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Synesthesia on Our Mind

Abstract. Synesthesia in perception and metaphor in language both provide ways to categorize and comprehend the world. Both operate through mechanisms that capitalize on the creation or discovery of links across disparate domains – notably, sensory experiences in different modalities, with cross-modal correspondences serving as perceptual links in synesthesia and as conceptual links in metaphor. The perceptual links in synesthesia are typically fixed and rigid. The conceptual links in metaphor, however, enable meanings to expand, creatively, through the active construction of novel, emergent relations: Metaphors transform meanings, thereby transcending the fixed correspondences of synesthesia. Recent evidence associates the presence of synesthesia with an augmented capacity for creative cognition. Other evidence associates synesthesia with neural hyperconnectivity – augmented connectivity between regions of the cerebral cortex that process the synesthetically linked domains. We suggest that mechanisms underlying synesthesia may also play a role in processes that foster creative transformations of meanings in metaphor.

Keywords: metaphor; meaning; cross-modal correspondence, neural hyperconnectivity; creative cognition.

Introduction

A relatively small proportion of the population exhibits synesthesia, a condition in which specific experiences in one domain – sensory, perceptual, or cognitive – consistently arouse specific experiences in other domains. Musical notes may arouse sensations of color, for example, or people's names may arouse flavors. To those of us who lack synesthesia, synesthetic experiences may be difficult to conceive. Imagine two friends, Synesthete Syd and Average Joe, listening to a recording of Glenn Gould playing Bach's *Well-Tempered Clavier*. Because Syd experiences a complex form of auditory-visual synesthesia, she sees colored squares move in synchrony to the notes of the first 'Prelude in C.' Average Joe, however, is not a synesthete. Consequently, when Syd describes these experiences to her friend, Joe has a hard time understanding exactly what Syd means, not certain just what it is that Syd is actually experiencing. Lacking synesthesia, Average Joe cannot share, first hand, the breadth of Synesthete Syd's multisensory perceptual experience. He hears the musical notes, as Syd does, but he does not see the shapes and colors, which she also sees. Nevertheless, Joe does have an inkling of what Syd sees, for he can *imagine* seeing a musical dance of colored squares.[1]

Lacking the first-hand experience of synesthesia, but knowing what colors look like and what notes sound like, Joe wonders whether Syd might be speaking figuratively, whether she too might simply be imagining colored notes dancing to the musical tempos. Indeed, there have been skeptics in the past who suggested that people reporting synesthesia were simply speaking figuratively. Several decades ago, an eminent psychologist – at the time, a faculty member at the first author's university – suggested that people reporting synesthesia simply have 'overactive imaginations'. To such a skeptic, there was little reason, at the time, to accept at face value the assertion that synesthetes were actually experiencing the *qualia* that they were reporting.

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[1] Because Joe has first-hand knowledge of color *qualia*, he is better able to share first hand the experience of note-color synesthesia than he is to share first hand the experience of an echolocating dolphin or bat (see Nagel 1974). Dolphins and bats emit ultrasonic signals (acoustic signals greater than 20 kHz) and use the resulting echoes to navigate and to locate objects. But the *qualia* associated with echolocation are not known, perhaps unknowable to humans, and these *qualia* may not mimic those of any human sense.

Evidence garnered over the past decade and a half, especially from neural imaging (discussed later), supports the view that synesthetes do have the phenomenal experiences they describe, that synesthetic *qualia* are more like sensations than like mnemonic images. Nevertheless, the skeptic mentioned earlier made a point that is important: It can be difficult to decide whether, for example, Syd's report that "that musical note is a bright yellow square" literally describes her auditory-visual experience, induced whenever, for instance, she hears the note of A at 880 Hz, or whether it (or a similar report) is instead a figurative description of auditory experience alone. The difficulty is exacerbated because the two accounts, synesthetic and metaphorical, have much in common – because, as we discuss later, both synesthetic experiences and metaphorical cognitions are often characterized by a common set of cross-domain relations (notably, cross-modal correspondences). We contend that both synesthesia and metaphorical language serve as ways of categorizing and understanding the world, each operating through processes that capitalize on the discovery or creation of connections between domains.

In this article, we explore several relations between synesthesia and metaphor, as these relations reveal themselves in perception, language, and figurative thinking. In particular, we explore the ways that correspondences across different domains, especially correspondences across different sense modalities (cross-modal correspondences), serve as perceptual or conceptual links in synesthesia and in metaphor. We also examine the possible ways that mechanisms that underlie synesthesia may also underlie the processes that generate novel, emergent, perceptual or conceptual combinations. Thus, to the extent that constitutional synesthesia is based on the presence of a surfeit of neural connections in the brain, this hyperconnectivity may also play a role in cognitively creative acts. The first author has a long-standing interest in the relation between synesthesia and metaphor (see Marks 1978, 1982a, 1982b, 2014), and the second author has studied the association between synesthesia and creativity, including their possible neural underpinnings (Kay and Mulvenna 2006; Mulvenna 2007, 2012, 2014; Mulvenna and Walsh 2005; Pollak et al. 2007).

Synesthesia or metaphor

The interchange between Syd and Joe raises several interrelated questions, two of which we address here: Is (or to what extent is) synesthesia a special kind of experience? And how is it possible to determine whether a person is describing synesthesia *per se*, the experiences of *qualia* in different

domains, or instead is waxing metaphoric, figuratively describing experiences of *qualia* within a single domain?

Regarding the special status and 'reality' of synesthesia: Scientific evidence gleaned over the past decade in particular has convinced many former skeptics that synesthesia is indeed a special kind of experience. In particular, studies using techniques of neuroimaging have shown how reports of synesthetic experiences often correlate with indicants of neural activity in regions of the brain known to be involved in the corresponding perceptual experiences. For instance, regions of visual cortex such as V4 are implicated in coding colors (Zeki et al. 1991) and regions of V4A and V5 are implicated in coding visual motion (Albright 1984; Tootell et al. 1996), activity being evident in these regions when synesthetes report color or motion induced by non-visual stimuli (Nunn et al. 2002) or by non-chromatic visual stimuli (Hubbard et al. 2005; Mulvenna 2012).

According to this view, augmented neural connectivity between different, and normally disparate, regions of the brain makes it possible for experiences in one domain – such as perceptions of sounds, numbers, or words – to arouse sensory, perceptual, or cognitive experiences in another domain – such as colors, flavors, or visual-spatial patterns. Ramachandran and Hubbard (2001) suggested, for example, that number-to-color synesthesia may reflect connectivity between proximal regions of the fusiform gyrus that separately process visual numbers and colors; as a result, presenting a printed number, although itself achromatic, nevertheless arouses a specific color, at least within an individual disposed to experiencing this form of synesthesia.

Determining whether a particular report, such as "that musical note is a bright yellow square," represents synesthesia or metaphor is not, however, always easy. This is especially the case with texts from the past, as in the example given in *Box 1*. In both synesthesia and metaphor, there are links between specific events in different perceptual or conceptual domains. The links may be idiosyncratic, or they may reflect shared relations. Indeed, a central thesis of this article is the notion that synesthesia in perception and cross-sensory metaphor in language can both rely on perceptual or conceptual features that overlap in different sense modalities; that is, synesthesia and metaphor sometimes depend on the same shared features. Such links to metaphor may, perhaps, even help demystify synesthesia.

"What a crumbly yellow voice you have," [Solomon Shereshevsky] once told L.S. Vygotsky…. – Alexander Luria (1968: 24)

Sound loves to revel in a summer night; / Witness the murmur of the gray twilight – Edgar Allan Poe, *Al Aaraaf* (1829: 27)

We assume – plausibly, from other evidence that Luria recounted – that Shereshevsky was indeed synesthetic and did 'see' Vygotsky's voice as yellow. By way of contrast, the poet Poe no doubt imagined, but probably did not 'hear' – as, perhaps on a cloud-drear day, Shereshevsky might in fact have heard – those indistinct sounds that Poe associated with the dwindling light of imminent night. Shereshevsky explicitly experienced a voice that was yellow, a voice that was not black or silver, neither emerald nor vermillion. If Shereshevsky responded synesthetically to fading light at dusk, then perhaps he too explicitly experienced the way that twilight murmurs. Surely twilight does not bellow.

Poe, however, may have known only implicitly that murmuring resembles twilight. Further, we suspect that Poe knew this because he comprehended, albeit indirectly, that because soft sounds barely rise above their background, they thereby resemble the indistinct light of falling day.

To speak or write *metaphorically* about twilight as murmuring is to express a resemblance between a particular event as seen and another event as heard. By way of analogy, to perceive the sound of a human voice as *synesthetically* yellow is also to express, implicitly, a resemblance (even an identity) between attributes of events that are seen and events that are heard.

Box 1. Synesthesia or metaphor?

Synesthesia

We base the present discussion on evidence gleaned from what has been called *developmental synesthesia* (Ward and Mattingley 2006) or *constitutional synesthesia* (Grossenbacher 1997) – that is, from those cases in which the synesthesia arises in childhood, presumptively with a genetic basis (e.g., Asher et al. 2009) leading to the acquisition of cross-domain correspondences (Simner et al. 2009), and not when the synesthesia is triggered by an adventitious event such as disease or central neural injury (e.g. Beauchamp and Ro 2008), nor by ingestion of psychoactive drugs (e.g., Delay et al. 1951), and not when synesthesia occurs transiently, following, for example, post-hypnotic suggestion (e.g., Cohen Kadosh et al. 2009).

Developmental or constitutional synesthesia, as already noted, has a strong neurophysiological foundation in the anatomical connectivity between regions of the brain that process the linked domains, such as colors

with sounds (Nunn et al. 2002) and colors with graphemes (numbers, letters) (Hubbard et al. 2005). The cortical connections presumably parallel the phenomenological experiences of colored music or colored graphemes. Synesthetic experiences themselves are discrete and idiosyncratic: Synesthetes experience their own idiosyncratic pairings, often disagreeing with one another (the letter E may be red to one synesthete but blue to another), and each synesthete's experiences typically remain stable over many years, even decades (Simner and Logie 2008). The best evidence suggests that at least 1 person in every 25 experiences one form or more of synesthesia (Simner et al. 2006), with forms of synesthesia such as grapheme-color and word-color being more prevalent than tone-color and word-taste.

Metaphor

Metaphors, it is sometimes said, are implicit similes, statements of resemblance that dispense with a linking 'similar to' or 'like.' Metaphors indicate how two concepts that differ in many respects are alike in some other, important respect or respects. While the topic of metaphor has a long history in discourse on language and rhetoric, there is a strong case for the argument that metaphor represents a fundamental mode of thinking, that much of human conception is couched in implicit metaphors (Lakoff and Johnson 1980).

As Langer (1967) emphasized, metaphors can extend and expand meanings, and extensions of meaning are fundamental to thinking, especially creative thinking. And although synesthesia is not identical to metaphor, synesthesia too helps to extend and expand meaning. So perhaps there is a sense in which synesthesia can appropriately be dubbed a form of *perceptual metaphor*.[2]

How do synesthesia and metaphor differ, and how may they overlap?

To use a common example, 'John is a wolf' is a metaphor, analogous to the similes 'John is like a wolf,' 'John is similar to a wolf,' and 'John resembles a wolf.' By invoking a principle of shared features, these statements imply that certain significant characteristics apply to both 'John' and 'wolf'.

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[2] We suspect that, in the long run, being quasi-metaphorical will become a defining characteristic of synesthesia. If so, then this feature could help distinguish normative, quasi-metaphorical forms of synesthesia, such as sound-color, from related but non-metaphorical phenomena, such as mirror-touch perception (cf. Rothen & Meier 2013).

To be sure, John and wolves share a large number of common properties; both, for instance, are terrestrial mammals, and so, therefore, are both also warm-blooded, although being terrestrial, warm-blooded, and mammalian is not likely to be crucial, save in certain contexts.[3] What is crucial to both producing and understanding the metaphor 'John is a wolf' is the process of determining which characteristics can or do matter (e.g., Ayoob 2007). Both John and wolves may be characterized, for instance, as 'predators,' and, as Black (1962) pointed out, men and wolves are predators in different ways – that is, the word 'predator' invokes different domains. Consequently, the process of selecting the characteristic 'common' to men and wolves is interactive – and, as we discuss later, inextricably linked to emergence and creativity, properties and processes that, in the end, subvert any explanation that seeks to rely solely on shared features *per se* (there are many critiques of the view that metaphors simply express similarities based in shared features; see, e.g., Koestler 1964; Tourangeau and Sternberg 1981, 1982; Gineste et al. 2000). Nevertheless, similarities characterized through shared features form part of the story, and are worth examining insofar as they apply to both metaphor and synesthesia.

Before we try to evaluate how models postulating shared features or attributes may help explicate the relation between synesthesia and metaphor, it is useful to ask: How might models that postulate shared features account more generally for resemblance or similarity?

One may note, for example, that Charlie resembles his father because they both have round heads, round noses, and close-set eyes. By this token, Charlie and his father would be similar in appearance to the extent that they have identical-looking or nearly identical-looking features (or proportions of features). Tversky (1977) has provided a sophisticated, quantitative model of perceptual and conceptual similarity, grounded in the notion that similarity relies on shared features.

The example of Charlie and his father alluded to features that were described as identical-looking or nearly identical, and this observation in turn leads us to recognize the role of perceptual and conceptual continua or dimensions.[4] Achromatic objects that vary on the dimension of the

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[3] Or when 'John is a wolf' is not even a metaphor – in, say, the context of a B-grade horror film in which John actualizes his aspiration to lycanthropy.

[4] It is imperative, of course, to avoid the circularity of using common features to explain resemblance while defining common features in terms of their similarity. In the case of sensory attributes, there are undoubtedly primitive similarity relations, related to the degree of overlap in underlying neural responses. In hearing, for ex-

lightness, for example, may take on a virtual infinitude of values, and when an object is achromatic, the regions near the low and high poles of the lightness dimension are characterized by the features or attributes of black and white, respectively. In the case of Charlie and his father, 'narrow-set' and 'wide-set' eyes refer to points or regions on a dimension of relative eye spacing, while 'round' refers to points or regions in a multidimensional characterization of shape. Often, therefore, similarities map onto relative values along dimensions across different domains, and not to discrete features or attributes. Henceforth, we shall take shared features to include shared locations on more-or-less continuous dimensions.

Synesthesia and metaphor

Now we are in a position to ask about the role of shared features in synesthesia and metaphor. The notion that synesthesia (perception) and cross-modal metaphor (language) both depend on shared perceptual or conceptual features, and sometime on the same set of shared features, has its roots in the early work of Karwoski, Odbert, and Osgood (1942), whose study of synesthesia and auditory-visual correspondences suggested that synesthesia is a cognitive system containing shared meanings (see also Wheeler and Cutsforth 1922). In that study, the authors reported the results of a set of three experiments, one testing subjects who had shown strong evidence of sound-to-vision synesthesia, and the other two testing subjects who lacked synesthesia. In the first experiment, synesthetic subjects drew the shapes that they saw when they heard musical excerpts – revealing, for example, associations between small size and angularity with high pitch and fast tempo. In the second experiment, non-synesthetic subjects drew whatever shapes the music suggested, also revealing associations between small size and angularity with high pitch and fast tempo. And in the third experiment, non-synesthetic subjects matched words describing visual experiences to words describing auditory and emotional experiences, the results showing similar patterns of associations across all three experiments. The three findings impressed Karwoski et al. as being strikingly similar and closely related, suggesting a possible commonality among perceptual processes underlying synesthesia (Experiment 1), perceptual processes underlying

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ample, perceived similarity in pitch and discrimination of pitch both seem to relate in roughly the same way to spatial patterns of activation of receptors in the inner ear (Stevens & Volkmann 1940).

cross-modal resemblances/correspondences (Experiment 2) and conceptual-verbal processes underlying cross-modal metaphor (Experiment 3). To non-synesthetic perceivers, the poet Swinburne's line, 'music bright as the soul of light,' not only *denotes* bright light, but also *connotes* correspondingly loud music (Marks, 1982a).

These findings led Karwoski et al. (1942) to "the realization that the distinction [between sensory versus non-sensory] has little value..., so we have shifted the emphasis to the more general concept of synesthetic thinking" (p. 221). The third author of that study, Charles Osgood, later integrated its findings with the principles of what was then, in the mid-twentieth century, a central theory of behavioristic psychology: the theory of learning developed by Clark Hull (1943).

Hull (1943) proposed that when an organism learns to make an overt response to an external stimulus, the organism does this by developing a chain of linking, intervening covert responses and stimuli. Consequently, in a simple Hullian chain, when, for instance, the driver of a car sees a red light, this external stimulus leads to a covert internal response, which in turn produces a covert internal stimulus, and it is this covert stimulus (or a subsequent one in the chain) that ultimately triggers the overt response of stepping on the brake pedal. In Osgood's scheme, these *internal, mediating responses constitute or contain affective or connotative meanings*, and *synesthesia reflects these connotative meanings* (Osgood et al. 1957). A voice is synesthetically yellow because the voice's connotative meanings are the same as those of the color yellow. By this account, cross-modal correspondences observed in both synesthetic perception and metaphor would reflect, at least in part, shared features or attributes that themselves reflect values on the underlying dimensions of connotative meaning. More recently, Peter Walker (2012; see also Walker and Smith 1984, 1985; Walker and Walker 2012) has set out a related scheme for explicating cross-modal correspondences.

Like metaphor, synesthesia constitutes a system that incorporates shared features. As mentioned earlier, synesthesia involves the arousal of additional sensory, perceptual, or cognitive features, the affordance of experiences from other domain. And like metaphor, synesthesia elaborates on meanings by expanding them. To a grapheme-color synesthete, for instance, the mental representation of the digit '7' includes not only ordinal and cardinal information about a numeric quantity (e.g., its location between '6' and '8' and its equivalence to the sum of 3 and 4), but also a hue, perhaps aquamarine. That is, synesthetic minds characterize certain mental objects both by a set of the literal attributes of those objects and also, often idiosyncratically, by

another set of attributes, which characterize objects in a different domain. Of course, this process of elaborating a concept by assigning to it an attribute from another domain also characterizes metaphor. Although synesthetic experiences are not (verbal) metaphors, they operate in cognition much like nonverbal metaphors (cf. van Camp 1996).

Cross-modal correspondences

As we've already implied, the cords linking synesthesia and metaphor are perhaps most evident in the realm of cross-modal correspondences, which define alignments of dimensions in different sense modalities. Karwoski et al. (1942) noted, for example, that music containing high-pitched notes played in rapid tempos tends to induce synesthetic visual percepts that are small in size and angular in shape, and tends to evoke analogous metaphors of small size and angular shape in non-synesthetes. In the case of Synesthete Syd, it is likely that she would experience similar auditory-visual correspondences, and, consequently, that her experiences would not be wholly alien to Average Joe. As Syd listens to Bach's first C-major Prelude, she hears the first four notes ascend in pitch from C to F, and she may notice that her synesthetic, sound-evoked colors correspondingly lighten, while the synesthetic visual shapes contract. And as she describes these visual sensations, Syd's account may well ring familiar to Average Joe.

This is to say that Syd's auditory-visual synesthesia expresses several cross-modal correspondences, for instance, between pitch and lightness (lightness increasing as pitch increases) and between pitch and size (size decreasing as pitch increases). Cross-modal correspondences are pervasive in perception (see Spence 2011 for review), not just in synesthesia. Significantly, however, cross-modal correspondences often do appear in synesthesia, and when the correspondences, such as those between pitch and lightness and between pitch and size, also characterize perception more generally, they provide a touchstone between synesthesia and non-synesthetic perception. Average Joe may recognize these correspondences, when Syd reports them, even if he does not experience them synesthetically.

Cross-modal correspondences pervade both synesthesia and cross-modal perception in individuals lacking synesthesia. Most of us, like Average Joe, are not synesthetic, so we do not see colors or shapes when we hear melodies. Nevertheless, most of us do readily associate higher-pitched versus lower-pitched notes with lighter versus darker colors, with pointed versus rounded shapes, and (in adults, at least) with smaller versus

larger sizes (Karwoski et al 1942; Marks 1974; Ward et al. 2006), much as, in auditory-visual synesthetes, the sound-evoked visual sensations or images increase in lightness, sharpen in contour, and decrease in size when the pitch of the inducing sound increases (Bleuler and Lehmann 1881; Flournoy 1893; Karwoski et al. 1942; Marks 1974; Ward et al. 2006).

Several pieces of evidence have strengthened and extended these findings in non-synesthetic individuals, both children and adults. Many (though doubtless not all) of the links or correspondences between auditory and visual experiences (auditory-visual correspondences) trace back to early childhood (e.g., Marks et al. 1987), even early infancy (Lewkowicz and Turkewitz 1980; Wagner et al. 1981; Walker et al. 2010; Haryu and Kajikawa 2012). Perhaps the most pervasive auditory-visual correspondence is the link connecting auditory pitch and visual lightness (see Marks 1974, 1975; also Wicker 1968), and this pitch-lightness correspondence reveals itself not only in people reared in literate, Western cultures but also in people reared in at least one pre-literate, non-Western culture, namely, that of the semi-nomadic Himba, who inhabit the deserts of northwestern Kaokoland in Namibia (Mulvenna 2012). Despite their minimal contact with Western culture[5] and despite the absence of a written form of their language, Otji-Herero, members of the Himba tribes overwhelmingly select light versus dark colors to match higher-pitched versus lower-pitched sounds, both when the sounds are familiar and when they are unfamiliar. Importantly, in Western children as well as adults, several auditory-visual correspondences (pitch-lightness, pitch-brightness, loudness-brightness) permeate both cross-modal perception and the comprehension of cross-modally metaphorical verbal expressions that allude to auditory and visual experiences (Marks et al. 1987) – although at any given age, the auditory-visual correspondences appear more pervasive in perceptual tasks compared to verbal tasks, an outcome that is consistent with the hypothesis that these auditory-visual correspondences originate in perception and subsequently infiltrate language.

The salience of cross-modal correspondences may help explain why cross-modal metaphors are among the easiest for children to understand (Gardner 1974) and appear easy for children to create (Koch 1970). Cross-modal correspondences commonly guide, at least in part, the interpretation of sensory metaphorical expressions: People readily understand a ‘bright noise’ to be loud and high in pitch, understand a ‘cough’ to be not only lower in pitch than a ‘sneeze’ but darker too (Marks 1982a). When faced

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[5] The Himba were still culturally isolated in 2005, when Mulvenna (2012) conducted her experiment.

with auditory-visual metaphors in English poetry, such as Swinburne's 'music bright as the soul of light' or Joseph Auslander's 'silver needle note of a fife,' native speakers readily use their implicit understanding of loudness-brightness correspondence (Marks 1982b). Auslander's fife note is, of course, not only relatively loud: It is also high-pitched and piercing because it is needle-shaped and silver; and it is relatively bright, perhaps because it is high in pitch. An implicit or explicit appeal to cross-modal correspondences often instigates the process of understanding sensory metaphors, but needs not finalize it.

Metaphor and creativity

> The primary IMAGINATION I hold to be the living Power and prime Agent of all human perception, and as a repetition in the finite mind of the eternal act of creation in the infinite I AM. The secondary Imagination I consider as an echo of the former, co-existing with the conscious Will, yet still as identical with the primary in the kind of its agency, and differing only in degree, and in the mode of operation. It dissolves, diffuses, dissipates, in order to recreate; or where this process is rendered impossible, yet still at all events it struggles to idealise and unify. It is essentially vital, even as all objects (as objects) are essentially fixed and dead.
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> – Samuel Taylor Coleridge, *Biographia Literaria* (1817/1907: 202)

Box 2. Primary versus secondary imagination

The Romantic poet Coleridge (1817/1907) famously discussed, albeit with ambiguity, two kinds of imagination, which he called primary and secondary. To Coleridge, the primary imagination is universal and central to human perception itself, a view that derives from theories holding that perceptions are internal mental representations of external physical events. Indeed, when Coleridge calls the primary imagination "a repetition in the finite mind of the eternal act of creation in the infinite I AM" (p. 202), he is alluding, we suspect, to Berkeley's (1710) suggestion that the universe exists as God's ongoing (creative) mental representation. Primary imagination is, therefore the source of (re)presentation, of presenting again, but it lacks not only the creativity of God's original creation, but also the creativity available to the secondary imagination, which "dissolves, diffuses, dissipates, in order to recreate." Within the present framework, Coleridge's notion of a primary imagination would incorporate pre-metaphors such as cross-modal correspondences and semi-metaphors such as synesthesia, but

not, for example, overtly creative works, which arise from acts of secondary imagination, which we identify with creative cognition.

Shared features may not suffice to account for metaphor, but they often do play a role nevertheless in instigating metaphoric relations – much as, we suspect, they can provide ingredients to synesthesia. If we conceive of colored-hearing synesthesia as a cousin to, say, *sauce Chantilly*, then the cross-modal correspondence between auditory pitch and visual brightness might be analogous to the raw egg yolks of the sauce. A core question regarding cross-modal correspondences, and the associated intersensory resemblances, asks of their origin, an issue that we now briefly address. Often, it is tempting to posit an experiential basis to cross-modal correspondences, as some correspondences can be found in the statistical distributions of environmental events. All else being the same, larger objects will resonate at lower sound frequencies than smaller ones, thereby, as many have noted, providing an inverse statistical correlation in the world between size and pitch (e.g., Osgood et al. 1957; Brown 1958).

This said, there are also opportunities to learn the reverse correlation: As a sound-emitting object recedes from a perceiver, the visual angle of the object and the frequency of the emitted sound at the perceiver's location, hence the sound's pitch, both decrease in concert (the Doppler effect). In this instance, the relation is between size and pitch is direct, not inverse (see Eitan et al. 2011). Perhaps, then, we can learn more than one cross-modal correspondence involving the same two sensory dimensions – although the preponderance of evidence that people in fact learn these relations itself remains indirect. It is plausible, however, that learn them we do. We likely learn, for instance, to classify voices by age (children versus adults) and gender (female versus male), in part by the negative statistical association between fundamental frequency and body size (hence size of the larynx).[6]

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[6] Note that even congenitally blind individuals may perceive an inverse association between pitch and size (Stevens 1934), suggesting the possibility that learning may not be necessary to appreciate the correspondence. In a related vein, Békésy (1957) reported that the perceived spatial spread or size of sensations aroused in three different ways – through sound presented to the ear, mechanical vibration of the skin, and electrical stimulation of the skin – decreases as the frequency (hence ‚pitch') of the stimulus increases, and thereby suggesting that pitch-size correspondence could originate in hard-wired physiological processes. On the other hand, a recent study by Haryu and Kajikawa (2012) reported evidence suggesting the absence of pitch-size correspondence in 10-month-old infants, despite the presence of pitch-lightness correspondence. As interesting as the issue of origins may be, the central point here concerns the potential multiplicity of correspondences – and the processes

As already suggested, metaphors may begin with, but need not end with, similarities based in shared features, such as those characterized by cross-modal correspondences. Metaphorical meanings form a network, with each meaning, like a Biblical patriarch or matriarch, potentially begetting another. 'The proliferation of resemblances extends an object,' wrote the poet Wallace Stevens (1951: 61). A metaphor does not simply catalogue a set of shared attributes or features, but is characterized by dynamic, interacting ensembles of meaning, and it is in this dynamism of metaphors that we see their potential for creativity. How is it, we ask, that metaphors engender meanings? Do metaphors operate like Volta's battery, which sparks electric current when plates of silver and zinc touch?

The process often begins with the recognition of correspondence, implicit or explicit, cross-modal or other, and it is tempting to denote these implicitly understood, first-order, non-literal correspondences as semi-metaphors, distinguishing them from their full-blown, creatively inspired siblings. In doing this, we are suggesting something akin to a quantification of *metaphoricity* – that cross-modal correspondences themselves act as pre-metaphors and may serve as starting point for more extensive production and understanding of metaphors. When cross-modal expressions activate cross-modal correspondence, for example, the initial interpretations are still only semi-metaphorical – albeit higher on an implicit scale of metaphoricity than the correspondences that underpin them. Metaphoricity further increases with the proliferation and refinement of resemblances. Metaphors do not simply connect but sometimes modify the elements in ways that create new meanings – as others have argued (e.g., Black 1962; Tourangeau and Sternberg 1981, 1982; Gineste et al. 2000). In this regard, the understanding of metaphors too, like their production, is active rather than passive, and hence involves creative cognition, thereby 'proliferating resemblances.'

Creativity: synesthesia, metaphor, and mental chemistry

That synesthesia is associated with creativity has long been suspected. Anecdotal observations and case studies suggest that people who experience synesthesia are disproportionately represented in the creative arts (e.g., as visual artists, composers, musicians). And, over the past two centuries, several movements within the arts have been inspired by

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responsible for choosing amongst them, a matter closely tied, in our view, to creativity.

synesthesia (see Dann 1998), as the older notion that each artistic form – painting, sculpture, architecture, music, dance – stands alone and unique, gave way, in the minds of some artists, to the notion of equivalence across different artistic genres, and hence, by implication, equivalence across their modes of expression: visual, tactile, auditory. Movements to unify the arts in turn provoked attempts at integrating music with visual arts (already true in dance, that primordially multisensory of art forms). Notable were Wagner's notion of *Gesamtkunstwerke* and the proliferation of multimedia events that preceded contemporary psychedelic culture (see van Campen 2008).

Individuals with synesthesia do seem to be especially likely to engage in what are generally acknowledged to be creative professions and activities – as painters, sculptors, musicians, composers, writers, and so forth. To mention three empirical findings: Rich, Bradley, and Mattingley (2005) found that synesthetes were much more likely than non-synesthetes to report artistic occupations, Ward et al. (2008) found that synesthetes were more likely than non-synesthetes to report engaging in artistic activities, and Rothen and Meier (2010) found synesthesia to be more prevalent in art students than control subjects.

More directly pertinent to creativity *per se* is experimental evidence indicating that synesthetes score higher than do non-synesthetes on several measures of creative cognition (Domino 1989; Mulvenna 2012). The notion of creative cognition (Finke et al. 1992) has been used in two slightly different but related ways. One refers to a distinct set of behaviors: the production of original, novel ideas or solutions to problems and is related to the capacity for abstract or divergent thinking. Thus, synesthetes as a group may be seen as high in 'creative intelligence.' The other refers to "patterns of cognition that set the stage for creative discoveries" (Smith 1995: 31) and that, as such, are subject to the same principles and mechanisms involved in other aspects of cognition (e.g., Smith et al. 2006; Smith and Ward 2012). The study of creative cognition is often contrasted with the study of creative output (e.g., Amabile 1983; see Smith et al. 1995), the implementation of creative ideas into products, such as works of art.[7] As suggested earlier in this article, the 'proliferation of resemblances' evoked by a reader's encounter with a novel metaphor – hence, the process of understanding metaphor – is active, not passive, and to this extent reflects the engagement of creative cognition.

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[7] Due to this differentiation, the propensities of synesthetes to produce creative works of art and creative ideas are not mutually exclusive (for review, see Mulvenna 2014).

Mulvenna's (2012) evidence that grapheme-color synesthetes show greater capacity for creative cognition than do non-synesthetes is noteworthy, in that she not only used a standardized test of creative cognition, the *Torrance Test*, and a 'blind' experimental design, but also used an objective criterion, test-retest consistency, to assess synesthesia in her populations. Although Domino (1989) too used a standardized test of creative cognition, the *Similes Test*, his measures of synesthesia relied on self-report, as was standard at the time in research on synesthesia. The connection between synesthesia and creativity appears to be specific to creative thinking and not necessarily to other aspects of creative behavior; Ward et al. (2008) found no difference, for example, between synesthetes and non-synesthetes in general verbal fluency. To quote a recent summary, "Overall, the picture that emerges is one of synaesthetes as creative thinkers. While synaesthetes pursue the arts more than others, the link to the arts is secondary to the robust and reliable relationship synaesthesia has with creative cognition. Thus, for synaesthetes, the distinction from non-synaesthetes lies not in the creativity of their art, but in the creativity of their *thoughts*" (Mulvenna 2014: 624).

Consistent with earlier findings (e.g., Hubbard et al. 2005; see Rouw et al. 2011), Mulvenna (2012) reported evidence that synesthesia is associated with augmented neural connectivity between regions of the cortex that process the synesthetically-linked domains, such as graphemes and colors, and she proposed, again along lines suggested earlier (e.g., Ramachandran and Hubbard 2001) that augmented neural connectivity underlies both constitutional synesthesia (enabling the sensory or cognitive cross-talk characterizing synesthetic experiences) and enhanced creative cognition (enabling novel connections of disparate ideas). Although synesthetic experiences may be creative when they begin, along the lines of Coleridge's claims regarding the primary imagination, they should not be considered endlessly creative: Noteworthy for their stability and consistency within an individual, ongoing synesthetic experiences lack the continued originality, the cognitive creativity, that characterizes the work of secondary imagination. They also lack the conscious intent of traditional creative cognitions. Nevertheless, a mechanism that appears to be responsible for constitutional synesthesia, neural hyperconnectivity in the brain, may also, perhaps independently, enhance the propensity for creative cognition associated with Coleridge's secondary imagination.

Along these lines, Brang and Ramachandran (2011) and Ramachandran and Brang (2014) suggested that the genes that underlie synesthesia may also augment metaphorical behavior, the creative production and understanding of linguistic utterances. Metaphors, many of them cross-modal, contribute

substantially to the creative richness of language, in part because – as Chomsky (1965) pointed out – language itself is indefinitely creative: People are always constructing novel sentences, never before spoken or written. Metaphorical transformations of meaning involve the construction of emergent relations, which transcend mere association of the elements. A similar notion was captured two centuries ago by the expression "mental chemistry," introduced by Thomas Brown (1820) and later adopted explicitly by John Stuart Mill (1843/2012) – and implicitly by Wilhelm Wundt, (1894), in his account of the process of creative synthesis.[8] What remain unclear, however, are the explicit mechanisms by which ideas synthesize and reformulate; still challenging is a scientific model or theory that can predict what appears, *a priori*, to be unpredictable (cf. Finke et al. 1992).

Conclusion and summary: the ties that bind

Synesthesia, metaphor, and creativity are associated, albeit in complex ways, and cross-modal correspondences often lie at the heart of the interrelations. Cross-modal correspondences relate dimensions in two (or more) sense modalities, as in the association between pitch in hearing and brightness in vision, where high-pitched versus low-pitched sounds correspond to white versus black colors. Cross-modal correspondences pervade both perception and language. In this article, we noted three principles as being central to the relations.

First, cross-modal correspondences act like primitive metaphors, serving as ingredients to both cross-modal synesthesia in perception and metaphor in language (metaphor being our 'model system' for creativity). Second, both the production and interpretation of metaphor are open-ended, thereby

[8] As Brown (1820) wrote, "In this spontaneous chemistry of mind, the compound sentiment that results from the association of former feelings has in many cases, on first consideration, ... little resemblance to these constituents of it, as formerly [existed] in their elementary state..." (p. 156). And Mill (1843/2012) wrote, "[T]he laws of the phenomena of mind are sometimes analogous to mechanical, but sometimes also to chemical laws. When many impressions or ideas are operating in the mind together, there sometimes takes place a process of a similar kind to chemical combination. When impressions have been so often experienced in conjunction that each of them calls up readily and instantaneously the ideas of the whole group, those ideas sometimes melt and coalesce into one another, and appear not several ideas but one..." (p. 502).

revealing their links to creativity, especially creative cognition. Contrary to the hypothesis that metaphors consist of specific, overlapping or common attributes in different domains and therefore represent fixed resemblances in meanings, metaphors serve to proliferate resemblances. As Marks (1978) noted in this regard, there is "a fertile plain of latent meanings, where various perceptual dimensions may engage one another in various ways. This is the property that H. Werner and Kaplan (1963) called 'plurisignificance'. From the multiplicity of pathways connecting the senses springs the possibility of creativity, of generating meaning through descriptive metaphors that select one actual from several potential cross-modal relations" (p. 232). And the next paragraph went on, "Much synesthetic language in poetry is of this sort: A sensory experience – a quality of touch or taste, of hearing or sight – is sent forth to tap some experience proper to another sensory modality, so that the one appropriates features or the other, *or both appropriate characteristics of each other. Neither, however, automatically or mechanically elicits the other*" (italics ours).

Third, the presence of synesthesia is associated with the presence of both enhanced creative cognition and enhanced functional connectivity in the brain. The neural processes that underlie synesthesia and creative cognition likely involve both feedback and feedforward, as resemblances proliferate, extending metaphorical meanings, with each extension in meaning potentially begetting further resemblances. Perhaps the greatest challenges to understanding the nexus of synesthesia, metaphor, and creativity are, first, understanding the 'mental chemistry' that creates novel meanings and, second, deciphering how the brain establishes them.

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