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Patrolling the Boundaries of Synaesthesia

A Critical Appraisal of Transient and Artificially Induced Forms of Synaesthetic Experiences

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12.1 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 seventy 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 (for instance, the Optophonic Piano built by Vladimir Rossine in 1916), and futurism in literature (Marinetti, 1911), the term gradually but progressively came 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 into synaesthesia changed again. Synaesthesia

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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 1980s), with the advent of cognitive neuroscience, synaesthesia has experienced a tremendous resurgence of interest (e.g., Baron-Cohen, 1996; Steven and Blakemore, 2004; Hubbard and 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.

Synaesthesia is 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 and 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 post-hypnotic suggestion (e.g., Cohen Kadosh et al., 2009), drug habits (e.g., Friedrichs, 2009; Shanon, 2002), flavor perception (e.g., Stevenson and Boakes, 2004), and use of sensory substitution devices (e.g., Farina, 2013; Proulx and Stoerig, 2006; Ward and Meijer, 2010), have been linked or directly associated with 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 crossmodal 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 synaesthetic experiences.

In section 12.2, 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 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 12.3, 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 12.4, 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 and Boakes, 2004). We then turn to sensory substitution, tackling the idea of artificially acquired synaesthesia. We report preliminary evidence for this claim (Proulx and Stoerig, 2006; Ward and Meijer, 2010, Farina, 2013; Ward and Wright, 2012) and then critically discuss it. In section 12.5, 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 and 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.

12.2 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: 193; see also Cytowic, 2003). Synaesthesia is thus normally described as a "startling sensory blending" (Cytowic, 1997: 17) "not experienced by most people under comparable conditions" (Grossenbacher and Lovelace, 2001: 36). In synaesthesia, in fact, sensory experiences (such as tastes) or concepts (such as numbers) automatically evoke additional percepts, such as colors (Cohen Kadosh and Walsh, 2006: 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 and 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 by imagining the meaning of certain words (Rich et al., 2005).

To date, more than sixty-five 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 synaesthesia 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 and Deroy, 2015, 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 and Lovelace, 2001: 36). As Deroy and Spence (2013a) 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 latter the crossmodal matching is not. Second, in synaesthesia the concurrent is determined in an *absolute* way (i.e., a particular sound associated with a shape), while in crossmodal correspondences it functions in a *relative* way (a higher-pitched sound associated with a higher position in space; see Marks, 1987; Pedley and 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 and Lovelace, 2001: 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 Bb and of a "dirty yellow-green" when hearing a D# (Ortmann, 1933). Another synaesthete 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 and Ramachandran, 2003). Rather, the set of observed concurrent pairings is broad and varies, even within the 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 synaesthesia, 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 and 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 and 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 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 (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 long period of time (e.g., after six 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 synaesthetes, and therefore assessed by means of further studies (Ward and 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 and 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 consistency over time should be a definitional criterion, or whether, instead, it should merely characterizes a subset of synaesthetes only (Simner 2012: 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 and Mattingley, forthcoming; Simner, 2012). They pointed out that almost all synaesthetes reported in the literature are synaesthetes who display consistency, but this is because 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 assessment of its role in defining synaesthesia. Consequently, while we believe that consistency 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, namely inducer-concurrent pairing, idiosyncrasy, and automaticity.

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., Cytowic and Eagleman, 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, while 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

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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 and Stoerig, 2006; Ward and Wright, 2012; Ward and 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.

12.3 Transient forms of synaesthetic experiences: post-hypnotic suggestion and drug-use

12.3.1 Synaesthetic 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 of 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 percent of the total population tested (see Laurence, Beaulieu-Prévost, and du Chéné, 2008; see also Terhune et al., Chapter 11 of 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-color 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) investigated whether a post-hypnotically induced synaesthesia 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 eye). Terhune and Cohen Kadosh first differentiated the participants who were responsive to hypnotic suggestions for either associator or projector grapheme-color synaesthesia. They subsequently administered post-hypnotic 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, no studies have been conducted on the neural mechanisms underlying post-hypnotically induced synaesthesia. Terhune (Chapter 11 of 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 be noted, however, 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 and Spence, 2013a, see also Spence and Deroy, 2013b for an analysis of the difference between mental imagery and synaesthesia). 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) study showed a positive result.

12.3.2 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 percent; 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 and Hollister, 1963; Simpson and McKellar, 1955) have investigated the possibility of triggering synaesthetic experiences through drug-use, mostly because this kind of research started to be prohibited in the 1960s. In one of these studies, two congenital synaesthetes and two controls (the two authors of the article) reported their synaesthetic impressions after ingesting mescaline when presented with a range of possible inducers (Simpson and 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 eighteen 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 of 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 study conducted so far has investigated whether the experience is genuinely perceptual as opposed to a mere vivid association (Aghajanian and Marek, 1999).

The described studies revealed variability among the inducer-concurrent pairing across people, satisfying the idiosyncrasy criterion. However, so far, no work has investigated systematically and experimentally automaticity in drug-use (see also Terhune, Chapter 11 of this volume). Sinke et al. (2012) suggest, based on previous verbal reports, that the experience of a synaesthetic concurrent is not necessarily triggered, which raises doubts about whether the automaticity criterion can be fulfilled. Indeed, sometimes, under the influence of drugs, one inducer can elicit a synaesthetic concurrent; however, in other occasions, the same inducer does not elicit anything (Studerus, Kometer, Hasler, and Vollenweider, 2011). Furthermore, even in cases of experienced synaesthesia, a stimulus does not always elicit its expected concurrent (Delay, Gérad, and Racamier, 1951; Leuner, 1962; Masters and Houston, 1966). For example, when a synaesthete perceives a letter (e.g., A), she always experience it with the same color (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-color 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 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.

12.4 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.

12.4.1 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, and Boakes, 1999). This phenomenon, known as sweetness enhancement, led Stevenson and Boakes (2004; see also Stevenson and 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 and Noble, 1990; Frank and Byram, 1988; Frank, Shaffer, and Smith, 1991; Schifferstein and 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, Prescott, and Boakes, 1995; Stevenson, Boakes, and 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, and 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 (Yeomans and 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, and 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 and Boakes, 2004; Stevenson and 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 gives 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 concurrents. 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 elements in the mixtures, this results in a decrease in sweetness enhancement (Prescott, Johnstone, and 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 latter 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 appear that mostly what is obtained is not an additional and distinct perceptual experience, but rather the replacement of one sensory experience with 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 by 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 criterion, automaticity of the process, however, remains controversial. Furthermore, sweetness enhancement does not satisfy the first 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.

12.4.2 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 and 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 shape recognition (e.g., Arno et al., 2001; Auvray et al., 2007; Pollok et al., 2005; see also Auvray and Myin, 2009; Deroy and Auvray, 2012b, Kiverstein et al., 2015, for reviews).

Proulx and Stoerig (2006) speculated that the long-term use of SSDs may induce, in practiced users, the emergence of forms of synaesthesia (for an analogous claim see also Farina, 2013; Proulx, 2010, Renier and De Volder, 2013; Ward and Wright, 2012). Ward and 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 ten 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 and Meijer, 2010: 497–8).

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 and Meijer 2010: 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 and Meijer 2010: 498).

Is the claim that SSD-use is comparable to the synaesthetic experiences enjoyed by colored-hearing synaesthetes (e.g., Ward and Meijer, 2010; Ward and Wright, 2012) 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 analyze them separately to establish the extent to which each fulfills the four criteria for genuine forms of synaesthesia that we listed in section 12.2.[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 both the inducer and the concurrent consciously perceiving at the same time. According to O'Regan and Noë (2001), for instance, in trained users, access to the substituting information fades away). In this case, the inducer and the concurrent cannot be perceived at the same time. On the other hand, Ward and Wright (2012) defend that both keep on being perceived 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, 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, which is at odds with congenital synaesthetic 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

[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 a reduction in the amount of inhibition along feedback pathways—a phenomenon known as cortical unmasking.

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 auditory information 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 are actually 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" (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 is: 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 (2012) 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, and motion effects she experienced. Thus, much more evidence is needed to build a case for consistency. With regard to the substituted information, even with a 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 criterion. 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 Deroy and Auvray, 2012a, 2012b 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.

12.5 Conclusions

12.5.1 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.

Table 12.1 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

Table 12.1 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, and lack of data is used when more empirical data are needed.

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

results by Cohen Kadosh et al., 2009 point in this direction). With respect to drug-use, there is an inducer-concurrent pairing, although the inducer and concurrent seem to be experienced as less demarcated than in congenital synaesthesia. 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 the influence of drugs, and it remains unclear whether the concurrent is different from vivid hallucinations. There is idiosyncrasy. However, there are no studies investigating automaticity experimentally. Furthermore, there are reports suggesting it is unlikely to be the case as under the influence of drugs someone can report a pairing one time and not the other. Consistency also remains controversial with preliminary studies pointing in 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 arises from only two verbal reports. These preliminary reports suggest 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 synaesthesia, and there are no substantial data to show 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 crossmodal correspondences than synaesthesia; see Deroy and 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 we established to single out genuine forms of synaesthesia.

12.5.2 Borderline cases: closer to crossmodal correspondences than synaesthetic experiences?

Table 12.1 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 analyze the non-shared ones. Many of the claims that link borderline cases to synaesthesia emphasize their automaticity and consistency; however, these two criteria alone do not allow these cases to be distinguished from crossmodal correspondences. Thus, obtaining a Stroop effect or any measure of automaticity allows the strength of an association to be assessed, 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, only further empirical data will 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 in 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, for us to say that the borderline cases resemble more synaesthesia than crossmodal correspondences, the other two criteria must be fulfilled. Idiosyncrasy is the easiest to discuss as the extent to which each of the borderline cases fulfills it is less subject to debate. 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 and 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 it would be impossible 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 are no data so far to distinguish the associated experience from mental imagery. As for drug-use, there are 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 us 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 that share a vague resemblance (thereby avoiding terminological confusion). First, 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 to allow research into these differences, which might prove to be the specificity of each of these borderline cases. Second, keeping different phenomena distinct is specifically what allows 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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