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Linguistic synaesthesia, perceptual synaesthesia, and the interaction between multiple sensory modalities*

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Recent studies on cortical processing of sensory information highlight the importance of multisensory integration, and define precise rules governing reciprocal influences between inputs of different sensory modalities. We propose that psychophysical interactions between different types of sensory stimuli and linguistic synaesthesia share common origins and mechanisms. To test this hypothesis, we compare neurophysiological findings with corpus-based analyses relating to linguistic synaesthesia. Namely, we present Williams' hypothesis and its recent developments about the hierarchy of synaesthetic pairings, and examine critical aspects of this theory concerning universality, directionality, sensory categories, and usage of corpora. These theoretical issues are verified against linguistic data derived from corpus-based analyses of Italian synaesthetic pairings related to auditory and tactile modalities. Our findings reveal a strong parallel between linguistic synaesthesia and neurophysiological interactions between different sensory stimuli, suggesting that linguistic synaesthesia is affected by tendencies similar to the rules underlying the perceptual association of distinct sensory modalities.

Keywords: Corpus linguistics, perception, sensory domains, synaesthesia, universality, Williams' hierarchy

1. Introduction

The term "synaesthesia" derives from ancient Greek *syn-*, "with", and *aisthēsis*, "sensation".[1] From a neurophysiological perspective it refers to a percept in a given sensory modality (e.g., vision) elicited by a stimulus belonging to a different sensory modality (e.g., audition or smell) or to a different submodality[2] of the

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same modality (e.g., a perceived black and white shape eliciting a colour percept — cf. e.g., Dixon et al. 2004: 837–838; Spector and Maurer 2009). Such "perceptual synaesthesia" (cf. Ramachandran et al. 2004; Sagiv and Ward 2006; Simner 2006, 2011; for a review on the tactile domain cf. Simner and Ludwig 2011) is a neurophysiological condition experienced by a minority of individuals, called "synaesthethes",[3] following sensory stimulation or while practicing certain activities (such as talking). From a linguistic perspective ("linguistic synaesthesia"; also labelled as "synaesthetic metaphors", "cross-modal metaphors", cf. e.g., Day 1996), synaesthesia consists in the pairing of words referring to different sensory modalities, such as "bright sound" (vision-audition), "warm colours" (thermoception-vision), and "delicate taste" (somatosensation-taste).[4]

More than 60 variants of perceptual synaesthesia have been reported and grouped in five sets, according to their features: coloured sequence synaesthesia, coloured music synaesthesia, non-visual sequence synaesthesia, spatial sequence synaesthesia, and coloured sensation synaesthesia (Novich et al. 2011). The different variants show different frequencies, where grapheme-colours synaesthesia is the most common, and pain-triggering synaesthesia is rare (Day 2005; Simner 2011; see also www.daysyn.com). Thus, stimuli belonging to different sensory modalities are not equally able to elicit a synaesthetic percept, as illustrated in Table 1.

Synaesthetes are not always aware of having a percept that is normally not elicited by a given stimulus. Furthermore, synaesthesia can be highly idiosyncratic in terms of coupling between eliciting stimulus and induced percept (e.g., not all visual-

Table 1. Synaesthetic types and their relative frequency (adapted from Cytowic and Eagleman 2009: 24).

Type	Frequency
Graphemes→colours	66.5%
Time units→colours	22.8%
Sounds (music, phonemes, general sounds)→colours	42.5%
Smell→colours	6.8%
Taste→colours	6.6%
Sound→tastes	6.2%
Pain→colours	5.8%
Touch→colours	4.0%
Sound→touch	4.0%
Smells→sounds	0.5%
Touch→sounds	0.4%
Touch→temperature	0.1%

auditory synaesthetes perceive high-pitch sounds in response to green stimuli, cf. Hubbard and Ramachandran 2005; Spector and Maurer 2009; Brang and Ramachandran 2011). In some instances, however, synaesthesthic experiences can be remarkably similar among different individuals (Simner et al. 2005; Ward et al. 2006). Notably, a recent report indicates that similar coupling between high luminance and high pitch occurs both in human and non human primates (Ludwig et al. 2011).

Recent studies[5] of perceptual synaesthesia have analysed the frequency of the phenomenon (cf. for example Simner et al. 2006), its neural basis (cf. for example Ramachandran et al. 2004; Hubbard 2007; Mattingley 2009), and explored some specific aspects. Ramachandran and Hubbard (2003) studied the robustness of colour perceptions evoked by specific graphemes, both within and between synaesthetes; interestingly, though the same grapheme does not evoke the same colour perception in every synaesthete, associations are not random:[6]

> [Synaesthetic associations] may reflect the manner in which phonemes […] are mapped near the TPO [temporal-parietal-occipital] junction in a systematic topographic manner, which in turn would make certain types of cross-activation more likely than others (e.g., front vowels might activate long wavelengths). Similarly, graphemes might be mapped in 'form space' in the fusiform in such a way that certain colour correspondences with colour neurons in V4 are more likely than others (Ramachandran and Hubbard 2003: 50).

In addition to the *interaction of different sensory perceptions*, perceptual synaesthesia is characterised by other features, which may vary in their occurrence (as prototype theory explains with regard to other phenomena):

- *stability* or *consistency*: Once a synaesthetic association is established, it remains largely invariable even after many years[7] (cf. Cytowic and Eagleman 2009: 5 and ff.);
- *genetic heritability* (cf. Galton 1880; for research on twins cf. Hancock 2006; see also Asher et al. 2009; Brang and Ramachandran 2011);
- *automaticity*: Synaesthetic perceptions automatically and immediately occur when the effective stimulus is presented;[8]
- *awareness* of the synaesthete, who is conscious[9] that her/his perception is uncommon. Cohen Kadosh and Henik (2007: 179) suggest that awareness is a prerequisite for synaesthesia. To some extent, everyone may experience "synaesthete like" perceptions without being aware of it (ibid.; cf. van Campen 2008). Furthermore, correspondences can be found between synaesthetes and non-synaesthetes: for example, like synaesthetes, some non-synaesthetes can experience numbers or months in space (cf. e.g., Sagiv et al. 2006), or correlations between letter and colour, or shape and colour (e.g., Simner et al. 2005; Spector and Maurer 2008);

– *affective component*: Synaesthetic experiences involve emotional and affective components.[10] For example, synaesthetes often love their synaesthetic experiences and are afraid to lose them.

A crucial issue refers to the relative contribution of genetic inheritance and learning or experience-dependent mechanisms in the development of perceptual synaesthesia (cf. Brang and Ramachandran 2011). Evidence that the ability to experience synaesthesias is not only learned, but also deeply linked to language development comes from several studies that correlated synaesthetic perceptions and language (e.g., Simner et al. 2005; Beeli et al. 2007). In these studies, linguistic parameters, such as the frequency of occurrence of given words, are shown to influence the features of the synaesthetic perceptions. For example, frequently used numbers elicit high-luminance colour perceptions. Similarly, the lexical frequency of the day of the week seems to influence the colour chosen. These findings suggest that synaesthesia may be bound to high cognitive processes, such as literacy and numeracy, and it is therefore established late in childhood (Beeli et al. 2007; Simner et al. 2009).

In parallel with the evidence suggesting that synaesthetic perceptions are dependent on learning, the innate theory highlights the congenital determinants of synaesthesia, suggesting that all newborns are synaesthetes, but because of the "neural pruning" (cf. e.g., Maurer and Mondloch 2005) or inhibition of functional connectivity between different cortical structures, this phenomenon is progressively lost. In other words, an inborn variety of multisensory interactions (and potential perceptual synaesthetic pairings) would be progressively sculpted and restricted by experience-dependent processes that shape developing neural circuitries. Accordingly, there is strong evidence that some kinds of synaesthetic pairings are present in toddlers (Spector and Maurer 2008; Cohen Kadosh et al. 2009), and some synaesthetic experiences are common both to synaesthetes and non-synaesthetes (cf. e.g., Simner et al. 2005; Ward et al. 2006; Simner et al. 2011), thus suggesting common neural bases for synaesthesia and cross-modal non-automatic associations in non-synaesthetes. Furthermore, synaesthesia is more frequent in members of the same family (cf. e.g., Ward and Simner 2005) and twins usually experience the same forms of synaesthesias (see above for the characteristics of genetic heritability).

Altogether, these considerations indicate that both genetic and epigenetic factors contribute to the development of synaesthesia. Brang and Ramachandran (2011: 2) suggested that "genetic undertones impose a predisposition to synesthesia, but not its expression". Furthermore, the integration of different sensory modalities in children is not an outcome of development; on the contrary, it is the starting point for development: "Development is seen as an emergent property of

the whole system and can only be understood in terms of the complex interaction of psychological, biological, and physical components" (Gibbs 2005: 225).

Linguistic synaesthesia is a particular form of metaphor, as it extends the meaning of an utterance from one sensory modality to another, through analogy.[11] As noted by Cytowic and Eagleman (2009: 172), one of the essential differences between the perceptual and linguistic synaesthesias is that the former are simultaneous and completely automatic, whereas the latter require a voluntary association between words belonging to two different sensory domains. Nonetheless, the frequency of linguistic synaesthetic pairings may be motivated and experience-based, and thus not completely arbitrary. Accordingly, in linguistic synaesthesia, the choice of the two sensory domains is context-dependent, whereas perceptual synaesthesia usually is not (e.g., for a synaesthete who perceives coloured numbers, even if the grapheme is black and white, number '1' is always perceived as red, no matter where it is written — see also 3.3.2).[12]

Given the privileged relation with perception and multisensory integration, on the one hand, and with the linguistic, metaphorical representation of sensory experience, on the other, synaesthesia can be considered as a significant interface between language (cf. Albertazzi 2009; Cacciari 1999; Holz 2007; Monopoli and Cacciari 2009), perceptual experience (cf. Cohen Kadosh et al. 2011), and cognition (cf. Cytowic 1989; Ramachandran and Hubbard 2003; Popova 2005). An interdisciplinary approach is essential to integrate such different cultural backgrounds and methodological perspectives. Neuroscience can fruitfully take advantage of the philosophical debate on mental representations and concepts, whereas the philosophical tradition can be enriched by new neurophysiological findings and notions. A growing body of studies is applying neuroscientific approaches and methods to address theoretical problems inherent in linguistic synaesthesia, such as its relationships to specific neurophysiological mechanisms and the related circuits.[13]

Here, we will first describe neurophysiological and neuropsychological studies on the interplay between different modalities (i.e., multisensory integration, Section 2), to highlight neural mechanisms that may link sensory associations to linguistic pairings. Then, we will discuss the hypothesis formulated by Williams (1976) on the hierarchy of synaesthetic pairings, and present corpus-based analyses derived from Italian (Section 3), to provide evidence suggesting that linguistic and sensory coupling of distinct modalities may be subject to common rules.

2. Neural basis of perceptual synaesthesia and multisensory integration

2.1 Perceptual synaesthesia and the multimodal brain

When asked to associate a shape with a sound (cf. Spector and Maurer 2008), or pitches with different degrees of lightness (cf. Ward et al. 2006), synaesthetes and non-synaesthetes tend to behave in the same way (i.e., they produce similar pairings). These observations have led scholars to hypothesize that at least some perceptual synaesthesias may be "an extension of the cross-modal mechanisms common to all adults" (Ward et al. 2006: 264), i.e., synaesthesia may exploit the same neural pathways that regulate the interactions between different sensory modalities.

Consistent with this hypothesis, an fMRI study (Weiss et al. 2009) indicated that grapheme-colour synaesthesia is related to an increase in functional connectivity at the level of the parietal cortices (cf. also Hubbard 2007), and to increased grey matter volume in the fusiform gyrus (V4) and in the intraparietal cortices (IPS). Interestingly, the parietal cortices (especially the posterior areas) and IPS were found to be involved in multisensory integration.[14]

Multisensory integration[15] is a neurophysiologic or neuropsychologic phenomenon defined as the neural integration of concomitant stimuli belonging to different sensory modalities. It is thought to occur in *multimodal* neural structures which process stimuli belonging to different sensory modalities, even when they are not presented simultaneously (cf. Driver and Noesselt 2008). Classically, high-order associative cortices, which are active in the late stages of sensory processing (including the posterior parietal cortex, the cingulate cortex, the insula and the human homologous of the upper bank of the superior temporal sulcus in monkeys, i.e., the superior temporal polysensory — STP — cortex), have been considered multimodal (ibid.; Ghazanfar and Schroeder 2006). This notion, however, has been recently challenged by several studies[16] indicating that even the primary sensory cortices (Driver and Noesselt 2008), which were considered strictly unimodal (Cappe and Barone 2005; Falchier et al. 2002; Bizley et al. 2007), contain neurons that respond to stimuli of different sensory modalities (Stein and Stanford 2008). These neurons appear to be located mainly at the border between two sensory cortices (i.e., the border between the auditory and the visual cortex — Ghazanfar and Schroeder 2006: 283, box 2). Furthermore, multimodal properties can be also attributed to subcortical structures, including the superior colliculus (cf. Stein and Stanford 2008; Driver and Noesselt 2008) and a subset of thalamic neurons (cf. Jones 1998).

2.2 Psychophysics of the interaction between different sensory modalities

2.2.1 *Interaction between visual and auditory processing*

The presentation of visual stimuli has a strong influence on the neural processing of auditory stimuli (cf. Marks 2004 for a review). For example, the detection threshold of auditory stimuli is reduced by the simultaneous presentation of visual stimuli (Lovelace et al. 2003). When white noise is delivered simultaneously with visual stimuli, it is perceived to be louder than in the absence of visual stimulation (Odgaard et al. 2004). These effects are actually due to reciprocal influences between the sensory inputs since they are not affected by variations of the probability of occurrence of the visual stimuli.

Soto-Faraco et al. (2002) described an interaction between visual and auditory stimuli producing a sensation of apparent motion. During the experiment, apparently moving auditory and visual stimuli were delivered through two loudspeakers and light emitting diodes (LEDs), positioned on either sides of the participant's midline. The auditory and visual motion streams could move either in the same or in the opposite direction. Subjects were asked to judge the direction of the auditory motion, trying to ignore the visual stimulation. The experiment showed that the direction of the auditory motion stream was more correctly detected when simultaneous visual motion streams were flowing in the same direction than when they were not. Similar results were also obtained by Oruc et al. (2008).

In summary, the presentation of visual stimuli lowers the detection threshold, increases the perceived intensity of simultaneously presented auditory stimuli, and improves the ability to detect the direction of apparently-moving auditory stimuli. Interestingly, these effects appear to be bidirectional. The presentation of auditory stimuli can affect the psychophysical responses to simultaneous visual stimuli (cf. for example Oruc et al. 2008; Jaekl and Harris 2007; Burr et al. 2009; Frassinetti et al. 2002).

2.2.2 *Interaction between auditory and tactile processing*

The processing of auditory stimuli is also strongly affected by simultaneous tactile stimulation. There is a crucial difference, however, when auditory and tactile stimuli are considered. Whereas tactile stimuli significantly alter the processing of auditory stimuli, the opposite is not true, i.e., auditory stimuli have minimal modulatory effects on tactile stimuli.

Gillmeister and Eimer (2007) showed that the detection threshold of auditory stimuli was enhanced by the simultaneous presentation of tactile stimuli of equal length (50 ms). Schurmann et al. (2003) showed that when auditory stimuli (500 ms tones) are presented simultaneously with tactile stimuli (fixed-intensity 200-Hz vibrations), the perceived intensity of the auditory stimulus is increased.

Caclin et al. (2002) demonstrated that the localisation of auditory stimuli may also be biased by the simultaneous presentation of spatially displaced tactile stimuli (i.e., "tactile capture of sound"). In this experiment, auditory stimuli were presented to the left or to the right of the subject's midline, either in isolation or together with tactile stimulation of the hand. Simultaneous tactile stimulation significantly worsened the ability to discriminate the location of the auditory stimuli.

Soto-Faraco et al. (2004), using the "apparent motion" paradigm described in the previous section, demonstrated that the perceived direction of an auditory stream of motion may be significantly affected by tactile apparent motion.

In general, touch appears to be weakly affected by auditory stimulation. Soto-Faraco et al. (2004) and Oruc et al. (2008) demonstrated that auditory influence on touch is less effective than touch influence on audition. Nonetheless, examples of auditory influence on touch perception have been reported (cf. for a review Soto-Faraco and Deco 2009; Bresciani et al. 2005).

In summary, the presentation of tactile stimuli lowers the detection threshold and increases the perceived intensity of simultaneously presented auditory stimuli, and improves the ability to detect their location and direction of apparent motion. These effects are not bidirectional, since the presentation of auditory stimuli only weakly affects psychophysical responses to simultaneous tactile stimuli.

2.3 The ambiguous role of the Anterior Cingulate Cortex (ACC) in multimodal processing: A bridge between multisensory and linguistic phenomena

A cortical area widely considered as multimodal is the Anterior Cingulate Cortex (ACC), because of its involvement in processing visual, auditory, somatosensory tactile, and somatosensory nociceptive stimuli (e.g., Mouraux et al. 2011; Iannetti et al. 2010). Furthermore, Banati et al. (2000: 121) suggested that the ACC, because of its connections with other brain regions, may have a fundamental role in multisensory integration (cf. Vogt 2005).

However, the ACC is often considered to respond obligatorily to nociceptive stimuli and to contribute to the generation of painful percepts — for these reasons it is included in the so-called Pain Matrix (i.e., "a set of brain regions involved in human nociceptive processing" — cf. Tracey 2005: 480). In contrast, recent studies using EEG and fMRI have shown that Pain-Matrix responses mainly reflect multimodal neural activity (i.e., brain responses elicited by painful tactile, auditory and visual stimuli were largely similar, with spatially indistinguishable responses in the insula, the S2 and the ACC), related to the perceived saliency of the applied stimulus, regardless of its quality (for a review cf. Iannetti and Mouraux 2010; Mouraux et al. 2011). Further evidence that the so-called pain-related brain

responses are not specific for pain perception, but depend on presentation context and on stimulus predictability and novelty comes from the studies by Clark et al. (2008), Iannetti et al. (2008), Wang et al. (2010) and Valentini et al. (2011).

These findings are also interesting from a linguistic perspective. Two studies (Kousta et al. 2010; Richter et al. 2010) have shown that linguistic stimuli elicit fMRI responses in the ACC. Richter et al. (2010) showed that pain-related words elicit responses in the Pain Matrix, and interpreted this result as indicating that pain-related words are processed in the same areas which generate the pain experience itself. In the light of the evidence presented above regarding ACC responses to salient and novel stimuli, an alternative explanation is possible. Pain-related words could activate the ACC because they were more salient than positive, negative, or neutral words. In the sample examined by Richter et al. (2010), words like "crampy", or "excruciating" seem to be definitely more salient and evocative than words like "dirty", "refreshing", "warming", and "disgusting". Although it is difficult to evaluate word saliency without considering the context of the utterance, it is possible that the setting of the experiment (where words were presented in isolation) even increased the saliency gap between pain-related and other words. Pain-related words can be considered as inherently salient (since they are semantically connected to pain, one of the most salient experiences in our lives), whereas negative, positive, and neutral words may principally gain their salience and valence from global and utterance context. For instance, colour words can surely be considered as inherently neutral words, since they cannot be automatically connected to positive or negative experiences, concepts, or events. However, as demonstrated by linguistic (cf. Regier and Kay 2009), psychological (cf. e.g., Heller 2004), and historical-philological studies (c.f. e.g., Pastoureau 2001), colour words are strongly context-dependent, and their values can vary significantly both from one culture to another and in time.[17] These observations suggest that the increase in the activation of the ACC reported by Richter et al. (2010) reflects the saliency of pain-related words rather than the representation of a painful experience. Further evidence in favour of this idea comes from the study of Kousta et al. (2010) who showed that ACC activation can be elicited by the presentation of abstract words, but not by concrete ones. This result is attributed to the higher positive or negative valence, and thus greater saliency, of abstract words. In summary, both neurophysiological and linguistic studies highlight the multimodal properties of the ACC, which is specifically involved in the processing of salient stimuli, regardless of their modality and typology (i.e., whether they are sensory or linguistic — cf. e.g., Mouraux et al. 2011; Iannetti and Mouraux 2011).

On the whole, the studies discussed in these sections show that several cortical areas, as well as subcortical structures, are involved in the integration of sensory stimuli of different modalities. The interaction between different qualities of

sensory information is governed by a consistent set of rules. Most importantly, similar rules seem to apply to both sensory processing and the elaboration of sensory-related semantic information, as we will see in the next sections.

3. Linguistic synaesthesia: Data and problems

3.1 Premise

Both pragmatics and cognitive linguistics have focused on the intertwining between experience, culture, and environment, and have emphasised the crucial notion of *embodiment*, which, in opposition to the classical mind/body dualism, underscores the role of physical laws, the human body, and its neurophysiological organisation both in cognition and language (cf. e.g., Lakoff and Johnson 1980; Johnson 1987; Hampe 2005; Gibbs 2005; Evans et al. 2007; Barsalou 2008). Within the perspective of interaction between perception, language, and thought, a significant research domain concerns the complex phenomenon of metaphor. Recent studies (although substantially anticipated in the past centuries by Aristotle, Vico, Richards, Black) have pointed out the force of metaphor as a powerful cognitive categorisation device, based on embodiment and experience, and constrained by context (cf. among others, Stern 2000; Leezenberg 2001; Bazzanella 2001, 2009).

This applies even more to *synaesthesia*, given the direct embodiment of sensory modalities in the process of perception. Synaesthesia, more clearly than other linguistic expressions and phenomena, involves "two broad categories of human experience: […] sensory experience [… and] introspective or subjective experience" (Evans et al. 2007: 64–65). The interplay of physiological and cognitive factors (i.e., neural bases and perceptive inputs on the one hand, knowledge processing, storage and categorisation, on the other; cf., e.g., Taylor 1995; Barsalou 2003, 2008; Ramachandran and Hubbard 2003) is both constrained and enriched by a specific linguistic system, and by the set of features of context (both global and local, according to Akman and Bazzanella 2003).

In the following sections, after discussing Williams' hypothesis (1976) on the hierarchy of synaesthetic pairings (see 3.2.1, 3.2.2, 3.2.3), we will limit ourselves to presenting linguistic data about auditory and tactile synaesthesias in contemporary Italian, on the basis of the *ItWaC* corpus as well as specific research on the lexical components in linguistic synaesthesia (see 3.3).

3.2 The hierarchy of synaesthetic pairings

3.2.1 *Williams' hypothesis*

Wishing to identify "a systematic way in which structures of meaning can change", and taking Berlin and Kay (1969) *Basic Color Terms* as a model, Williams (1976: 461) studied semantic changes and the metaphorical mapping of sensory adjectives in English: "[…] in the lexical field of English adjectives referring to sensory experiences, there has been a continuing semantic change so regular, so enduring, and so inclusive that its description may be the strongest generalization in diachronic semantics reported for English or any other language." (Ibid.).

Williams' starting point was the work of Ullmann (1957: 266 ff.), who had analysed the sensory lexicon in the work of Byron, Keats, Wilde, and other 19th-century English poets. Ullmann (1957) noted various degrees of differentiation in the lexicon of sensory modalities and described the following hierarchy: sight > sound > smell > taste > touch. He concluded that sight is the most differentiated modality, whereas touch is the least differentiated one. Following this hierarchy, Ullmann (1957) introduced *the directionality principle*, which states that metaphorical mapping goes from lower to higher modalities (note that within the hierarchy, the only possible direction is from right to left). A synaesthetic expression, such as "warm colours", is composed of a head and a modifier. The modifier usually refers to a lower modality (e.g., touch, on the right side of the hierarchy), whereas the head of the noun phrase refers to a higher modality (such as sight, on the left side of the hierarchy). In Shen and Gil's words (2008: 3): "[…] with greater than chance frequency, synaesthetic metaphors involve mapping upwards on the Hierarchy of Sensory Modalities". Furthermore, Ullmann noted the poets' frequent use of tactile modifiers (i.e., mainly adjectives) and acoustic nouns.

Using the definitions given in *the Oxford English Dictionary* (OED) and *the Middle English Dictionary* (MED), Williams proposed a hierarchy of possible synaesthetic combinations with regard to English sensory adjectives. He particularly focused on words referring to perceptual domains — colour-related words, such as *red* and *yellow*; and touch-related words, such as *soft*, *tender*, etc.

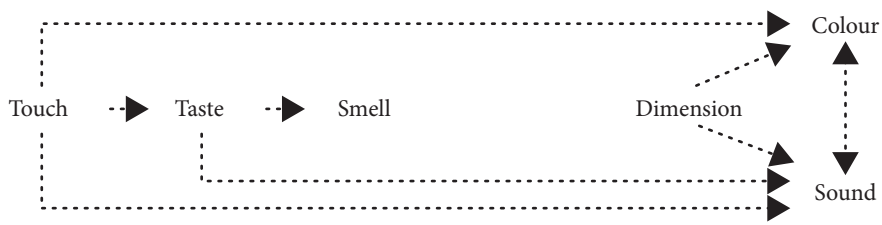

Figure 1. Williams' hierarchy of synaesthetic pairings (1976: 463 — modified)

In the first phase of his research, Williams grouped sensory words (a sample of sixty-six terms)[18] into six different categories: colour, sound, dimension,[19] touch, taste, and smell. In the second phase, he examined the synaesthetic pairings occurring between the sampled sensory words and other sensory words. Eventually, the synaesthetic pairings were grouped according to their modifier.

The proposed hierarchy shows the direction of possible synaesthetic modifications. As shown in Figure 1, a touch-related word may shift to taste, colour, or sound, but not to smell; colour-related words transfer only to sound, while sound-related words may shift only to colour, etc. As Ullmann had previously noted, touch-related words are the principle source of synaesthetic transfers. The arrows in the diagram show the (preferential) directionality in synaesthetic pairings. According to Williams (1976: 464), a touch-related word may modify a colour-related word (such as "warm colour"), but the opposite is not possible: an expression such as "yellow temperature", for example, does not make sense.

From a historical point of view, the hierarchy shows that "[…] if a lexeme metaphorically transfers from its earliest sensory meaning to another sensory modality, it will transfer according to the schedule" (Williams 1976: 463). Therefore, if a touch-related word metaphorically transfers, it may shift to taste (e.g., *sharp taste*), to colour (e.g., *warm colour*), or to sound (e.g., *soft sound*). Touch-related words do not transfer to dimension or to smell (e.g., **warm odour*, **soft angle* — Williams 1976: 464). Colour-related words shift only to sound (e.g., *brilliant sound*), while sound adjectives transfer only to colour (e.g., *quiet colour*; ibid.).

The majority of these words may metaphorically transfer more than one time. Accounting for these second order transfers is more difficult, as it is not always possible to say whether they follow the hierarchy or not (cf. Williams 1976: 465). For example, the touch-related adjective "sharp" is connected with taste, smell, dimension, and sound; while it is relatively easy to predict that the taste meaning is related to the one connected with touch, it is not possible to decide whether the sound meaning derives from touch or from taste (ibid.).

On the basis of Ullmann's study of Hungarian, limited research on Japanese, and similar evidence from other Indo-European languages (i.e., Greek, Latin, Italian, Middle High German), Williams (1976: 469 ff.) hypothesised that the hierarchy was universal, and confirmed Ullmann's *directionality principle*.

3.2.2 *Recent developments*

Other semantic-typological studies (e.g., Wise 1997; Yu 2003; Shibuya et al. 2007) assumed the presence of a universal tendency in the pattern of linguistic synaesthesias. The universality of the directionality principle was confirmed by a number of studies, although some variations were found, mainly due to the arbitrary position of some elements, such as hearing and sight.[20] Using a corpus of literary texts,

Day 1996 essentially validated Ullmann's hierarchy in English and in German.[21] He showed that in both languages, the most common synaesthetic pairing consists of a touch modifier and a hearing head (e.g., *soft word*). The least frequent pairings are composed of a vision modifier and a smell head, or between a hearing modifier and a smell head. Interestingly, some pairings never occur. For instance, pairs with a temperature head and a hearing modifier (e.g., **melodic temperature*), or with a taste head and a visual modifier (**pink taste*)[22] do not occur.

Evidence supporting the universality of the hierarchy also comes from other languages, such as French, Chinese, and Indonesian. Wise 1997 confirmed Williams'1976 hierarchy for everyday French, with some exceptions for poetic French (using Baudelaire's poems as a corpus).[23]

Using a sample of synaesthesias taken from novels and short stories by Mon Yan (a well-known contemporary Chinese novelist), Yu 2003 largely validated the directionality principle for Chinese. The hierarchy was also confirmed by Shen and Cohen (1998: 8–9) with regard to Modern Hebrew poetry (only seven percent of the synaesthesias in their sample did not follow the directionality principle); while Shen and Gil 2008 verified the hierarchy for Indonesian.

How can the universality of the directionality principle be explained? According to Shen and Cohen (1998: 10), the synaesthetic pairings which conform to the directionality principle are considered more natural by speakers and easier to recall; in other words, the concepts represented in the lower part of the hierarchy are more accessible and more concrete than the ones expressed by the higher part of the hierarchy, and follow a general cognitive principle: "In this respect a synaesthesia is but a special case of a cognitive principle which applies to metaphors in general" (Ibid.).

Other explanations, more related to neurophysiological aspects, have been put forward, such as the one proposed by Shibuya et al. (2007: 216–217). These authors hypothesised that the difference in the acceptability of expressions such as "warm colours" and their inverse "yellow temperature" is due to the "structure of sensory experiences". Accordingly, the sensory associations that generate linguistic synaesthesias are produced by the sensory co-occurrence of two sensory modalities. Despite this, the sensory associations do not only refer to the simultaneous involvement of two sensory modalities, but also reflect the strength of different associations; as they claim: "For example, the tactile sense and the visual sense co-occur frequently, but the strength of the sensory association which the tactile sense has with the visual sense differs from what the visual sense has with the tactile sense. We call the specification of a sensory association the 'structure of sensory experiences'" (Shibuya et al. 2007: 217). This means that the reason why some sensory associations are stronger and others weaker is to be sought in our daily sensory experience and the frequency of the co-occurrence of two sensory

modalities. Referring to touch and vision, when we observe an object we usually do not get any tactile information about it; on the contrary, when we touch something, there is normally also some simultaneous visual information (Ibid.).

From a cross-linguistic point of view, Shibuya et al. (2007: 218) suggested that, since our bodily experiences are universal (see above for the notion of *embodiment*), similar sensory associations are learned in every language, and similar synaesthetic metaphors are produced.

According to Williams, a touch-related word may modify a colour-related word ("warm colour", for example), but the opposite is not possible (Williams, who considered "temperature" a touch-related word, noted that an expression such as "red temperature" does not make sense). Furthermore, not all pairings are unidirectional. Indeed, colors and sounds may modify each other (e.g., "bright sounds", "musical brightness").

Another possible cognitive explanation for the hierarchy was proposed by Popova (2005: 401), who noted that, out of the approximately seventy words describing sensory experience in Williams' sample, forty-eight referred to touch[24] and another nine to taste. According to Popova, the particular phenomenology of touch may explain its dominance as a source domain in synaesthetic mapping, and even the directionality principle. She first argues that "certain attributes like thickness, hardness, or the presence of vibration" may be perceived only by touch (Popova 2005: 400). Secondly, she points out that touch is the only modality that differentiates between active and passive perceptions (we can intentionally explore an object by moving our hands, but we passively perceive pain; ibid.). She then states that the way touch is perceived differs from the way we experience our other senses. "While I can feel myself touching, I cannot see myself seeing"[25] (Popova 2005: 401). Finally, and most importantly, touch is different from vision because it explores objects "[…] slowly and sequentially, not globally and simultaneously, as does vision" (Popova 2005: 402). As a result of the fragmentation of tactile experience, touch may be the experiential grounding for the concept of *scalarity* (ibid.). In cognitive linguistics, with regard to this concept, which is often equivalent to *gradability*, the fundamental property of adjectives is traditionally considered to be the latter. As Popova (2005: 404) pointed out, adjectives (or modifiers) code qualities or properties of objects, which usually have "inherent degrees of intensity" (i.e., gradability). In most cases, adjectives are locational, i.e., they are not absolute, but instead refer to points along a scale of intensity (*gradable adjectives*). For example, the touch-related modifier "smooth" cannot be defined without an implicit comparison with its opposite "rough". On the contrary, non-gradable adjectives, configurational ones, are rare. As an example, shape adjectives can be considered configurational: in no way is being round in shape scalar; an object may or may not be round, but it cannot be more or less round than

another, similar to the way objects can be softer or less soft in comparison to others (Popova 2005: 409). Consequently, since touch is typically a scalar, gradable experience, tactile adjectives can be considered prototypical modifiers. Visual and sound adjectives instead refer preferentially to configurational properties (Ibid.). Touch and taste provide relative, locational sensations, which are likely to qualify configurational experiences, such as the perception of a shape or of a single note, whereas the inverse is not possible.

To sum up, the mapping delineated by the directionality principle can be seen as the tendency to describe configurational concepts through locational ones.

3.2.3 *Discussion of Williams' hierarchy*

Studies of preferential synaesthetic pairings reveal a close connection between perceptual experience and language (see Section 1), thus making plausible the hypothesis of a neurophysiological basis for synaesthesia, even though further investigations are needed to clarify some crucial problems.

The first of these is the question of universality, which is very difficult to establish for linguistic phenomena. To verify the universality of any aspect of language, hundreds of languages, from different regions in the world, would need to be considered. In addition, the use of a certain structure or expression in a language should be ascertained by interviewing mother-tongue speakers, or through the analysis of wide corpora. Williams based his hierarchy on a relatively small sample of words (about seventy), and it is possible that the quotations from the *OED* and the *MED* (especially the literary ones) were not representative of standard English. Similar criticisms may be expressed when considering the typology and size of the sample selected by Yu (2003) (the language used by Mon Yan might not be a representative sample for Chinese) and by Shen and Gil (2008), who failed to indicate the number of words included in their corpus of Indonesian. Without a large sample of languages, systematically analysed with reference to large-scale corpora (representative of both written and spoken language and of different conversational registers), it is not possible to assume the universality of the directionality principle.[26]

Secondly, in order to demonstrate a tendency in preferential synaesthetic pairings, the sensory domains have to be selected by using robust neurophysiological criteria, that is, by considering the actual organization of sensory systems.

Thirdly, several aspects of Williams' 1976 categorisation of sensory words (touch, taste, smell, dimension, sound, and colour; see 3.2.1) are problematic. From a neurophysiological point of view, the set of touch cannot be considered as a single domain, but should be split into the three submodalities of somesthesia: "actual" touch (mechanical pressure), pain, and temperature (cf. Kandel et al. 2000). Williams' inclusion of the dimension set appears to be arbitrary, since it is not grounded on any physiological correlate; furthermore, dimension attributes

(e.g., "big", "thick", "thin", "flat") seem to describe properties that are inherently synaesthetic: the shape of an object, its internal and external structure, and its global dimension can be perceived either via touch or vision. Finally, it should be noted that Williams' colour-related set consists mainly in luminosity attributes (e.g., "dark", "dim", "bright", "brilliant"), while there are no actual chromatic terms (such as "red" or "yellow").

A more rigorous categorisation of sensory domains, grounded on neurophysiological criteria, is required. Such a new categorisation would reorganise the dimension by inserting it into a larger synaesthetic set. Eight different sensory domains should be included: touch, pain, temperature, colour-related vision, non colour-related vision, sound, taste, and smell.

3.3 A corpus-based analysis of auditory and tactile synaesthesia in Italian

3.3.1 *Methodological issues*

To verify the universality across languages of the hierarchy proposed by Williams (1976), and the kind and frequency of synaesthetic pairings in Italian, we carried out a corpus-based analysis of auditory and tactile synaesthesias (the latter with particular focus on the texture domain).[27]

In the first phase of our study we used neurophysiological notions (Kandel et al. 2000) to identify the reference sensory domains. After this, through dictionary analysis, we identified and collected sensory-specific lexica; the relevant sensory domains of the selected words (nouns and adjectives) were assessed by fifty mother-tongue speakers. Subjects had to choose from eight possible sensory domains: audition, touch, pain, temperature, taste, olfaction, colour-related vision, and non colour-related vision. Subjects were allowed not to answer, if they thought that a word was ambiguous, or to choose more than one sensory domain. Therefore, some terms proved to be *polysensory*; for example, *pungente* (pungent) in Italian refers to both olfaction and somatosensation. Other words were assigned to a sensory domain that differed from their literal/etymological meaning (we labelled these words as polysemic); to cite an example, *cremoso*, creamy, was mainly connected with taste, even though its meaning refers to the tactile domain of texture.[28] We excluded both polysensory and polysemic words from the sample. Finally, we quantified and analysed the sensory lexica of audition and touch (see Table 2). The identification of these lexica was crucial in determining the approximate number of words belonging to each set, and their grammatical class. The auditory set (180 words in total) was composed mainly of nouns (approximately ninety percent), and the few adjectives rarely gave rise to synaesthetic pairings. On the contrary, almost seventy percent of the tactile words (110 out of 160) were adjectives (Table 2).

Table 2. Number of touch and audition adjectives and nouns.

Modalities	Adjectives	Nouns
TOUCH	110	50
AUDITION	20	160

In the third phase we prepared a representative sample of words (labelled "anchors") for audition and touch. With regard to these anchors (that correspond to twenty percent of the entire sample) the percentages of adjectives and nouns in each sensory domain reflect the proportions of the group as a whole. As an example, if auditory nouns were thirty percent of the entire sample of nouns, auditory nouns chosen as anchors would be thirty percent of the total number of anchor-nouns.

In the last phase, we identified linguistic synaesthesias containing the anchors. We used the *ItWaC* corpus, a collection of texts made by the University of Bologna (Forlì centre) as part of the *WaCky* project, whose aim is to employ textual resources from the web in order to build linguistic corpora for different languages. *ItWaC* contains two billion words taken from texts gathered from web pages with the domain '.it' (that is, the abbreviation for Italy in internet addresses). Since the material was taken from the Internet, it comprises many different text types, such as literary works, blogs, newspapers, advertisements, etc., thus covering broad aspects of Italian written language.

3.3.2 *The results of a corpus-based analysis and parallels with multisensory experiments*

The corpus-based analysis revealed the existence of preferential synaesthetic pairings in Italian, suggesting that the directionality principle and Williams' (1976) hierarchy do apply to this language.

In auditory synaesthesias (Figure 2), forty-one percent of auditory nouns are paired with tactile adjectives e.g.,:

(1) *suono delicato*
sound delicate
'delicate sound'

(2) *suono morbido*
sound smooth
'smooth sound'

(3) *rumore secco*
noise dry
'sharp noise'

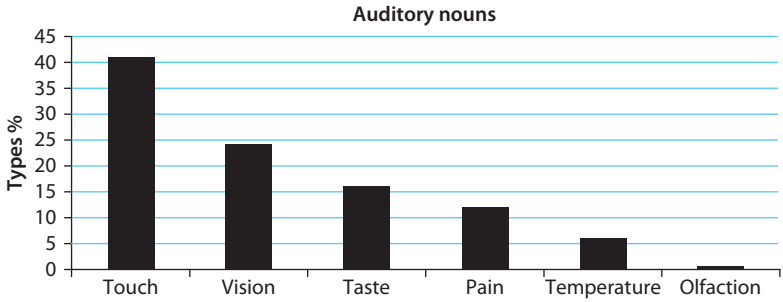

Figure 2. Auditory nouns. The graph shows the frequency of occurrence of different kinds of synaesthesia, composed of auditory heads. The sensory modality of the modifying adjectives are shown on the x axis, their frequency distribution on the y axis.

whereas twenty-four percent of auditory nouns are paired with visual adjectives e.g.,:

(4) *rumore brillante*
noise bright
'bright noise'

(5) *suono oscuro*
sound dim
'dim sound'.

Sixteen percent of auditory nouns are paired with taste adjectives e.g.,:

(6) *musica dolce*
music sweet
'sweet music'

(7) *suono aspro*
sound sour
'grating sound'

and twelve percent with pain attributes e.g.,:

(8) *canto doloroso*
song painful
'painful song'.

In contrast, eighty percent of auditory adjectives (Figure 3) are paired with visual nouns e.g.,:

(9) *ombra silenziosa*
shade silent
'silent shade'

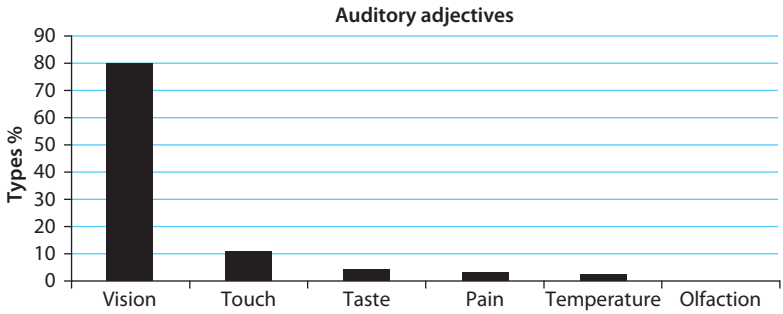

Figure 3. Auditory adjectives. The graph shows the frequency of occurrence of different kinds of synaesthesia, composed of auditory modifiers. The sensory modality of the heads is shown on the x axis, their frequency distribution on the y axis.

(10) *limpidezza melodica*
limpidity melodic
'melodic limpidity'

and eleven percent are paired with tactile nouns e.g.,:

(11) ruvidezza acustica
roughness acoustic
'acoustic roughness'.

In order to ensure that our results in the acoustic domain were not biased by the choice of anchors, we calculated the frequency of occurrence of synaesthetic pairing between auditory nouns and texture adjectives, using the texture adjectives as anchors. Figure 4 shows that fifty-nine percent of texture adjectives are paired with auditory nouns e.g.,:

(12) *voce grinzosa*
voice wrinkled
'harsh voice'

(13) *sussurro vellutato*
whisper velvety
'velvety whisper',

while twenty-eight percent are paired with visual nouns e.g.,:

(14) *aspetto ruvido*
appearance rough
'rough appearance'

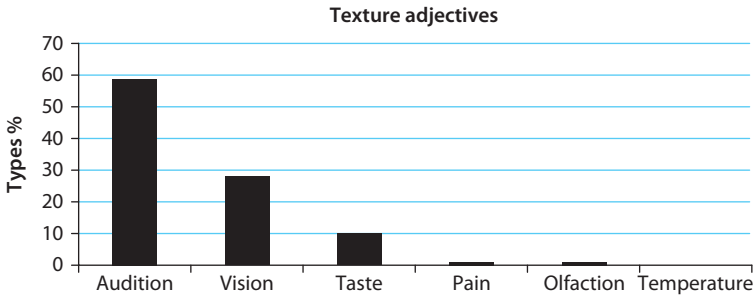

Figure 4. Texture adjectives. The graph shows the frequency of occurrence of different kinds of synaesthesia, composed of texture adjectives. The sensory modality of the heads is shown on the x axis, their frequency distribution on the y axis.

(15) *sguardi vellutati*
gazes velvety
'velvety gazes';

thus confirming that there is preferential pairing between tactile modifying adjectives and auditory nouns.

Crucially, the most frequent synaesthetic pairings observed in the corpus-based analysis (Figures 2–4) seem to correspond to the most effective interactions between distinct modalities (see Section 2). Auditory nouns are mainly paired with tactile modifiers, consistently with the observation that tactile stimuli strongly influence auditory perception. In contrast, auditory adjectives rarely modify tactile nouns and, accordingly, tactile perception is weakly affected by concomitant auditory stimulation (see Section 2.2.2).

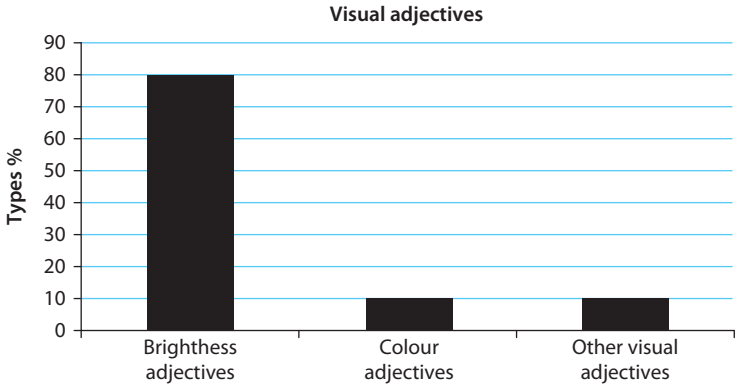

Figure 5. Visual adjectives. The graph shows the frequency of occurrence of different kinds of synaesthesia, composed of auditory heads and visual adjectives. The sensory modality of the heads is shown on the x axis, their frequency distribution on the y axis.

Similarly, visual and auditory words are frequently paired, (i.e., visual adjectives are paired with auditory nouns, and auditory adjectives are paired with visual nouns), a notion consistent with the psychophysical evidence of a reciprocal influence between these modalities (see Section 2.2.1). Interestingly, psychophysical interactions between vision and audition are not present in experimental paradigms involving colours (cf. Leo et al. 2008; Arieh and Marks 2008). Figure 5 shows that in synaesthetic pairings between auditory nouns and visual adjectives, eighty percent are constituted by auditory nouns modified by visual adjectives referring to brightness (see examples 4–5), whereas only ten percent are constituted by auditory nouns modified by visual adjectives referring to colour,[29] e.g.,:

(16) **suono giallo*
sound yellow
'yellow sound'.

4. Conclusions

The comparison between linguistic and neurophysiological data indicates a strong parallel between frequent linguistic synaesthesias and effective interactions between distinct stimuli, thus suggesting that linguistic synaesthesias follow the same tendencies governing the perceptual integration of different sensory modalities.

Associative processes and functional interactions between different sensory systems play a crucial, albeit different role, both in perceptual and linguistic synaesthesias. In Mazzone's (2011: 2151) terms, with regard to apprehended neural connections:

> […] there is the largest possible evidence that we collect information from the environment by coding regularities thanks to the strengthening of synaptic connections between neurons and between neuron assemblies, and that we can subsequently exploit that information thanks to a simple dynamics of accessibility: the more two pieces of information are regularly connected in our experience, the more the connections between them (between their representations) are strong, and the more accessible they are to each other. Since this is basically the way in which we detect and store information, it can be expected that associative access forms the basis of the brain's automatic activity every time we have to resort to our stored knowledge.

In this article, we have highlighted the possible correlation between some preferential connections which are selected in linguistic synaesthesia, neurophysiological features, cerebral architecture, and the role of multisensory processes: reciprocal influences between different types of stimuli profoundly shape perception, thus modeling and influencing the way we describe our sensory experiences.

Further multisensory experiments exploring the effectiveness of the preferential pairings identified in our corpus-based analysis are needed to confirm these parallels and clarify related issues.

Perceptual/embodied experience, genetic/epigenetic/cultural constraints, and recurring patterns of activity, interacting with different sensory systems, converge in driving human cognition in an adaptive fashion, both in phylogenesis and ontogenesis. As the psychologist Kelso (1997: 268) maintains: "Musculoskeletal structures coevolved with appropriate brain structures so that the entire unit must function together in an adaptive fashion […] it is the entire system of muscles, joints, and proprioceptive and kinaesthetic functions and appropriate parts of the brain that evolve and function together in a unitary way".

With regard to language, according to a view that consider it as a complex, dynamic, and emergent system (cf. Hopper 1987; Bybee and Hopper 2001), the phenomenon of synaesthesia, and in general of metaphorical language, will contribute to a better understanding of the richness of this fundamental human device, its flexibility, its multiple interactions and constraints, and will further clarify how connections with sensory perceptions become conceptualised and lexicalised, in both conventional and creative ways, where cognition and pragmatics meet.

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Notes

1. Nikolić 2009 proposes an alternative word, ideaesthesia, which is a combination of two ancient Greek words, one for concept, "idea", and the other for sensation, "aisthesis". In translation, ideaesthesia means sensing concepts or perceiving meaning.

2. Some modalities may be divided in submodalities. For example, *somesthesia* refers to somatic sensibility, and is usually divided in submodalities including touch, proprioception and nociception, and thermoception (cf. Kandel et al. 2000).

3. As Simner et al. 2006 claimed, synaesthesia is far more common than previously thought. When testing a sample of 500 participants, they found 22 synaesthetes (4.4%), and showed that the most common form of synaesthesia is coloured days. Their study also excluded a gender bias, as it found no asymmetry in the distribution of the synaesthetic trait between men and women (a ratio of 1.1:1).

4. Accidentally, in the literature, the same, umbrella term "synaesthesia" has been used to describe different aspects, according to the different disciplinary perspectives (that is, philosophical, psychological, neurological, linguistic, let alone the artistic one). From a linguistic point of view, for centuries it has indicated a rhetoric figure, whereas neurophysiologists have employed exactly the same word to describe a neurological condition. Importantly, both in the rhetorical-linguistic literature and in the neurophysiological one, we can find a huge number of publications (spread among centuries of studies) in which the two phenomena are referred simply as "synaesthesia". In this paper, the rhetoric figure is referred to as "linguistic synaesthesia", and the neurological condition as "perceptual synaesthesia", in order to avoid any possible ambiguity.

5. According to data presented in Cytowic and Eagleman (2009: 16) concerning peer reviewed papers on synaesthesia written between 1859 and 2006, interest in synaesthesia has changed: "There was considerable interest at the turn of the twentieth century, followed by a marked dropping off during the decades that behaviorism held sway as the dominant psychological paradigm. Increasing of interest characterizes recent decades, indicating a second renaissance of synaesthetic study".

6. Spector and Maurer (2008) found that both adults and colour-grapheme synaesthetes consistently map some letters to certain colours (for example A is often considered to be red, O white, and X black). Some of these associations seem to be language-based. Most adult English people associate G with green, whereas for children who are not able to read this pairing is not consistent. However, other associations, such as O with white and X with black, are already present in toddlers and therefore cannot be language/literacy driven. It is possible that there are natural biases which link some grapheme shapes with specific colours (for example the round shape of the O with white, and X with black) similarly to what happens with associations found between pitch and lightness (see for example Ward et al. 2006).

7. For a critical discussion on synaesthesia stability, see Simner 2011.

8. An interesting effect, related to automaticity in synaesthesia, is *Stroop interference*, discovered by J. Ridley Stroop in 1953. According to Stroop, more time is required, and a strong visceral discomfort like "nails scratching a blackboard" is experienced (ibid.), when the colour of a printed colour word, such as *blue*, *green*, or *red*, does not match its semantic meaning, or when the number is presented in the "wrong" (or incongruent) colour. In other words, the named colour does not coincide with the one with which it is automatically associated by the individual synaesthetic subject (cf., among others, Ramachandran and Hubbard 2003). According to Cytowic and Eagleman (2009: 48), "Stroop interference proves that synaesthesia is automatic, but it does not by itself tell at what stage the interference takes place. Is it in early, unconscious processing stages, or instead during the later, consciously deliberate selection of a response?".

9. For a recent, stimulating debate on consciousness, cf. Cole and Dascal (eds) 2010.

10. As the synaesthete Rebecca Price wrote in a letter to Dr. Cytowic (1 May 1987 — quoted in Cytowic and Eagleman 2009: 39): "One of the things I love about my husband are the colors of his voice and his laugh. It's a wonderful golden brown, like crisp, buttery toast, which sounds very odd, I know, but is real.".

11. On the central role played by analogy in metaphorical modelling, cf. e.g., Gentner et al. 2001; Formigari 2009.

12. In a broader sense, some perceptual-synaesthetic effects are context-sensitive. In letter-colour synaesthesia, for example, the colour of a word may be triggered by the first letter (cf. e.g., Cytowic and Eagleman 2009).

13. Other problems, such as the subject's degree of awareness (cf. e.g., Mazzone and Campisi 2009 with regard to embodiment and metaphor in general) will not be dealt here, while the discussion on the unidirectionality of synaestethic pairings will be briefly addressed in Section 3.2.3.

14. The involvement of parietal multisensory areas in grapheme-colour synaesthesia has also been proposed by Muggleton et al. 2007, and by Beeli et al. 2007, who also indicated the orbitofrontal multisensory cortex is involved in synaesthetic effects.

15. Multisensory integration can be investigated both psychophysically and with a wide range of neurophysiological techniques, including anatomical tracing studies (cf. Cappe and Barone 2005), single- and multi-neuron electrophysiological recordings (cf. Stein and Stanford 2008; Ghazanfar and Schroeder 2006), and probabilistic modelling of EEG and fMRI data (cf. Driver and Noesselt 2008).

16. As Ghazanfar and Schroeder (2006: 278) conclude: "the work published to date may reveal only the 'tip of the iceberg', as ongoing studies continue to reveal extensive interactions among low-level sensory areas and between those areas and association cortex.".

17. For example, in contemporary western culture, "blue" has a positive valence and a certain saliency (it is the favourite colour of the large majority of adult Europeans; c.f. e.g., Pastoureau 2001; Ronga 2009). There are social and historical reasons why this is so (it is the colour associated with the Virgin Mary, the colour of the European Union flag, etc.,). But, this is not true in non-western cultures and even in Europe, in the past blue had negative connotations: it was associated with deprivation, shadow, darkness, weakness, cold, and distance (cf. Goethe 1810).

18. Williams (1976: 474) excluded from his sample sensory words that did not generate synaesthetic metaphors; examples of these terms are: *wet*, *damp*, *long*, and *short*, and derived words, such as *muddy* or *lemony*.

19. In the dimension set, Williams (1976: 463) included terms related to the "visually perceived dimension" of objects (e.g., *big*, *flat*, *high*, *low*), and their three-dimensional structure (e.g., *thick*, *thin*, *full*).

20. As Ullmann observed, the order of hearing and sight is not relevant in the hierarchy, as they may be respectively modified by each other. This is the reason why some authors propose vision be considered the first sensory modality, while others indicate hearing as the first (see e.g., Day 1996, and note 21).

21. Day (1996: 6 ff.) added the category "temperature" to the five standard modalities, by splitting the set of touch. The hierarchy was modified as follows: hearing > vision > temperature > smell > taste > touch. Regarding the opportunity to split the different modalities by employing neurophysiological criteria, instead of the common sense, see below.

22. It seems that some pairings coupling a taste head with a visual modifier may be acceptable and widely used (especially to describe food and drink), but only if the visual adjective refers to

brightness instead of colour (e.g., *bright taste*, *bright flavour*). For a discussion of these exceptions and possible explanations, see below.

23. Wise's 1997 analysis may have been influenced by the kind of samples she selected, since Ullmann 1957 examined French creative synaesthesias and concluded that they follow the directionality principle. Although the complexity of the parameters involved and the search for generalisations and systematic patterns (cf. e.g., Biber et al. 1998) necessarily require resorting to corpora, the selection and characteristics of a given corpus may affect, at least in part, the results obtained. The crucial problems can be attributed to: non-complete representativeness, lack of adequate contextualisation, the '*partiality*' of the evidence provided, the need for interpretation and theoretical explanation (cf. Bazzanella forthcoming).

24. Popova (2005: 401 ff.) considered dimension to be a touch-related set; on the contrary, Williams (1976: 463) classified dimension as visual-related. Although Williams also noted the large number of touch modifiers, in Popova the disproportion between touch-related words and other sets is even greater. It is true, however, that the dimension set is composed of attributes such as *thick*, *thin*, *round*, etc. These kinds of shape properties of objects can be perceived both visually and tactilely, and it is therefore difficult to ascribe this set of words to a specific sensory modality (for a hypothesis that dimension can be seen as a set of inherent synaesthetic words, see below).

25. More specifically, when I perceive my finger touching my lips, I can feel the pressure of the finger on my lips and, at the same moment, the texture of my lips on my finger; conversely, I can see myself looking at myself only from a different point of view, such as a mirror. In other words, "tactile experience provides us with sensations that are continuous, sequential and non-discrete. Vision is different: it construes its objects not sequentially but discretely; it experiences not by degree but by totality" Popova (2005: 409).

26. A synaesthetic expression is generally considered to be a noun phrase composed of a noun and an adjective. Demonstrating the universal validity of Williams' hierarchy is likely to prove difficult as in some languages (e.g., Eastern Ojibwa, Algonquian spoken in eastern Canada and the United States), adjectives (i.e., the term which denotes a property) do not form a distinct word class (insofar as they may be nouns or verbs), and in others (e.g., Mesa Grande Diegueño, Yuman, spoken in southern California and northwest Mexico), they do not really modify nouns as they are predicates in internally headed relatives clauses (cf. Dryer 2005: 354–355).

27. Generally speaking, texture is the feel and the appearance of a certain surface or substance. In common usage, texture properties may also refer to consistency (in the *Oxford English Dictionary* we find the example: "the cheese is firm in texture"). However, in scientific papers (for a review see Lederman and Klatzky 2004) texture usually pertains to surface microstructure, especially concerning a specific set of properties ideally equally perceived by touch and vision (such as the grain of the surface of a stone, or the roughness/smoothness of fabric). Accordingly, in most cases, texture describes the perceived roughness of a certain surface (see for example Guest and Spence 2003).

28. In Italian "creamy" is generally paired with "taste", thus forming the collocation "creamy taste". Therefore, even if the reference to the tactile domain is present in the meaning of "creamy", the common linguistic use of the adjective profoundly affects its semantics.

29. According to Popova 2005 (see Section 3.2.2), colour adjectives cannot be employed as modifiers, since they are configurational. However, this does not seem to be true, as the difference between configurational and locational modifiers cannot always explain the distribution of synaesthetic pairings. For instance, temperature-related modifiers are a very good example of locational adjectives and, contrary to Popova 2005's prediction, they do generate a few synaesthetic pairings.

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