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SCENTED COLOURS

Artistic interest in the crossmodal connection between colour and odour

ABSTRACT: Artists have long been interested in the crossmodal links that exist between colour and scent. While traditionally envisioned as a kind of synaesthesia, contemporary accounts of the connections between this particular pair of senses have typically focused on explanations in terms of involuntarily-induced cross-modal mental imagery and crossmodal correspondences instead. A large body of empirical research now supports the view that the majority of non-synaesthetic individuals do indeed systematically match colours to odours, via semantic (or source-object based) matching, and/or on the basis of emotional-mediation or perceptual similarity. Universal agreement with regard to the best-matching colours for odours is, however, never obtained. What is more, the consensuality of the crossmodal mappings obtained within groups of individuals (and especially across culture, and age) tend to decline when one moves away from semantically-based crossmodal matches. As such, the longstanding aim amongst certain artists to play with the abstract correspondences between scent, colour, and, on occasion, also sound in order to try to deliver universally-meaningful crossmodal correspondences seems unlikely ever to be realized. Nevertheless, that does not mean that scent and colour can't still be linked in intriguing ways, as illustrated by a number of the exhibits at the 2015 *Tate Sensorium* multisensory exhibition in London.

1. INTRODUCTION

The existence of crossmodal links between colours and odours have long been of interest to artists, and more recently, to designers wishing to convey the olfactory attributes of their products by means of meaningful colours and colour schemes (see [Spence in press](#), for a review). However, progress in understanding, and thereafter incorporating, crossmodal correspondences into artistic design practice have long been limited by the assumption that they constitute a form of synaesthesia (e.g., see [Haverkamp 2014](#); [Merter 2017](#); [Spence 2015c](#)). Historical interest in the topic of crossmodal correspondences involving odour first emerged amongst artists and scientists during the middle decades of the 19th century ([Baudelaire 1857/1954](#); [Piesse 1857](#); [Taylor 1963](#)). However, while a small number of cases of olfactory-colour synaesthesia have been reported over the intervening years (e.g., see [Speed & Majid 2018](#)) the topic of involuntarily-induced crossmodal mental imagery ([Spence & Deroy 2013](#)) would appear to provide a much more satisfactory explanation for the experience of scent that artists such as Cézanne once hoped to evoke in those viewing their paintings ([Merleau-Ponty 1964](#)).

A large body of empirical research conducted over the last century has demonstrated that even non-synaesthetic individuals tend to match colours to odours in a systematic (i.e., non-random) manner. In the case of recognizable odours (as in the case of the aroma of food and drink, for example), these crossmodal mappings are often based on semantic (or source-object based) matching. By contrast, when presented with unfamiliar, odours (such as perfumery materials and perfumes), crossmodal matches often appear to be based on emotional ([Schifferstein & Tanudjaja 2004](#)) and/or perceptual similarity instead (e.g., [Gilbert et al. 1996](#); [Kemp & Gilbert 1997](#); [Stevenson et al. 2012](#); [von Hornbostel 1931](#)). Researchers have demonstrated that the latter (i.e., perceptual correspondences) may be based on one of a range of stimulus attributes including intensity, brightness, and/or stimulus quality. However, while a large number of such colour-odour crossmodal correspondences have now been demonstrated in the general (i.e., non-synaesthetic) population, what has become increasingly clear is that they are never shared universally, even in the most consensual of cases. What is more, they tend to be more relative than absolute – mean-

ing, for example, that the mappings obtained are typically influenced by range, sequence, and/or anchoring effects (see Belkin et al. 1997; Cohen 1934; cf. Spence 2019c).

Extending odour-colour crossmodal correspondences research both cross-culturally (e.g., Levitan et al. 2014), and developmentally (Goubet et al. 2018), also tends to reduce the consistency of the crossmodal mappings that are obtained still further. Indeed, as an extreme example, groups of hunter-gatherers, such as the Maniq, have been documented who apparently do not associate colours with odours at all (de Valk et al. 2017; see also Wnuk & Majid 2014). As such, the longstanding aim amongst certain artists to use abstract correspondences between scent, colour, and, on occasion, also sound in order to deliver universally-meaningful, or accessible, crossmodal correspondences (e.g., Fleischer 2007; Marvick 1999; Shepherd-Barr 1999) seems unlikely ever to be realized. Nevertheless, as I will show later, that does not mean that scent and colour can't still potentially be linked in a number of intriguing ways, as, for example, illustrated by the technologically-enhanced multisensory *Tate Sensorium* exhibition that was held in London in the summer of 2015 (see Davis 2015; Pursey & Lomas 2018).

1.1. Outline of the review

This review begins by summarizing the historical interest in colour-odour and auditory-odour correspondences amongst artists and scientists during the late 19th and early 20th Centuries (**Section 2**). As Hans Rindisbacher (1992, p. 147) has noted the way that smell was conceptualized changed: *“In the time from about 1880 to the 1910s, significant shifts take place in olfactory perception. ... [Smells] are no longer mere objects, but they enter into an interactive perceptual relation with that vibratory organism the modern human has become, breaking down borders of subject and object, transgressing present and past, linking immediacy and memory.”* The possibility that cross-sensory impressions might be elicited in those viewing colour (e.g., as in a painting) famously intrigued the likes of French post-Impressionist painter Paul Cézanne (1839-1906). Some commentators (e.g., Merleau-Ponty 1964), have described such crossmodal effects as synaesthetic, though a more appropriate explanation in terms of involuntarily-elicited cross-

modal mental imagery is suggested here (Spence & Deroy 2013). That said, the synaesthetic account of crossmodal correspondences undoubtedly did become very popular at the end the 19th century and in the opening decades of the 20th century (e.g., Dann 1998; Jewanski et al. 2020; Lorusso & Porro 2010). However, most attempts to incorporate such putatively synaesthetic connections between colour and odour into an artistic, or performance, context (e.g., as explored by Italian Futurist artists such as Azari (1942); described in Verbeek 2017) ultimately failed to deliver multisensory experiences that either critics or audiences would seem to have appreciated (see Fleischer 2007). Discussion of what may have gone wrong in such cases, leads us on to a brief review of the relevant literature on genuine cases of olfactory-colour synaesthesia (**Section 3**).

In **Section 4**, the results of a prototypical psychophysical study of colour-odour correspondences in the general (i.e., non-synaesthetic) population are presented. Thereafter, in **Section 5**, the review summarizes what is currently known concerning olfactory-visual crossmodal correspondences in the non-synaesthetic population. Evidence regarding both the consistency and causes of such crossmodal mappings is then reviewed. Given that universally agreed odour-colour correspondences have never been reported, it is suggested that the artist's dream of a universal abstract crossmodal correspondence (or translation) involving colours, scents, and, on occasion, also sounds is unlikely ever to be realized. In **Section 6**, I describe the *Tate Sensorium* in which various crossmodally corresponding odours were used to try and modify a viewer's experience of several famous works of art. The aim in this case was to use scent to enhance, or at the very least to prolong, the viewer's engagement with the works. The success of this temporary exhibit highlights the continued interest amongst artists, designers, curatorial professionals, and their audiences, in the incorporation of scent into multisensory experience design. In fact, a number of recent artistic events/installations have incorporated an olfactory element into the performance (e.g., Sebag-Montefiore 2016; see also Bremner 2019). As such, there would appear to be continued interest in the use of both semantically-meaningful and abstract olfactory stimuli in an artistic context.

2. EARLY INTEREST IN CROSSMODAL CORRESPONDENCES AMONGST ARTISTS AND SCIENTISTS

*'Like prolonged echoes mingling in the distance
In a deep and tenebrous unity,
Vast as the dark of night and as the light of day,
Perfumes, sounds, and colors correspond.'*

Baudelaire's (1857; 1954) famous poem, "The Correspondances" (see Anderson (1980), for a couple of other translations) captures what at first sounds like an almost synaesthetic connection between distinct sensory impressions.¹ But what, exactly, does it mean to say that "*Perfumes, sounds, and colours correspond?*" Is this an early description of synaesthesia, or rather an expression of what has since come to be known as crossmodal correspondences instead (see Spence 2011)? In 1855, a couple of years before Baudelaire's poem was first published, and along similar conceptual lines, George William Septimus Piesse published *The Art of Perfumery*. In this seminal work, the Paris-based English chemist and perfumer (by training/trade) first proposed his innovative scent scale in which 46 odours were paired with musical notes. While Piesse seems primarily to have been interested in the way in which certain fragrances would harmonize when mixed (as happens when different musical notes are combined),² he nevertheless still published one of the first explicit attempts to match individual fragrances with specific musical notes (see Figure 1).

The fact that Baudelaire's poem and Piesse's book were both first published more than 150 years ago now, hints at the longstanding interest, at least amongst artists, perfumers, and scientists, in how the abstract impressions conveyed to the different sense organs might cor-

¹Note that this poem was likely inspired by earlier Romantic writer E. T. A. Hoffmann's novel *Kreiskleriana* (Taylor 1963, p. 75), as well as by the writings of Swedenborg (see Marvick 1999). For instance, Hoffmann once wrote that: "I find correspondences of colours, scents and sounds."

²For instance, at one point, Piesse (1857, p. 40), writes that: "*Scents, like sounds, appear to influence the olfactory nerve in certain definite degrees. There is, as it were, an octave of odours like an octave in music; certain odours coincide, like the keys of an instrument. Such as almond, heliotrope, vanilla, and orange-blossoms blend together, each producing different degrees of a nearly similar impression. Again, we have citron, lemon, orange-peel, and verbena, forming a higher octave of smells, which blend in a similar manner.*"

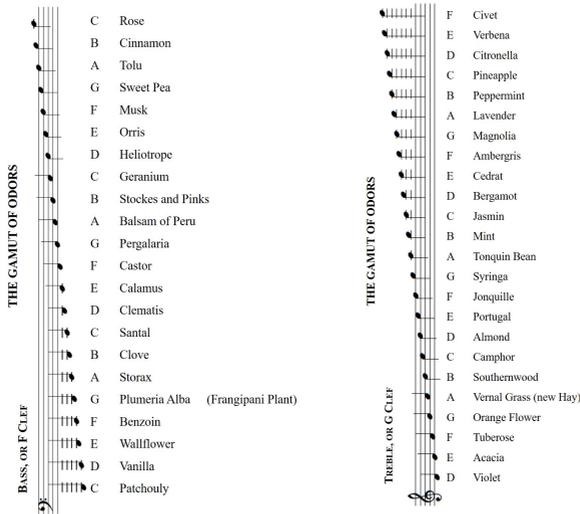


Figure 1: Scale of correspondences between sound and odours reproduced from Piesse (1857).

respond crossmodally. Not in the sense of the colour yellow and a sour taste belonging together (i.e., because both are sensations that can be linked with the same source object, namely a lemon; cf. [Kandinsky 1977](#)), but rather in terms of how they might relate in an almost spiritual manner (see, once again, [Kandinsky 1977](#); the latter's essay, *Concerning the Spiritual in Art*, was first published in 1911). In fact, both Baudelaire and Kandinsky were of the opinion that more abstract cross-modal correspondences likely reflected some kind of more fundamental sensory harmony (see also [Argüelles 1972](#)). At one point, [Kandinsky \(1977, p. 24\)](#), even went so far as to write about sensations sharing “spiritual vibrations” (see also [Swedenborg 1744/2006](#), on the spiritual angle to the correspondences). Meanwhile, a couple of years after Kandinsky's work was first published, the Italian Futurist artist [Carrá \(1913a\)](#) echoed the suggestion, writing that ‘*sounds, noises and smells are nothing but different forms and intensity of vibration*’.

Several Symbolist artistic performances at the end of the 19th century involved audiences being presented with corresponding colours,

sounds, and scents (see Fleischer 2007; Marvick 1999; Shepherd-Barr 1999). In one (in-)famous example, from 10th and 11th December 1891, for example, two performances of the Old Testament text of the *Cantique des cantiques* (Song of Songs) of Solomon by Paul-Napoléon Roinard were given at the Théâtre des Arts in Paris. Roinard had in mind an almost synaesthetic multisensory work in which original music, words, vowel sounds, colours, and scents were all to be harmonized (Halperin 1988, p. 199; Stokes 1972, p. 167). For each of the eight poetic sections (or ‘mystic devices’), Roinard provided details of the exact combination of color (e.g., ‘pale purple’), scent (e.g., ‘frankincense’), speech (e.g., ‘in i illuminated with o (white)’), and music (e.g., ‘in C’) that were to be presented in synchrony (Fleischer 2007, p. 111).

In this case, a total of nine scents (frankincense, white violets, hyacinth, lilies, acacia, lily of the valley, syringa, orange blossom, and jasmine) were released into the theatre, while the audience listened to words and music (Roinard et al. 1976), Roinard wanted to realize the ideal of a synthetic and perfect union of the arts and of the senses. However, as various commentators have subsequently made clear, practical constraints with trying to deliver (and thereafter to rapidly clear) a sequence of scents would seem to have limited the audience’s appreciation of these early performances (Deak 1993, p. 156, Fleischer 2007; Shepherd-Barr 1999). Here, one might also want to question whether the crossmodal mappings suggested by Roinard really did correspond, or whether instead they were based on nothing more than idiosyncratic (possibly synaesthetic) combinations of stimuli instead.

On November 30th, 1902, Sadakichi Hartmann attempted to incorporate a series of semantically-meaningful scents into his performance of *A trip to Japan in Sixteen Minutes* at the New York Theatre (see Hartmann 1913). In this case, the scents were released while a pair of Geisha’s danced on stage. A text was read out and accompanied by the release of eight perfumes, especially chosen so as to be perceptible when presented one after another. The aim was to evoke the stages (and locations) of the journey through the scent associated to specific regions, including the almond smell of Southern France, bergamot for Italy, cedarwood for India, and carnation for Japan (Hartmann 1913). Hartmann’s hope was that the scents would be recognized by the audience, and hence trigger thoughts on the appropriate (i.e., intended)

theme. Once again, though, the one-off experience was regarded as a critical failure (see [Hartmann 1913](#); [Shepherd-Barr 1999](#)). Technical problems with scent release and clearance were undoubtedly partly to blame. However, a more fundamental realization that connecting scents to visual impressions was more difficult than it may at first have seemed soon dampened the enthusiasm of many of the artists who were tempted to meddle in this space of scent-enhanced performance. In hindsight, Hartmann also notes that people's emotional associations with these semantically-meaningful scents tended to be unpredictable, and hence was not as uniform as he would have liked ([Hartmann 1913](#), p. 222).

The last popular mention of the use of synaesthetically-corresponding colours and odours in this era was suggested, through never successfully executed, by Alexander Scriabin. The famous Russian composer often talked about, though never managed to deliver (at least not in his lifetime), fragrances to synchronize with the lighting score that he had designed for his 1911 tone poem *Prometheus: Poem of Fire* Op. 60 ([Hull 1927](#); [Runciman 1915](#)). While fragrance has occasionally been released in subsequent performances of Scriabin's work (e.g., see [Macdonald 1983](#), for the description of one such occasion), there has been little attempt to pick a specifically corresponding scent for the music and/or light show.

2.1. *Synaesthetic smells, or a case of involuntary crossmodal mental imagery*

Around the turn of the 20th century, the French post-Impressionist painter Cézanne became interested in the connection between colour and odour. According to [Merleau-Ponty \(1964, VII\)](#), Cézanne thought that: “*We see the depth, the smoothness, the softness, the hardness of objects; Cézanne even claimed that we see their odour too. If the painter is to express the world, the arrangement of his colours must carry with it this indivisible whole, or else his picture will only hint at things and will not give them in the imperious unity, the presence, the unsurpassable plenitude which for us is the definition of the real.*” (see also [Classen 1998](#)). Cézanne was certainly not unique in wanting to elicit non-visual sensations in those who viewed his work. There is, in fact, a long line of earlier artists who deliberately attempted to make their viewers salivate by portraying, for

example, glistening sliced lemons in their still life paintings (Leonhard 2020; Sander 2008; see also Steel 2020, p. 306).

The French philosopher Maurice Merleau-Ponty (1964), and after him, architectural historian Alberto Pérez-Gómez (2016), both describe the Cézanne example in terms of synaesthesia. While never clearly defining quite what they mean by the term (see Abath 2017, on this theme), the latter authors' use of the term is very different from the carefully-defined condition that has been studied by cognitive neuroscientists in recent years (e.g., see Simner 2012; Simner & Hubbard 2013).³

However one chooses to describe it, though, several subsequent reports have suggested that people sometimes do indeed experience olfactory sensations on looking at pictures. For instance, in 1909, Martin reported that olfactory impressions were amongst the sensory experiences that people occasionally reported when shown reproductions of paintings. Martin chose to describe this as a kind of 'aesthetic synaesthesia'. Given recent observations that nasal inhalation (i.e., sniffing) is often observed in the case of consciously-triggered olfactory mental imagery (Bensafi et al. 2003), it would be interesting to know whether sniffing occurs more frequently in those who report experiencing olfactory sensations when viewing olfactorially-evocative paintings as well.

A letter that appeared recently in *The Times* newspaper (UK) described the experience of one individual that captures what Cézanne would seem to have had in mind all those years ago. The writer describes how she lost her sense of smell at the age of 22 but describes herself as currently having 'smell synaesthesia' (Fenning 2019). She writes "*I sometimes 'smell' something by seeing it. This happens only when I surprise my brain – if I consciously tried to stimulate smell by flicking through a rose catalogue, nothing would happen. But coming across Manet's still life of yellow roses in a museum a few years ago, I found the fragrance fleetingly overwhelming.*" The writer continues that: "*Other recent 'smells' triggered momentarily have been: green bracken shoots seen from a train window; a photograph of a bowl of Seville oranges; the lavender on a floral pattern dress; and the crackling fire in a*

³Indeed, given the widely varying use of the term 'synaesthesia' over the decades/centuries, one might, I suppose, be tempted to question whether the contemporary desire to constrain the term's exact meaning necessarily fits with the term's traditional/ folk usage.

friend's Facebook video."

The notion that we, in some sense, experience the odour of that which is painted/ portrayed hints, I think, at a very literal kind of crossmodal relation between colour and odour (see Jay 1994, p. 159; Verbeek 2017, p. 111). It might, for example, be taken to suggest a particularly vivid form of involuntarily-induced stimulus-driven crossmodal mental imagery (see Nanay 2018; Spence & Deroy 2013, for reviews). After all, it has long been acknowledged that people differ markedly in terms of the vividness of their visual mental imagery (e.g., Cui et al. 2007), and there would seem little reason to doubt the idea that similar individual differences would not be found in the case of crossmodal mental imagery involving scent as well (e.g., Plailly et al. 2012; Sugiyama et al. 2006; cf. Marks 1989; Rader & Tellegen 1987).⁴

In conclusion, the semantically-related illusory smell sensations that would appear to be evoked in certain individuals when viewing paintings of (or images depicting) fragrant objects would seem much better described as an involuntary form of crossmodal mental imagery (Spence & Deroy 2013), rather than a form of synaesthesia (Aboth 2017). As we have just seen, such crossmodal effects, namely the elicitation of olfactory experiences and possibly even other physiological responses (such as salivation) by means of visual stimulation have long interested artists such as, famously, Cézanne.

2.2. *Scented colours: Artistic interest in abstract and concrete crossmodal correspondences*

Russian artists such as the painter, Wassily Kandinsky, and the composer Alexander Scriabin (e.g., Runciman 1915) were both interested in the much more abstract, almost synaesthetic (literally in this case), notion of cross-sensory correspondences. That said, Kandinsky, who may well have been a synaesthete himself (see Harrison 2001; Just 2017, on this score), tended to focus more on those associations between colour and visual form (i.e., on intramodal rather than crossmodal correspondences). In his essay, '*On the Spiritual in Art*' (first published in English in 1912), he talks extensively on the theme of the

⁴Interestingly here, Hartmann (1913, p. 226) denied the existence of olfactory mental imagery, contrasting its absence with the vivid visual images that people can bring to mind.

correspondences between the senses.⁵ However, Kandinsky devotes no more than a couple of sentences to the sense of smell, writing, at one point, that: “*The expression “scented colours” is frequently met with.*” (Kandinsky 1977, p. 25). No sooner had he got started on this particular theme, though, than the discussion is immediately curtailed when the author draws attention to those synaesthetic individuals who exhibit highly idiosyncratic, rather than commonly shared, crossmodal associations (Grossenbacher & Lovelace 2001). Note that it was the universally-shared correspondences that artists such as Kandinsky were really striving after in their creative practice (see also Marvick 1999, on this theme).

Elsewhere, meanwhile, minor Italian Futurist artists, such as Azari (1942), and Carrà (1973, first published in 1913), were also intrigued by what they considered to be the existence of synaesthetic correspondences between odours, colours, textures, sounds, and even tastes.⁶ Writing back in 1913, Carlo Carrà (1973, p. 114 proclaimed that: “*We Futurist painters maintain that sounds, noises and smells are incorporated in the expression of lines, volumes and colors, just as lines, volumes and colors are incorporated in the architecture of a musical work.*”⁷ Interestingly, Italian Futurist artist Luigi Russolo (1885 – 1947) also completed one work, entitled Profumo (meaning “scent”, “fragrance”), in 1910 (see Figure 2).

Scientists and commentators still debate whether Kandinsky and Scriabin were synaesthetes or not and, if so, what was the extent to which their particular form of synaesthesia informed their artistic practice (see Harrison 2001, and Just 2017, on the question of Kandinsky’s synaesthesia; and Galeyev & Vanechkina 2001, and Myers 1914, on Scriabin’s case). Certainly, when Scriabin was interviewed, the Russian composer apparently repeatedly stressed that the associations between sound, colour, and scent that he was interested in were based on intu-

⁵Indeed, his writing can be seen as prefiguring later work on the semantic differential technique (e.g., Osgood et al. 1957), especially in his interpretation of the meanings/feelings associated with colours.

⁶F. T. Marinetti’s *The Futurist Cookbook*, first published in 1932, also makes frequent reference to ‘syn-olfactismo’, ‘syn-tactilissimo’, etc.

⁷In 1913, Carrà published a short piece arguing that Cézanne should not be considered a Futurist, because of the latter’s primitive and traditional approach to art (Carrà 1913b; see also McKeever 2016).

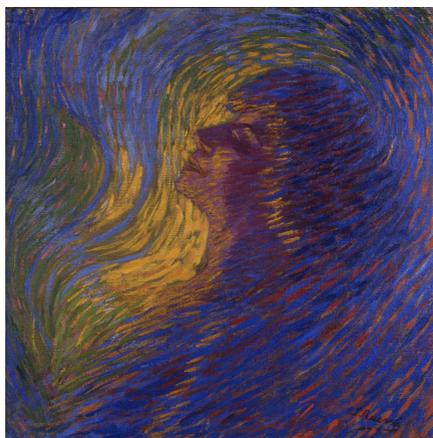


Figure 2: Profumo (meaning “scent”, “fragrance”), divisionist painting by Italian Futurist artist Luigi Russolo (1885-1947); dated 1910. [Wikicommons; <https://www.pitturiamo.eu/wp-content/uploads/profumo-luigi-russolo.jpg>]

ition, not on any form of scientific evidence, nor explicitly on his synaesthesia either (Runciman 1915). Furthermore, the carefully-constructed colour circle that was developed for Scriabin when working on the visual score for his *Prometheus* hints at a very particular use of colour (i.e., to help disambiguate certain sounds in the work; see Gawboy & Townsend 2012, on this theme). When writing about French symbolist poet René Ghil (1978), Marvick (1999), also draws attention to the belief that may well have been common at the end of the 19th century, namely that universal correspondences need not necessarily have been open to questioning by the scientific method (see also Argüelles 1972).⁸

At one point, Carrà (1973, p. 114) writes: “*Our canvases will therefore express the plastic equivalents of the sounds, noises and smells found in theatres, music-halls, cinemas, brothels, railway stations, ports, garages, hospitals, workshops, etc., etc.*” Here, once again, talk of ‘plastic equivalents’⁹ would appear to reference a direct crossmodal visual semantic

⁸This despite the flourishing of mutual interest, if not necessarily always collaboration, between artists and scientists, so eloquently captured in Brain’s (2015) book, *The Pulse of Modernism*.

⁹According to Higgins (2014, p. 196): “The term “plastic” refers to a painting’s flatness,

evocation of smells. However, hinting at a more abstract connection, Azari (1942) writes elsewhere that: “*I state that, beyond such affinity caused by habituation of two simultaneous sensations, there is a connection between form-colour and perfume like there is between music and colour.*” (as cited in Verbeek 2017, p. 112; see Spence 2020b, for a review of the latter).

Despite this brief flourishing in the abstract crossmodal correspondences that exist between odour and colour (as well as form), interest in ‘scented colours’ soon faded amongst the artistic community in the opening decades of the 20th century. In part, this was undoubtedly due to the challenges associated with trying to provide a widely-shared, even if not entirely universal, translation between this particular pair of senses. Critics and audiences alike did not seem to ‘get it’, as soon became apparent to the artists involved. As has been mentioned already, the practical challenges associated with delivering (and clearing) scent at the appropriate moment also proved difficult, given the technological solutions that were available at the time (Fleischer 2007; Hartmann 1913).

While semantically-meaningful individual scents have, on occasion, been used in a theatrical setting to provide a certain atmosphere, they tended to be presented in isolation and hence there was no problem if they lingered in the auditorium (Banes 2001; Shepherd-Barr 1999). The aroma of roasting Brazilian coffee that greeted the nostrils of visitors at the 1938 International Surrealist Exhibition held at the Galerie des Beaux Arts was also a semantically meaningful smell (Kachur 2001). In this case, it has been suggested that the smell may have been chosen both because of its incongruency with the interior setting of the gallery (at the time it would have been more congruent with an outdoor café), but the fact that it was specifically (and to some, recognizably) the smell of Brazilian coffee roasting perhaps referencing 1938 as the year in which the Brazilians joined the Surrealist movement (Verbeek & Van Campen 2013). It is also worth noting the shift from the Baudelairean interest in universally harmonious combinations of sensations to the incongruent, mismatching, combinations of sensation that the Surrealists experimented with (Breton 1969, pp. 174-175; Classen 1998).

Another artistic attempt to connect the senses of smell and sight was

color, and framing edge—that is, painting’s primarily visual aspects.”

reported by Langner (1997). Langner was particularly interested in the question of whether it is possible to translate, or convey, the qualities of an odour by means of colour, form, and texture (see also Bildsoe n.d.; Smets & Overbeeke 1989). Langner (1997, p. 193) writes that: “Many records already exist of the fact that human beings assign specific colors and shapes to smells. But could our sense of smell be structured in such a way that we are also able to perceive smells as complete images? Are there specific natural laws or natural characteristics that permit images to become ‘odor images?’” Langner wondered whether abstract visual images could be used to evoke matching odour sensations. In background research for this project, Langner showed c. 120 people a selection of 15-20 abstract photos (from an initial set of 60 images). The latter were instructed to select only those images for which they could make spontaneous odour associations. Langner, a student of graphic design, eventually mounted an exhibition of odour-related images. The aim was to create an odour walk composed of a series of abstract images mounted on the walls of a gallery, with the matching scent descriptors that had been evoked in those who had been surveyed printed under each image. However, Langner failed to provide any assessment of how successful his approach to the communication of olfactory attributes by means of colour, form, and texture had actually been.

The Belgian smell artist Peter de Cupere (see de Cupere 2017) developed a range of colourful odoriferous plastic flowers for use in a care centre for the elderly suffering from dementia. For instance, “Smelloflowers” (2004-2005) at the care center Sensire Demn Ooiman in Doetinchem (The Netherlands), was designed to try and help the residents navigate through the space. De Cupere used distinctive scents and colours for each of the three sculptures situated in different pavilions. De Cupere has also developed a range of scratch ‘n’ sniff cards illustrating fantastical colourful flowers, again raising the question of how colour and scent should correspond.

2.3. Interim Summary

In this section, we have seen that there has long been an artistic interest in the crossmodal links between colour and scent. This was largely conceptualized, rightly or wrongly, in terms of synaesthesia. Two other points to note regarding the early interest in scent is that the symbolist

artists tended to be particularly enamoured with floral scents while, at the same time, wanting to stay away from those scents that were associated with, and hence stimulated thoughts of, food (cf. [Hartmann 1913](#); [Shepherd-Barr 1999](#)).¹⁰ However, there appears to be little evidence that the artists ever succeeded in terms of playing effectively with the abstract connection between the senses. One reason for this failure is that the correspondences have typically been conceptualized in terms of the rare and idiosyncratic inducer-concurrent relations exhibited by synaesthetes, rather than in terms of the commonly-shared crossmodal correspondences, and it is to these that we turn in the next three sections.

3. SYNAESTHESIA

Many of the artists working in the opening years of the 20th century were minded to consider cross-sensory correspondences as a kind of synaesthesia. As [Dann \(1998\)](#) notes, press and academic reports regarding synaesthesia had undoubtedly been on the rise in the latter half of the 19th century (e.g., [Binet 1892](#); [Jewanski et al. 2009](#); [Jewanski et al. 2011](#)) and many artists (at the very least) claimed to be synaesthetic (though see [Harrison 2001](#), for a discussion of how many of them actually were by today's standards). However, while synaesthesia appears not to be as uncommon as it was once believed to be (e.g., see [Cytowic 1989](#); [Harrison 2001](#)), it turns out that coloured graphemes, phonemes, and units of time represent by far the most common form of the condition (see [Day 2005](#)). By contrast, cases of olfactory-visual synaesthesia are relatively rare. In fact, according to a survey of 572 synaesthetes reported by [Sean Day \(2005\)](#), coloured odours (that is, colours that induce olfactory concurrents) were reported in just 6.9% of cases, while no cases of odours inducing colour concurrents have yet been reported. What is more, according to [Marks \(1978, pp. 98-99\)](#), synaesthesia involving the sense of smell would likely turn out to be “*much more erratic and idiosyncratic*” than coloured hearing synaesthesia (though, it should be noted, seemingly without providing any empirical evidence to support the claim).

¹⁰As [Hartmann \(1913, p. 222\)](#), puts it: “*And in a perfume recital, if this term be permissible, we hardly wish to become acquainted with smell as an anticipator of taste.*”

Over the course of the last century or so, a number of striking cases of odour-colour synaesthesia have been reported in the literature (see [Cytowic 1993](#); [Ginsberg 1923](#); [Luria 1968](#); [Speed & Majid 2018](#)). Despite the fact that cases of odour-colour synaesthesia obviously do exist, it is not clear that the nature of the idiosyncratic colour-odour associations involved necessarily have any relevance in terms of either predicting, or else helping to explain, the widespread crossmodal correspondences between odour and colour that have been documented in the general (that is, the non-synaesthetic) population. And, as the symbolist poets and artists soon realized, non-synaesthetes did not necessarily seem to appreciate being exposed to idiosyncratic crossmodal mappings that were based on inducer-concurrent relations experienced by synaesthetes.

While acknowledging the existence of a very small number of individuals who may well experience olfactory-colour synaesthesia ([Speed & Majid 2018](#)), in the contemporary era, researchers have generally tended to consider these shared odour-colour correspondences as representing a somewhat distinct class of empirical phenomenon (see [Spence in press](#), for a review). In fact, nowadays the majority of researchers have tended to explain these crossmodal mappings in terms of learned associations instead ([Spence 2011, in press](#)) and/or in terms of less clearly defined ‘natural mappings’ (see [Spector & Maurer 2012](#)). That said, the extent to which synaesthesia and the crossmodal correspondences can be distinguished undoubtedly remains something of a contentious issue amongst researchers (e.g., see [Deroy & Spence 2013](#); [Martino & Marks 2001](#); [Rader & Tellegen 1987](#); [Sathian & Ramachandran 2020](#)). For example, Martino and Marks (2001) have argued that they should be considered as two ends of one and the same continuum (e.g., as weak vs. strong synaesthesia, respectively). Others, meanwhile, have instead wanted to argue that they represent fundamentally different empirical phenomena that simply happen to bear a number of superficial similarities with one other (see [Deroy & Spence 2013](#), for a review). Confusing matters somewhat, several researchers have also characterized synaesthetic inducer-concurrent relations as little more than learned associations (e.g., [Calkins 1893](#); [Harrison 2001](#); [Héroult 1934](#)), while other researchers have described the idiosyncratic inducer-concurrent relations documented in synaesthetes as crossmodal

correspondences (see [Harrison & Baron-Cohen 1996](#)), thus further blurring the distinction.

Nevertheless, the point remains that while the synaesthetic interpretation of olfactory-visual correspondences was undoubtedly popular a little over a century ago, in the recent era, the focus has largely shifted away from idiosyncratic, unidirectional, and rare synaesthesia to the study of the consensual, bidirectional, and common mappings that are seemingly shared by many people. Indeed, the majority of researchers nowadays either make no mention of synaesthesia whatsoever, or else, if they do, they tend to treat it as a distinct condition ([Dérivé 1978](#)), one that affects only a very small subset of those whom they test. As an example of the contemporary scientific approach to crossmodal correspondences, the next section summarizes the results of an as yet unpublished psychophysical study that we conducted some 15 years ago on the theme of odour-colour mappings in the general (i.e., non-synaesthetic) population ([Österbauer et al. 2005](#)).

4. CROSSMODAL ODOUR-COLOUR MAPPINGS IN NON-SYNAESTHETES: EMPIRICAL EVIDENCE

[Österbauer et al. \(2005\)](#) conducted a psychophysical odour-colour matching study of odour-colour correspondences in which participants ($N = 40$) were presented with 17 odorants. The participants were required to pick the best- and worst-matching of ten approximately isoluminant colour patches (red, yellow, green, blue, orange, pink, brown, turquoise, purple, and gray) presented simultaneously on a computer monitor. Galbanum, aldehyde C-16, cinnamic aldehyde, methyl anthranilate, and caramel furanone were chosen because [Gilbert et al. \(1996\)](#) had previously reported these odorants as eliciting strong crossmodal odour-colour associations.¹¹ A further ten odorants (orange, strawberry, peppermint, grape, lemon, apple, banana, plum, spearmint, and cucumber) were essential oils of various fruits and herbs, that had been extracted from natural sources. Their hypothesized colour associations were thus based on the colour of the source they naturally occur

¹¹Intriguingly, [Gilbert et al. \(1996\)](#) documented a high test-retest correlation in terms of colours chosen for odours when participants were tested on a couple of occasions separated by two years.

in (e.g., banana and yellow). A fragrance called ‘Out at sea’ was also included because no object or food item was associated with it, while the final odorant, benzaldehyde, was chosen because people typically associate it with cherry and/or almond (i.e., red and yellowy-white, respectively).

For each odorant, the participants first selected the best-matching colour, before indicating the certainty of their choice on a scale from 0% (very unsure) to 100% (absolutely sure). Next they rated the odorant on a 7-point rating scale with respect to its pleasantness (very unpleasant – very pleasant), intensity (very weak – very strong), and familiarity (completely unknown – very familiar). The participants were instructed to write down the name of the odorant if they felt that they could identify it. Next, they selected the least matched colour for the odour from the display, before indicating the certainty of this judgment as well.

As predicted, the majority of the odours (all except aldehyde C-16, methyl anthranilate, cucumber, and ‘out at sea’) showed significant (non-parametric χ^2 test, $p < .01$) associations with one or more of the colours (see **Table 1**). The majority of these odours were matched to the prototypical colour of the source objects that they are associated with (i.e., lemon-yellow). However, a number of the colour matches were a little more surprising. For instance, pink was the second most frequently chosen colour to match the aroma of banana after yellow. Österbauer et al.’s (2005) results also revealed that none of the colours blue, purple, or gray were matched to any of the odorants at a level that was significantly greater than chance (cf. Gilbert et al. 1996). On average, the participants were quite confident of their matches, as indicated by the mean reported certainty of 69%.

A similar analysis of the least matching colour data revealed that significant associations with one or more colours also existed for all but six of the odorants (galbanum, aldehyde C-16, cinnamic aldehyde, methyl anthranilate, caramel furanone, and benzaldehyde) (see **Table 2**). Intriguingly, gray was picked as the least fitting colour for most of the odorants. The exceptions were peppermint and spearmint where the match was with red and the ‘out of sea’ odour that was matched to both red and brown. The average certainty (%) for choices of the mismatching colour was significantly lower (paired t-test, $t = 5.28$, $p < .001$) than for the colour matching condition. Taken together, the

Table 1: Matching colors as reported in Österbauer et al.'s (2005) study – see text for details.

Odorant	Hypothesized colour association	Observed colour association	Percentage of choices	Certainty (%)
Orange	Orange	Yellow Orange	50.0%* 27.5%*	87.5±10.7 92.0±10.3
Strawberry	Red	Pink Red	35.0%* 27.5%*	63.9±29.3 72.7±23.3
Peppermint	Green	Green	30.0%*	79.2±20.1
Grape	Purple	Pink	37.5%*	64.7±21.3
Lemon	Yellow	Yellow	77.5%*	87.7±13.6
Apple	Green	Green	42.5%*	75.9±21.5
Banana	Yellow	Pink	45.0%*	71.1±22.5
Plum	Purple	Pink	35.0%*	63.6±24.1
Spearmint	Green	Turquoise Green	40.0%* 27.5%*	73.1±25.2 92.7±7.9
Galbanum	Green	Brown Green	35.0%* 32.5%*	66.4±13.9 76.9±14.4
Aldehyde C-16	Pink	Purple	17.5% (n.s)	64.3±17.2
Cinnamic Aldehyde	Red	Brown Orange	30.0%* 27.5%*	77.3±19.5 70.9±18.7
Methyl Anthranilate	Pink	Pink Purple	20.0% (n.s) 20.0% (n.s)	76.3±17.7 43.8±29.7
Caramel Furanone	Brown	Brown	72.5%*	73.5±19.0
Cucumber	Green	Pink	17.5% (n.s)	61.3±23.0
'Out at Sea'	No hypothesis	Turquoise	22.5% (n.s)	67.8±19.2
Benzaldehyde (Almond)	Orange-yellow	Orange	32.5%*	66.9±26.9

The odorants used in Österbauer et al.'s (2005) study are shown together with their hypothesized color associations. The most frequently matched colors for each odorant are shown as well as the percentage of choices for that color and the average certainty (SD) of the match measured on a scale from 0% (very unsure) to 100% (absolutely sure). In the case of a single distinct peak in the color choice distribution, only one colour is listed. If two colours were chosen at a level that was significantly above chance, both of the colours are shown. If no color was significantly often matched to an odor the most frequently matched color is shown. (* = $p < .01$; (n.s.) = non significant.)

Table 2: Mismatching colors as reported in a study by Österbauer et al. (2005) – see text for details.

Odorant	Colour Mismatch	Percentage of choices	Certainty (%)
Orange	Gray	40.0% *	85.0±15.1
Strawberry	Gray	35.0% *	75.0±20.7
Peppermint	Red	32.5% *	69.2±21.0
Grape	Gray	37.5% *	62.7±22.8
Lemon	Gray	32.5% *	82.3±14.2
Apple	Gray	30.0% *	74.2±15.6
Banana	Gray	45.0% *	66.7±22.2
Plum	Gray	37.5% *	65.7±20.6
Spearmint	Red	35.0% *	71.4±17.5
Galbanum	Red	20.0% (n.s.)	63.8±15.1
	Turquoise	20.0% (n.s.)	60.0±26.2
Aldehyde C-16	Pink	17.5% (n.s.)	60.0±21.6
Cinnamic Aldehyde	Turquoise	20.0% (n.s.)	57.1±29.3
Methyl Anthranilate	Red	20.0% (n.s.)	57.5±14.9
	Gray	20.0% (n.s.)	65.0±18.3
Caramel Furanone	Red	17.54% (n.s.)	61.4±24.8
Cucumber	Gray	30.0% *	65.0±18.3
'Out at Sea'	Red	35.0% *	71.4±18.3
	Brown	25.0% *	67.0±20.6
Benzaldehyde (Almond)	Turquoise	20.0% (n.s.)	61.3±24.2

The results of Österbauer et al.'s (2005) study showing the least-matching colors for each odorant together with the percentage of choices for that color and the associated certainty on a scale from 0% to 100% are shown. In the case of a single distinct peak in the colour choice distribution only one colour is shown. If two colors were chosen at a level significantly above chance, both colors are shown. If no colour was significantly often chosen as mismatching to an odor the most frequently selected color is shown. (* = $p < .01$; (n.s.) = non significant.)

results of Österbauer et al.'s (2005) psychophysical study are representative of many of the studies in this area, in showing that even non-synaesthetic individuals consistently match colours to odours. At the same time, however, it is worth noting that even in the best case scenario, one never observes complete agreement concerning the most appropriate colour match for an odour. What is more, their results also show that while crossmodal mapping sometimes occurs on the basis of a familiar source object, that is by no means always the case.

5. CROSSMODAL CORRESPONDENCES BETWEEN OLFACTION AND COLOUR: CAUSES

Evidence concerning the existence of consistent crossmodal correspondences between olfaction and colour in non-synaesthetic individuals has been growing rapidly in recent years. A large part of this research has focused on the colours that are associated with the aroma, or flavour, of food and drink (e.g., see Spence et al. 2010; Spence 2019a; Zellner 2013). However, it is important to stress here that more than 20 peer-reviewed academic studies have also been published in which more abstract crossmodal correspondences between colour and odour have been assessed, away from the primary context of food (or sometimes of any other obvious source object for the smell). While a few of the latter studies were published in the middle decades of the 20th century (e.g., Déribéré 1971, 1973a,b, 1978; von Hornbostel 1931), the majority of the research in this area has been conducted over the last 25 years or so, hinting perhaps at the growing interest in this area.¹²

5.1. *Source-object, or semantic, crossmodal correspondences*

Summarizing the literature on crossmodal correspondences between colour and odour in the non-synaesthetic population, Spence (in press) recently highlighted the existence of several distinct classes of explanation. Perhaps the most popular account is in terms of associative learning (e.g., Chen & Spence 2017; Connolly 2014; Fifer et al. 2013; Walker-Andrews 1994), specifically, the internalization of crossmodal

¹²As has already been mentioned, those looking for a detailed critical review of this literature on non-food related odour-colour correspondences are directed to my recent review on the topic (see Spence in press).

semantic object-related associations. The suggestion here is that the configurations of features that are present together in objects, such as the sight, sound, and smell of a dog, say,¹³ are internalized as object-based, and conceptual, representations and contain the associated multisensory information (e.g., Barsalou et al. 2005; Hutchison 2003; Lucas 2000; Pecher et al. 2003). The crossmodal mappings in this case are, in a sense, arbitrary (see Walker-Andrews 1994). The existence of such multisensory semantic object-based representations might also help to explain the aesthetic synaesthesia reported by Martin (1909). That is, presenting one of the features of an object might well be expected to prime the others, perhaps to the level of awareness.

The suggestion, then, is that in those experiments where participants are presented with an olfactory stimulus, in the absence of any contextual information, say, and asked to pick the matching colour, they will first try to identify the source object for the smell. If they are able to do this then the next thing they do is to pick the prototypical colour for that object. In fact, the evidence from a number of studies suggests that odour-colour crossmodal mappings tend to be more consistent (or consensually agreed) in those situations where the source object for an odour has been correctly identified (Goubet et al. 2018; Kaeppler 2018; Stevenson et al. 2012). For example, 75% of those who correctly identified the odour of grenadine in the study by Goubet et al. picked red, whereas those who couldn't identify the odour chose yellow, brown, and orange instead. When a crossmodal correspondence between colour and scent occurs because of the co-occurrence of these features in a common source object then the mapping is presumably likely to be at least reasonably consistent amongst individuals. That being said, people may sometimes be mistaken in their source object attribution hence, on occasion, leading to inconsistent colour responses.

Given such a semantic explanation for the existence of odour-colour correspondences, one might ask why we need to invoke the notion of crossmodal correspondences in the first place. The reason, in this case, relates to one of the peculiarities of the olfactory system, namely the fact that we often struggle to identify/name the source object for odours when they are presented out of context (Yeshurun & Sobel 2010;

¹³Or the colour yellow and a sour taste, for a lemon, this the example mentioned by Kandinsky (1977).

though see also Croijmans & Majid 2016; Majid & Burenhult 2014). Very often, in fact, we find ourselves in the ‘tip-of-the-nose’ state where we know that we recognize the smell (i.e., we know that it is familiar) but just can’t quite manage to put a name to it (e.g., Djordjevic et al. 2004; Lawless & Engen 1977). In part, this naming difficulty may be linked to the relatively small amount of cortex that is given over to olfactory information processing, at least when compared to the other senses (e.g., Gallace et al. 2012; though see also McGann 2017). As has often been remarked upon in the literature, we appear to lack a vocabulary for smell, and normally can say little more than it smells like “X” (Dubois 1997, 2000; Olofsson & Gottfried 2015).

It is precisely this inability to identify the source object connected with an olfactory stimulus, then, that distinguishes olfaction from the case of audition and vision, where semantic congruency effects have typically been studied previously (e.g., see Chen & Spence 2010, 2018a, 2018b). For when studying audiovisual semantic congruency, researchers have typically been careful only to present those auditory and visual stimuli that participants find it easy to match to the appropriate object, or semantic category. Under such conditions, the crossmodal mapping of auditory and visual features occurs as a result of the conceptual knowledge that has been internalized following prior exposure to the co-occurring features, presumably as a result of associative learning.

At this point, however, it is worth noting, that even if the specific source object for an odour may be difficult to identify (e.g., is it blackcurrant, bilberry, or blueberry), the more general category of which the specific odour is a member may sometimes be easier to ascertain. As such, a colour match might be made to the general category rather than to the specific source object. So, for example, the participant in a crossmodal matching study might think something of the sort: “I know that this aroma reminds me of black fruits, but I just can’t decide which one”; see Croijmans et al. 2020). Relevant here, several studies have shown a similar category-based choice of matching colour when people are presented with commercial fragrances (e.g., Kim 2013; Schifferstein & Tanudjaja 2004; Zellner et al. 2008). In particular, it turns out that people’s choice of matching colours for unfamiliar perfumes often depends on whether the latter are categorized, or classified, as male or

female. For instance, Zellner et al. reported that participants chose darker colours (e.g., blue and to a lesser extent green) for those unisex fragrances considered male while if they thought of them as being feminine they picked lighter colours instead (pink and, to a lesser extent, yellow).

The research shows that even in the case where an odour stimulus is reliably matched to the appropriate source object, there may still be cultural/individual differences to be aware of. For example, the smell of lemon tends to be associated with the colour green, not yellow, in Colombia and certain other countries. Similarly, it has also been suggested that the smell of cinnamon is typically associated with the brown colour (of the spice) in Europe, while being associated with the red hard-boiled sweet in North America. Meanwhile, the smell of cucumber may be associated with red, not green, in Spain because of the cucumber odour and red colour found in gazpacho soup (see Demattè et al. 2006). More subtle cross-cultural differences in the specific hues matched to familiar odours, such as cucumber, lavender, and mint, have also been reported (Jacquot et al. 2016). Meanwhile, Nehmé et al. (2016) reported that pineapple odour was reliably matched with yellow by Taiwanese participants, while being matched with red by a number of the French participants.

Demattè et al. (2006) also reported that the synthetic smell of strawberry tended to be associated with the colour pink (as in strawberry-flavoured processed foods – think here only of bubble gum pink), and not red. There may also be a historical element to this too, with carrots once being associated with the colour pink not orange (Steel 2020, p. 121), while Sprite, when it was first launched, was coloured brown (see Spence 2019b), not the transparent colour we think of today (e.g., Goubet et al. 2018). Here one might also be tempted to question when people first started to associate the colour blue with the aroma, or flavour, of raspberry (e.g., Shankar et al. 2010; Spence 2018). It is, though, worth bearing in mind here that the artists, and especially the symbolist poets, who were active 100-150 years ago, were mostly interested in the abstract associations with floral scents, not food aromas (e.g., see Hartmann 1913, on this theme), hence meaning that such food flavour/aroma-related changes in colour associations are likely to be less relevant here.

To conclude, while the sensory features linked in a source object would normally qualify this as an example of object-based semantic congruency, or mapping (Chen & Spence 2010), the fact that we often struggle to bring the relevant object to mind turns this into more of a crossmodal correspondence (in the sense that the crossmodal mapping is surprising – this one of the distinctive features of both crossmodal correspondences and synaesthesia; see Deroy & Spence 2013). While the semantic account helps to explain the crossmodal mapping of colour to odour in the case of smells whose source object can be identified, the next question is what happens in those cases where no source object springs to mind (Zellner 2013). According to Stevenson et al. (2012), when odorants are neither nameable nor familiar, people may base their colour matches on the intensity, irritancy, and/or hedonics associations instead. In such cases, crossmodal matches are often made on the basis of perceptual similarity and/or emotional-mediation instead. It is to these cases that we turn next.

5.2. *Perceptual mapping*

Several researchers have highlighted a crossmodal correspondence between lightness (e.g., of a greyscale) and olfactory stimuli (von Hornbostel 1931). In fact, on the basis of his early research, von Hornbostel (1931) suggested the existence of an amodal dimension of sensory brightness. Von Hornbostel had his three or four participants make pairwise judgments of smell-lightness (or smell-brightness “Geruchshelligkeit”) for approximately 800 chemicals. Von Hornbostel was able to order the odours based on their position on the greyscale (i.e., in terms of increasing smell lightness). Others, meanwhile, have argued that the latter’s results might instead reflect the matching of the relative position of stimuli along unimodal perceptual scales. This was the suggestion put forward by Cohen (1934) based on his own limited assessment of the transitivity of olfactory crossmodal correspondences (though see also Hartshorne 1934, p. 277; and Ryan 1940). Certainly, the relative nature of many crossmodal correspondences, especially those involving the auditory dimension of pitch is quite different from the absolute mappings that one sees in the case of synaesthesia proper (e.g., Deroy & Spence 2013). As such, end-anchoring, context, range, and sequence effects tend to influence the crossmodal

correspondences that are observed. It would seem likely that odour correspondences with greyscale values would also be relative too.

Kemp and Gilbert (1997) documented an intensity-based correspondence between olfactory intensity and visual brightness (cf. Stevens 1957, on intensity-based crossmodal correspondences). The latter researchers presented 38 participants with five odours (caramel lactone, cinnamic aldehyde, aldehyde C-16, galbanum oil, and methyl anthranilate) at three concentrations each. The odorants were chosen because of the strong and consistent colour associations that had been documented in an earlier study (see Gilbert et al. 1996). The participants picked one of 1565 Munsell colour chips for each of the 15 odorants, as well as rating the perceived intensity of each odorant. Kemp and Gilbert looked for any systematic variation in hue, chroma (degree of saturation), and value (colour brightness from white to black) that was linked to variation in perceived odour intensity. A dimensional relationship was observed, such that colour lightness varied systematically (inversely) with perceived odour intensity for three of the five odorants (methyl anthranilate, cinnamic aldehyde, and galbanum). That is, a significant negative correlation was documented between Munsell value and perceived odour intensity, with darker colours being associated with the stronger odours. Taken together, such results clearly highlight the fact that brightness/intensity is one of the perceptual dimensions on which at least certain olfactory-visual crossmodal correspondences are based.

5.3. *Emotional-mediation of colour-odour correspondences*

A number of researchers have deliberately presented unfamiliar odours (either individual chemicals or perfumery materials, or else unfamiliar perfumes) where there isn't necessarily a source object to visualize, or where the source object simply doesn't come to mind). Under such conditions, as we have just seen, there may be a more direct perceptual correspondence, or else the correspondence may be emotionally-mediated instead (e.g., Kim 2008, 2013; Schifferstein & Tanudjaja 2004). In the case of unfamiliar fragrances, for example, people have sometimes been shown to pick matching colours on the basis of their emotional connotation. Indeed, it turns out that people link both colours (Gilbert et al. 2016; Ou 2015; Palmer et al. 2013) and unfamiliar odours to emotions

(e.g., Benderly 1988; Hinton & Henley 1993; Schiffman 1974).¹⁴

At the same time, however, specific (possibly familiar) odours may also be linked idiosyncratically to memories that may themselves be emotionally-valenced (either positively or negatively; e.g., see Hartmann 1913; Runciman 1915), and are unlikely to be the same for everyone. Here one need only think of the Proust effect (e.g., Van Campen 2014). The pleasant memories for Proust that were associated with the smell of madeleine biscuits and tea might well have no association for someone else, or else be negatively-valenced instead (Herz & Schooler 2002; Toffolo et al. 2011; Willander & Larsson 2006). It was precisely these individual differences in the emotional associations triggered by specific familiar odorants that Runciman (1915) drew attention to when criticizing Scriabin's idea of presenting olfactory stimuli that would correspond, in a universally-meaningful manner, with the light show accompanying his tone poem *Prometheus: Poem of Fire*. Hartmann (1913, p. 222) also points to the idiosyncratic meanings, or associations, with scents as one of the reasons that his olfactory performance did not work.

The emotional account of crossmodal correspondences has become increasingly popular in recent years (e.g., see Palmer et al. 2013; Spence 2020b, for a review). That said, it is worth noting that this account is not without its own problems/ ambiguities. On the one hand, the range of affective states labelled as 'emotions' feels rather unconstrained: For instance, just take the following so-called 'emotional' dimensions from a study by Whiteford et al. (2018) to get a sense of the broad use of the term 'emotion' by researchers: complex vs simple; harmonious vs disharmonious; loud vs quiet; spicy vs bland; warm vs cool; whimsical vs serious). Second, it is often unclear whether it is emotion that is associated with the stimulus or felt by the observed that is doing the work. While these may often be in agreement, they undoubtedly can dissociate in the case of art. i.e., just think about how you might feel happy while watching a movie or opera that is itself depressing or sad (e.g., Gabrielsson 2001; Schubert 2013).

One potential way out of this problem is to consider connotative

¹⁴It is, however, worth noting that when presented together, the emotional associations of one stimulus may be influenced by the presence of the other (e.g., Arao et al. 2011; Ferrier et al. 2009; Hörberg et al. 2020).

meaning of stimuli as a possible basis for crossmodal perceptual matching – i.e., the idea would be that people match stimuli on the basis of connotative meaning, as typically assessed by means of semantic differential technique (SDT; see Osgood et al. 1957; Walker 2012; Walker et al. 2012). Such an account might well help to provide an overarching account of the emotional-mediation account of crossmodal correspondences. It might also provide an explanation for perceptual matches as well. At the same time, however, critics might want to question whether the granularity of certain perceptual matches that have been obtained to date can easily be accounted for within the SDT framework. While this is certainly not the place to resolve this question, it is undoubtedly an intriguing question for future research.

5.4. *Interim summary*

One might be tempted to suggest that there is something of a hierarchy as far as the basis on which olfactory-visual crossmodal correspondences are established. If a source object for an odour comes easily to mind, then it is likely that the matching colour (i.e., hue, lightness, or saturation) will be based on the prototypical colour of the source object. If, however, no source object comes to mind then a more general categorical membership may sometimes determine the match instead (e.g., “this smells like a man’s/woman’s fragrance”; see Zellner et al. 2008). The salient dimension for matching may also depend on the context in which the scent happens to be presented (e.g., if intensity or pleasantness is the more salient dimension of stimulus variation). While the focus in this section has been on the colours that people match to odours, it should be noted that, just as hinted at by Azari (1942) almost a century ago, people also match textures and shapes to odours. In this case, though, it does not seem that the mapping is based on the properties of the source object – i.e., the smell of lemon is matched with an angular rather than rounded shape, despite the source object itself (the citrus fruit) being round (Adams & Doucé 2017; Crisinel et al. 2013; Hanson-Vaux et al. 2013; Kaeppeler 2018; Seo et al. 2010a). The matching of colours to odours is especially intriguing because it can be both source based and more abstract (e.g., perceptual or emotionally-mediated).

6. WELCOME TO THE TATE SENSORIUM

Having reviewed the literature on crossmodal correspondences between odour and colour, and having distinguished it from both synaesthesia as well as the intriguing phenomenon of involuntarily-evoked crossmodal mental imagery, we are now in a position to consider the *Tate Sensorium*, in order to see how Flying Object, the London-based creative studio who won the 2015 IK Prize¹⁵ used such crossmodal connections in order to change the way in which the viewer interacted with the works of art. Four items from the collection were chosen for the *Tate Sensorium* exhibition. Flying Object developed a multisensory experience around each work of art that incorporated the latest in digital technology, including everything from mid-air ultra-haptics to directional sound and the movement-controlled release of scent (Ablart et al. 2017; Vi et al. 2017). This experience was limited with only four people being allowed in the one room exhibition space at any one time (Davis 2015). The experience was a sell-out, with a 100% capacity of 4000 visitors over the two months of the exhibit (see Pursey & Lomas 2018), perhaps hinting at the appeal of multisensory experience design more generally. It is also worth noting that the installation was set up as an experiment with the visitors wearing wireless galvanic skin response (GSR) wristbands to measure their responses to the multisensory exhibits.

Two of the four works at the *Tate Sensorium* were accompanied by scents, and a third painting was to be viewed while tasting an aromatic, smoky, dark chocolate, thus presumably stimulating olfaction retronasally (see Spence 2015a). In Richard Hamilton's (1964) *Interior II*, a Black and White full-bodied screenprint portrait of actress Patricia Knight from the 1949 movie *Shockproof* dominates the scene. The smell of wood polish (Pledge) was introduced, referencing the parquet flooring depicted in the scene. At the same time a carnation perfume was dispensed from another device to link to the scent of hairspray, which was mentioned frequently in the film itself. Finally, the smell of glue was used to reference the collage involved in the creation of the work. The release of each scent was triggered by hidden sensors when the

¹⁵This prize is awarded annually for the innovative use of digital technology to engage the public with Tate Britain's extensive collection of British art (Davis 2015).

visitor moved around in front of the work (Pursey & Lomas 2018). In this case, note, all three of the scents had a source object linked to, or contained within the scene.



Figure 3: David Bomberg's *In the Hold* (c. 1913-14), on of the exhibits at the 2015 *Tate Sensorium*. Note that the viewer is holding a scented shaker with one of two scents designed to correspond to different colours in the scene. [<https://dl.acm.org/cms/attachment/2bc2a633-747a-4ffa-ba96-30121bcab3b5/ins03.gif>]

David Bomberg's *In the Hold* (c. 1913-14), made up of a multitude of black and coloured triangles (see **Figure 3**) was supposed to be experienced while inhaling the contents of one of two triangular-shaped salt shakers. The 'high-pitched' scent in one shaker was meant to bring out the blues in the scene, while the scent in the other was intended to bring out the browns and ochers instead. It is, though, unclear on what basis these putative colour-odour crossmodal correspondences had been established (see [Spence 2020a](#) for a review). Relevant here, semantically-based colour correspondences have been shown to bias visual search for congruently coloured objects in the scene ([Chen et al. 2013](#); [Seigneuric et al. 2010](#); [Seo et al. 2010b](#)). What is currently less clear is whether the same is true for indirectly mapped stimuli, though it is perhaps worth noting that famous perfumer Edmond Roudnitska was also convinced of the existence of crossmodal correspondences between visual and olfactory art ([Stamelman 2006](#), p. 186). What is more, given that people associate shapes with odours, it may well be relevant that there is only

one shape (the triangle) repeated throughout this work (see [Spence 2020a](#)) for other artistic/curatorial uses of fragrance in the art gallery / museum context.

Francis Bacon's (1945) *Figure in a Landscape* was to be viewed while tasting a chocolate composed of edible charcoal, sea salt, burnt orange, cacao nibs, and smokey lapsang souchong tea designed, apparently, to bring out the painting's dark nature. Once again, the colour associations with the retronasal aromas (see [Spence 2015a](#)) are with the source objects. Since 2015's *Tate Sensorium*, there have been a number of other examples of scent and music being combined in an artistic setting, though their use tends to be more semantic rather than abstract ([Sebag-Montefiore 2016](#)). For instance, in 2016, the Australian Art Quartet presented a project entitled "Scent of Memory" in which scent was combined with various pieces of classical music, such as the Estonian composer, Arvo Pärt's *Fratres* (see also [Ward 2014](#)). Scents were also created in 2019 to match nine of the works in The Louvre (see [Bremner 2019](#); [Spence 2020a](#)). Meanwhile, more abstract cross-modal correspondences between odours and sounds are increasingly to be found incorporated into musical wine tasting events (e.g., see [Spence 2020c](#); [Spence & Wang 2015a,b,c](#)).

7. CONCLUSION

The last few years have seen a rapid growth of interest amongst researchers in the crossmodal correspondences. One of the classes of correspondence that has long intrigued a number of artists is the putative association between colours and odours. While traditionally conceptualized in terms of synaesthesia, over the last quarter century or so, more than 20 peer-reviewed published studies have assessed the consistent, and non-random, nature of the colours that non-synaesthetes intuitively associate with specific (both familiar and unfamiliar) odours when presented in the absence of any other contextual information (see [Spence in press](#), for a review). Importantly, many of these correspondences have been demonstrated outside of the context of coloured food (see [Spence et al. 2010](#), for a review).¹⁶ In this review, I have taken a

¹⁶The evidence then argues against [Nehmé et al. \(2016\)](#)'s suggestion that crossmodal links between olfaction and vision are hardly mentioned in the literature.

close look at the background, history, and putative explanation(s) for the existence of such crossmodal correspondences between colours and odours, while also distinguishing the phenomenon from the frequently-linked, and undoubtedly closely-related, phenomena of synaesthesia and crossmodal mental imagery (Nanay 2020).

As we saw earlier, there has been a long history of interest, though often wrapped up, at least initially, in the separate literature on what is often referred to (rightly or wrongly) as synaesthesia (e.g., Azari 1942; Baudelaire 1857/1954; see also Kandinsky 1977). A number of early artists and composers (in the opening decades of the 20th Century), from Cézanne to Scriabin (Hull 1927; Runciman 1915), through little-known Futurist artists such as Azari (1942) and Carrà (1973) were undoubtedly curious about the connections, or correspondences that linked colours with odours (see Verbeek 2017, for a review). However, one of the stumbling blocks that stymied this early interest was that the phenomenon was primarily considered in terms of ‘synaesthesia’, what the Futurists called ‘syn-olfactismo’ (Marinetti 1932/2014). By reframing the debate in terms of crossmodal semantic associations and crossmodal correspondences based on emotional-mediation or perceptual similarity such crossmodal mappings become easier to work with and to study.

The research on more abstract crossmodal correspondences (i.e., those where a source object for an odour cannot easily be brought to mind) that has been published to date would appear to suggest that while there are a number of commonalities in the associations that are observed across both culture and age, there are also some salient culture-specific, and developmental, differences in the mappings that people make (de Valk et al. 2017; Goubet et al. 2018; Levitan et al. 2014). Indeed, consensuality of colour responses for odours, while very often significant, rarely exceeds 50-60% concordance (in the best-case scenario). What is more, the ease or difficulty of picking a colour appears to depend on whether or not a concrete source object for the smell can easily be brought to mind (Goubet et al. 2018; Stevenson et al. 2012). The latter observation presumably making it difficult for those artists wishing to transpose, or translate, sensory impressions between the visual and olfactory modalities in a manner that is both universally meaningful and, at the same time, abstract. The relative nature of cer-

tain crossmodal correspondences adds to the challenges associated with trying to deliver a universally-agreed match.

One of the other important issues to bear in mind is that while the crossmodal correspondences between odour and colour may be apparent/salient when the two stimuli are presented in isolation, in the majority of realistic contexts, colours are presented in relation to a variety of other visual stimuli. Hartmann (1913, p. 226), for example, noted long ago that a rapid succession of single odours (an olfactory melody) would be necessary in order to deliver an aesthetic olfactory response. All the evidence suggests that intramodal perceptual grouping will likely dominate over the much weaker crossmodal grouping under such conditions (see Spence 2015b, for a review). It should also be pointed out that the task of deciding which colour matches an odour (as typically the case in studies of odour-colour correspondences) constitutes quite a different situation from being given a particular combination of abstract stimuli and being told that they correspond (as has been more common in the typical artistic situation). Nevertheless, the more we learn about the crossmodal correspondences, their frequently relative nature (Spence 2019c), and the lack of perfect consensuality (see Spence in press, for a review), what becomes increasingly clear is that the artist's aim of delivering perfectly consensual combinations of stimuli crossmodally is unlikely ever to be achieved, even amongst a homogenous group of individuals. That said, as has been demonstrated by a number of recent artistic examples, semantically meaningful scents can be used effectively. Alternatively, as in the *Tate Sensorium*, one can also work within the framework of more abstract (perceptual or emotionally-mediated) crossmodal mappings, as when the lighter of two fragrances is matched with the lighter colours in a scene.

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