *42*, 281-289.

Simner, J., Ward, J., Lanz, M., Jansari, A., Noonan, K., Glover, L., & Oakley, D.A. (2005). Non-random associations of graphemes to colours in synaesthetic and non-synaesthetic populations. *Cognitive Neuropsychology*, *22*, 1069-1085.

Simner, J., Mulvenna, C., Sagiv, N., Tsakanikos, E., Witherby, S.A., Fraser, C., Kirsten, S., & Ward, J. (2006). Synaesthesia: The prevalence of atypical cross-modal experiences. *Perception*, *35*, 1024-1033.

Simpson, L., & McKellar, P. (1955). Types of synaesthesia. *Journal of Mental Science*, *101*, 141-147.

Sinke, C., Halpern, J. H., Zedler, M., Neufeld, J., Emrich, H. M., & Passie, T. (2012). Genuine and drug-induced synesthesia: A comparison. *Consciousness and Cognition, 21*, 1419-1434.

Skinner, B.F. (1938). *The behavior of organisms: An experimental analysis.* Oxford, UK: Appleton-Century-Crofts.

Smilek, D., Dixon, M.J., Cudahy, C., & Merikle, P.M. (2001). Synaesthetic photisms influence visual perception. *Journal of Cognitive Neuroscience*, *13*, 930-936.

Spence, C., & Deroy, O. (2012). Crossmodal correspondences: Innate or learned? *Perception*, *3*, 316-318.

Spence, C., & Deroy, O. (2013). Crossmodal mental imagery. In S. Lacey and R. Lawson (Eds), Multisensory imagery: Theory and applications (pp. 157-183). Philadelphia, USA: Springer.

Spence, C., Auvray, M., & Smith, B., (forthcoming). Confusing tastes and flavours. In S. Biggs, M. Matthen, & D. Stokes (Eds.), *The senses*, Oxford: Oxford University Press.

Steven, M.S., & Blakemore, C. (2004). Visual synaesthesia in the blind. *Perception, 33*, 855-868.

Stevenson, R.J., & Tomiczek, C.M. (2007). Olfactory induced synesthesias: A review and model. *Psychological Bulletin*, *133*, 294-309.

Stevenson, R. J., & Boakes, R. A. (2004). Sweet and sour smells: Learned synaesthesia between the senses of taste and smell. In G. A. Calvert, C. Spence, & B. E. Stein (Eds.), *The Handbook of Multisensory Processing*, (pp. 69–83). Cambridge, MA: MIT Press.

Stevenson, R.J., Boakes, R.A., & Wilson, J.P. (2000a). Counter-conditioning following human odor-taste and color-taste learning. *Learning and Motivation*, *31*, 114-127.

Stevenson, R.J., Boakes, R.A. & Wilson, J.P. (2000b). The persistence of conditioned odor perceptions: Evaluative conditioning is not unique. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *26*, 423-440.

Stevenson, R.J., Prescott, J. & Boakes, R.A. (1999). Confusing tastes and smells: How odours can influence the perception of sweet and sour tastes. *Chemical Senses*, *24*, 627-635.

Stevenson, R. J, Boakes, R. A., & Prescott, J. (1998). Changes in odor sweetness resulting from implicit learning of a simultaneous odor-sweetness association: An example of learned synesthesia. *Learning and Motivation*, 1998, *29*, 113-132.

Studerus, E., Gamma, A., & Vollenweider, F. X. (2010). Psychometric evaluation of the altered states of consciousness rating scale (OAV). *PLoS One, 5*, e12412. doi: 10.1371/journal.pone.0012412.

Tart, C. T. (1975). *States of Consciousness*. New York, USA: E. P. Dutton.

Terhune, D.B., & Cohen Kadosh, R. (2012). Synaesthesias. In: J.D. Blom, & I. Sommer (Eds.), *Hallucinations. Research and Practice* (pp. 91-104). New York, USA: Springer.

Ward, J. (2013). Synaesthesia. *Annual Review of Psychology, 64*, 2-27.

Ward, J, & Meijer, P. (2010).Visual experiences in the blind induced by an auditory sensory substitution device. *Consciousness and Cognition*, *19*, 492-500.

Ward, J., Jonas, C., Dienes, Z., & Seth, A. (2010). Grapheme-colour synaesthesia improves detection of embedded shapes, but without pre-attentive “pop-out” of synaesthetic colour. *Proceeding of the Royal Society London B Biolological Sciences*, *277*, 1021-1026.

Ward, J. (2004). Emotionally mediated synaesthesia. *Cognitive Neuropsychology*, *21*, 761-772.

Ward, J., & Simner, J. (2003). Lexical-gustatory synaesthesia: Linguistic and conceptual factors. *Cognition, 89*, 237–261.

Wasson, R. G. (1978). *The road to Eleusis: Unveiling the secret of the mysteries*. New York, USA: Harcourt.

Watson, J. B. (1930). *Behaviorism* (Revised edition). Chicago, USA: University of Chicago Press.

Ward, J., & Wright, T. (2012). Sensory substitution as an artificially acquired synaesthesia. *Neuroscience and Biobehavioral Review,* doi: 10.1016/j.neubiorev.2012.07.007.

Yeomans, M. R., & Mobini, S. (2006). Hunger alters the expression of acquired hedonic but not sensory qualities of food-paired odors in humans. *Journal of Experimental Psychology: Animal Behavior Processes*, *32*, 460-466.

Yeomans, M. R., Mobini, S., Elliman, T. D., Walker, H. C., & Stevenson, R. J. (2006). Hedonic and sensory characteristics of odors conditioned by pairing with tastants in humans. *Journal of Experimental Psychology: Animal Behavior Processes*, *32*, 215-228.

1. The two authors contributed equally to this work [↑](#footnote-ref-1)
2. Besides an in-depth analysis of the four criteria we discussed in this entry, Farina (2013) also reported two other interesting analogies between developmental forms of synaesthesia and SSD-use. According to him, both SSD-perception and developmental forms of synaesthesia exploit cross-modal plasticity and both could be characterized by analogous neural mechanisms. In other words, both these forms of perceiving (on his account) are cross-modal and both exhibit "disinhibited feedback", or better a reduction in the amount of inhibition along feedback pathways - a phenomenon known as cortical unmasking. [↑](#footnote-ref-2)