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Music-Colour Synaesthesia: Concept, Context and Qualia

Caroline Curwen
Department of Music, The University of Sheffield, Jessop Building,
34 Leavygreave Road, Sheffield S3 7RD

Corresponding Author: Caroline Curwen
Mailing address: 44 Queens Drive, Heaton Mersey, Stockport, SK4 3JW
Mobile phone: 07967 206785
E-mail: ccurwen1@sheffield.ac.uk

1 Introduction

Synaesthesia is a relatively rare condition that manifests itself in approximately four percent of the population. It is a phenomenon that occurs automatically and, generally, with considerable consistency over time. It has been described as a ‘union of the senses’ (Cytowic, 1989, 2002; Marks, 1975; Motluk, 1994; Vernon, 1930) and, typically, arises as result of stimulation in one sense (an inducer) triggering a reaction in an unstimulated second sense (a concurrent). The most commonly examined form is grapheme-colour synaesthesia in which colours are experienced in response to digits or letters (Hubbard, 2007) although many other combinations exist: a sensation of colour may be elicited on hearing certain sounds, or in association with certain tastes, or by touch. Furthermore, although often described as a purely sensory to sensory phenomenon, it is also possible for inducers to be non-sensory in nature. For example, some common forms result in an experience of colours and spatial layouts in association with days of the week or calendar months; neither months, nor days of the week, can be described as delivering any sensory input, per se. This review provides a commentary in three parts on the existing literature that explores a form of synaesthesia also known as chromesthesia, or coloured hearing, that arises on hearing music. The first part of the review begins by considering the characteristics of music-colour synaesthesia and the commonalities between the synaesthetic experience and normal cross-modal perceptions in non-synaesthetes (Ward, Huckstep, & Tsakanikos, 2006a; Isbilen & Krumhansl, 2016). The second part of the review discusses the two main neurological hypotheses pertaining to the cause of synaesthesia: the hyperconnectivity theory (Ramachandran & Hubbard, 2001a) and the disinhibited feedback theory (Grossenbacher & Lovelace, 2001) followed by a discussion of the results of eight neuroimaging studies with a sound-colour focus. The final section explores how some types of music-colour synaesthesia provide further evidence in support of the importance of the role of conceptual and semantic inducers in synaesthesia, and the alternative theory of ‘ideaesthesia’ (Nikolić, 2009; Mroczko-Wąsowicz & Nikolić, 2014). The review concludes with a consideration of the challenge presented by synaesthesia to established philosophical theories and the position music-colour synaesthesia might occupy within the larger context of musical qualia.

2 CHARACTERISTICS AND COMMONALITIES

2.1 The Characteristics of Music-Colour Synaesthesia

The umbrella term ‘music-colour synaesthesia’ or simply ‘coloured-hearing’ has been applied to the experience of colour elicited on hearing sounds. There are several different types of music-colour synaesthesia which manifest in quite different ways and might include not just the experience of colours, but also of textures, shapes and spatial landscapes (Eagleman & Goodale, 2009). Peacock (1985) broadly classified four groups of ‘inducers’ related to compositional style, timbre, tonality, and pitch (or tone). These may be further differentiated to include relationships between colour per individual composer, colour and certain keys, and colour occurring from differing harmonic progressions (Vernon, 1930). It is not uncommon for synaesthetes to experience combinations of these different types, and the idiosyncratic nature of the condition frequently results in individual synaesthetes disagreeing about the colours and imagery associated with musical inducers: one synaesthete may consider B minor to be the colour of sunlight on a window pane, yet for another B minor is sea green. Examples of the different types of music-colour synaesthesia experienced are given by GS, the subject of Mills, Boteler, and Larcombe’s (2003) study. Her experiences encompass shapes, texture, and movement, in addition to colours. GS reports big blocks of dark colours in response to heavy metal music, and displeasing combinations of colours to music that she does not like. GS does not possess absolute pitch but found that higher pitches would be accompanied by lighter colours and lower pitches by darker colours. GS also explained that different instruments, or combinations of instruments, would produce different colours and patterns, and that the same note played at the same pitch but on a different instrument would result in a different colour. Musical intervals, tonality and themes created landscapes that she referred to as maps, and the tempo of the music would dictate the speed at which the maps moved. GS commented that she often found the maps easier to follow than standard musical notation.

2.2 Normal Cross-Modal Associations

Although there is a uniqueness to the visual and/or spatial phenomenon synaesthetes experience on hearing music, some commonalities with cross-modal association**s** in non-synaesthetes have been identified (Ward, 2013). For example, in the general population the visualised size and location of pitches has been shown to be associated with certain auditory characteristics: higher pitches tend to be associated with an elevated spatial position and a smaller size, and lower pitches with a lower space and a larger size (Marks, 1987, 2004; Gallace & Spence, 2006; Walker et al., 2010; Ward et al., 2006a). Ward et al. (2006a) posits that although there are differences between synaesthetes and non-synaesthetes in respect of automaticity, consistency and specificity of colour selections, both groups do appear to employ similar pitch mapping with regard to pitch-lightness. Tsiounta, Staniland, and Patera (2013) also found that non-synaesthetic people appeared to use comparable mental processes to make associations between colours and music, and to make similar pairings at a conceptual level. The study examined the correlations that people from different cultures and backgrounds made between colour and music. Twenty different music genres were presented to participants and then twenty different themes from movies and television soundtracks. In each case participants were required to select a colour from a pallet that they thought was best associated with the track they were hearing. The results demonstrated a level of common association in some genres between colour and music in non-synaesthetic people

2.3 Role of Emotion

Similarly, a level of common association has been demonstrated between emotion and music, and emotion and colour (Palmer, Schloss, Xu, & Prado-Leon, 2013; Palmer, Langlois, & Schloss, 2016). Palmer’s studies were carried out with non-synaesthetes and demonstrated an association between major keys and more saturated, yellow, and brighter colours, and an association between minor keys and darker, bluer, less saturated colours. In addition, emotional ratings of the colours and the musical excerpts showed a correlation between the emotional state and the musical excerpts, and emotional state to the colours, suggesting that music to colour associations might be mediated by emotion in the general population.

Isbilen & Krumhansl (2016) carried out further studies to test this hypothesis including in their study musicians, non-musicians, absolute pitch possessors, and music-colour synaesthetes. Using the preludes from Bach's Well Tempered Clavier, musical excerpts were presented in each of the major and minor keys and in a diverse range of styles. The study comprised three experiments. Experiment 1 required participants to choose from a pallet of eight colours and to match them to excerpts heard from 24 preludes. From the colour choices made, it was found that the preludes could be grouped together in terms of tempo, key, pitch height and attack rate. In Experiment 2, participants were asked to rate the colours on an emotional scale, and in Experiment 3, they were asked to rate the preludes they heard on the same emotional scale. The results of Experiments 2 and 3 were then combined and it was found that the music-colour associations observed in Experiment 1 could be predicted by the colour-emotion rating given in Experiment 2, and the music-emotion rating given in Experiment 3. The possession of synaesthesia or absolute pitch was shown to have very little effect on the actual colours chosen for each of the musical excerpts, but it might be reasonable to expect that music that elicits a strong emotional response may be more likely to induce synaesthesia than music that does not (Marks, 2004). Such results suggest that there may be similarities on a general level in the way that people conceptualise emotions associated with music and those associated with colours. The conceptual meaning of music may vary with its emotional (Cutsforth, 1925; Marks, 2004) which in some forms of music-colour synaesthesia may also be represented by a corresponding change in colour.

Although the studies above lend support to the hypotheses that synaesthesia may rely on normal cross-modal associations (Marks, 2013; Simner, 2013) and that chromesthesia is a general mental mechanism that helps us process aural information (Marks, 1975), this apparent common association should not be used to dismiss synaesthesia as a distinct phenomenon per se. Both synaesthetes and non-synaesthetes are exposed to the same learned cultural and environmental associations: large objects do tend to make louder noises on impact than smaller ones, and higher pitches are generally associated with the sounds made by smaller objects (Spence, 2011). Indeed, Parise and Spence (2009) posit that the connection between pitch and elevation might be the brain's employment of coupling priors to enable it to interpret the natural environment. However, it has been pointed out that it is the automaticity, general consistency, and specificity of inducer and congruent pairings that set synaesthesia apart from normal cross-modal associations (Ward et al., 2006a).

Notwithstanding the similarities to the cross-modal associations made between music excerpts, emotion, and colour by non-synaesthetes, studies exploring coloured hearing or auditory-colour synaesthesia frequently focus on those synaesthetes who report sensations of colour arising from the sound of pure tones (Ward et al., 2006a). From this stems comparisons to the hypothesised mechanisms of absolute pitch and the ability to assign a label to individual notes (Gregersen et al., 2013; Loui, Zamm, & Schlaug, 2013; Profita, Bidder, Optiz & Reynolds, 1988; Takeuchi & Hulse, 1993). However, music-colour synaesthesia is not simply about the ability to label an isolated pitch or a chord and is not always accompanied by the possession of absolute pitch (Mills, Boteler & Oliver, 1999). As previously discussed, music-colour synaesthesia is often dependent on timbre, context, and key, and accompanied by shapes, spatial layouts and textures (Eagleman & Goodale, 2009). Self-report is often the only means of discovery and although questionnaires and interviews are useful means of gathering data these do not provide a method of verification of its existence and properties.

2.4 Methods of Verification

The development of the test of genuineness (TOG) for word-colour synaesthesia established consistency over time as the primary measure to distinguish real cases of synaesthesia from non-genuine cases (Baron-Cohen, Wyke, & Binnie, 1987). From this principle, the Synaesthesia Battery ('the Battery') was developed by Eagleman, Kagan, Nelson, Sagaram and Sarma (2007) to provide a quantifiable battery of online tests for several different types of synaesthesia. The Battery comprises a questionnaire to identify the type of synaesthesia that might be present, which is then tested by appropriately designed software programs. A pallet of 16.7 million colours is offered from which a corresponding concurrent may be chosen. Each inducer is presented three times during the trial and any variation in the colours chosen is analysed for consistency by measuring the geometric distance in RGB (red, green, blue) colour space. A total colour variation score per participant is then calculated from this. Those who score less than 1 are verified as having synaesthesia, with controls generally scoring over 2 (Eagleman et al., 2007). The Battery has been used successfully in verifying grapheme-colour synaesthesia (Rothen, Seth, Witzel, & Ward, 2013) and also offers tests for tone-colour synaesthesia, single chords to colour, and instruments to colour (Zamm, Schlaug, Eagleman, & Loui, 2013). However, the sheer number of colour choices available may make it difficult to find the exact same colour the second time around, and not all synaesthetes just experience a single colour. Synaesthetes who experience textures, shapes, and movement in addition to colour, may find the colour palette too limited. Music-colour synaesthetes are frequently reported to experience combinations of different colours, hues and shapes (Mills et al., 2003; Marks, 2011) and so the Battery may be less useful in identifying this form of synaesthesia. Indeed, the exclusive use of the Battery might result in certain types of music-colour synaesthesia being ruled out altogether. Synaesthesia elicited from music is mediated by more than just sound. Changes in timbre, pitch height, tempo, emotional content and style, either individually or in combination, might significantly affect the synaesthetic texture, hue, saturation and movement of a musical excerpt, possibly making the perceived colour inconsistent across presentation (Mills et al., 2003). Consequently, those that require the context of an entire piece of music to elicit colours may find that the presentation of isolated chords, tones or instrumental timbres simply insufficient to bring about a synaesthetic response.

The requirement of consistency as the primary measure in the TOG for the existence of synaesthesia has been placed under scrutiny by both Simner (2012) and Cohen Kadosh and Terhune (2012). Simner points out that with the existence of so many different types of synaesthesia it may be incorrect to assume that each type operates through the same mechanism. The danger of the reliance on measures that solely use the consistency test for verification might result in some forms of synaesthesia being overlooked, such as the types of music-colour synaesthesia mentioned earlier that require more than an isolated tone to elicit a synaesthetic response. Furthermore, it has been demonstrated that in reality there can be some inconsistency in synaesthesia and that some variation over time has been observed, particularly in children (Cytowic, 2002; Eagleman et al., 2007; Rogers, 1987). The subject of Mills' case study, GS, reported inconsistencies in her experiences: 'Sometimes the same note would be played, but will be a different color. I don't know why, even on the same instrument it'll be a different color' (Mills et al., 2003, p.1364). Ward and Mattingley (2006b) also question the prescriptive nature of the consistency requirement in the TOG asking, 'Would we not consider a person to be a synaesthete if the colours he or she experienced for particular musical notes changed over time?' and suggests that it should be regarded as an 'associated characteristic' rather than as an all defining one (p. 130). Simner (2012) presents the challenge of finding a better measure than consistency. Cohen Kadosh and Terhune (2012) agree and remark that failure of a consistency test should not result in the exclusion of those that none the less report synaesthetic experiences equally well demonstrated through behavioural tests such as Stroop interference (Stroop, 1935). For example, a synaesthete who sees a '7' as green and a '6' as red may find it more difficult to identify a '7' in red ink or a '6' in green ink, should this be incongruous with their synaesthetic colour (Mills et al., 1999; Dixon, Smilek, Cudahy, & Merikle, 2000; Mattingley, Rich, Yelland & Bradhaw, 2001). Yet, it should be noted, as demonstrated by Elias, Saucier, Hardie and Sarty (2003), that Stroop interference alone is not sufficient to confirm the existence of synaesthesia, as it may demonstrate the presence of learned associations. In this study one control had been using cross stitch patterns for eight years during which time learned associations had formed between certain colours and numbers. Significant Stroop interference was noted for both the grapheme-colour synaesthete and the control, but it was not possible to categorically distinguish between the two. However, although the consistency test might be best used in association with other measures rather than alone, it does show us that a difference exists between synaesthetes and non synaesthetes (Hubbard, Arman, Ramachandran & Boynton, 2005) and suggests that the experience is vivid and specific enough to be able to select very precisely.

2.5 Individual Differences between Synaesthetes

A further complication in finding a suitable method of verification for synaesthesia is a noted difference in phenomenological experience between categories of synaesthetes themselves: 'associators' and 'projectors', and 'higher' and 'lower' synaesthetes. Associators often describe their experience of colour as being in 'the mind's eye' (Dixon, Smilek & Merikle, 2004; Dixon & Smilek, 2005) or as 'knowing' the colour (Ward, Li, Salih & Sagiv, 2007) suggesting the application of higher cognitive processes (Meier & Rothen, 2007). In contrast projectors describe being able to 'see' colours which are often projected outside the body and into external space (Smilek, Dixon, Cudahy, & Merikle, 2001). A behavioural study carried out by Dixon et al., (2004) demonstrated that the distinction is not just confined to the self-reporting phenomenal experience but that it also points to different cognitive mechanisms. The study carried out a Stroop test on grapheme-colour synaesthetes and demonstrated that projectors were slower in naming the actual colour of digits when the colour was incongruent with their synaesthetic colours, whilst the reverse pattern was demonstrated by associators. Overall, different patterns of Stroop interference were shown by projectors and associators. Van Leeuwen, den Ouden and Hagoort (2011) also demonstrated differences in processing between associators and projectors using dynamic causal modelling (DCM) of fMRI data. Evidence was shown that associators demonstrated disinhibited feedback from the parietal cortex to the V4 colour area, whilst projectors favoured cross-activation from an area that processed letter shape, or form, directly to the V4 area. Compared to the literature on associators and projectors, there is less empirical evidence for the categorisation of higher and lower synaesthetes (Chiou & Rich, 2014). The distinction between higher and lower synaesthetes was first proposed by Ramachandran and Hubbard (2001b) in the face of contradictory results, who posited that cross-activation mechanisms were occurring at a different time and place in the brain in each case. Lower synaesthetes were thought to be processing at an earlier stage in the fusiform areas that manage grapheme form and the perception of colour, whilst higher synaesthetes were thought to process at a later stage in the areas that dealt with conceptual aspects of colour. The distinction between higher and lower synaesthetes lies in the type of inducer and the level of processing. Synaesthesia in a lower synaesthete is thought to be triggered by bottom-up lower level features such as the shape or texture of an inducer, whilst in higher synaesthetes the conceptual characteristics of the inducer influence higher level later stage processing (van Leeuwen, 2013). The early stage in processing in lower synaesthetes can lead to early perceptual effects known as ‘pop out’ (Ramachandran & Hubbard, 2001b). It was originally thought that all synaesthetes would demonstrate the ability to do this, as in Ramachandran and Hubbard’s (2001a) experiment asking participants to find a hidden shape of ‘2’s in a pattern of ‘5’s. However, a later study found that this was not the case. Lower synaesthetes might be able to identify a target amongst distractors very fast, but in higher synaesthetes this ability is not as strong (Hubbard et al., 2005). This is because it is not the shape of the digit that induces the concurrent for higher synaesthetes, but the concept or meaning of the letter (Cytowic & Eagleman, 2009). Although on the face of it, it may be reasonable to suppose that associators should be mapped to higher synaesthetes and projectors to lower synaesthetes, this has not been substantiated and in some studies proved to be orthogonal (Ward et al., 2007). The distinction between associators and projectors is in the experience of the concurrent, whilst that between higher and lower synaesthetes is the nature of the inducer. Consequently, in principle, it is not impossible to have a lower synaesthete that perceives colours in his ‘mind’s eye’, or a higher synaesthete that is a projector. Although much of the literature has focused on grapheme-colour synaesthesia (Dixon et al., 2004; Rouw & Scholte, 2007; Ward et al., 2007), the distinction between higher and lower synaesthetes has significant implications for music-colour synaesthesia. Experiences resulting from different musical styles, composers, harmonic progressions, association with keys, written notation (Ward, Tsakanikos & Bray, 2006c) or emotion (Isbilen & Krumhansl, 2016; Ward, 2004) present a variety of types of inducer. The correct categorisation of synaesthetes as associators, projectors, and or lower or higher synaesthetes is pertinent to the true interpretation of experimental results. Only with consideration of the individual differences between synaesthetes can an understanding of the mechanisms at work in music-colour synaesthesia be achieved. If all the synaesthetes in a study are classed as higher synaesthetes, then results cannot be expected to support a hypothesis based on synaesthetic responses from early stage processing.

3 NEUROLOGICAL THEORIES

3.1 Disinhibited Feedback Theory and Hyperconnectivity Theory

Much of the literature in the last twenty years has focused on establishing the existence of synaesthesia as a true phenomenon and explaining its cause. Currently, the general agreement is ‘that synaesthesia is neither imagination nor is it

metaphorical thinking, instead it has a neural basis' (Rothen, Meier, & Ward, 2012, p. 1953). The two primary neurological theories for the causes of synaesthesia are the disinhibited feedback hypothesis (Grossenbacher & Lovelace, 2001) and the hyperconnectivity theory, or the revised hyperbinding theory (Ramachandran & Hubbard, 2001a; Hubbard, Brang, & Ramachandran, 2011). The disinhibited feedback theory has been developed from behavioural studies and suggests that synaesthesia may come about through a diminution of inhibition travelling through feedback pathways. Information travels in either direction between primary sensory areas to association areas such as the parietal lobe or limbic system. It could be possible that later stages of processing might influence earlier stages of processing if feedback signals were not sufficiently inhibited (Neufeld et al., 2012b).
In contrast, the hyperconnectivity theory suggests that direct connections exist between the areas of the brain that process the inducer stimulus and those that process the concurrent experience. No higher-level processing is involved and the process is purely bottom-up without the parietal cortex playing a major role (van Leeuwen, Singer & Nikolić, 2015). However, it should be noted that the more recent hyperbinding model revises the hyperconnectivity theory by adding a role for the parietal cortex in binding together colour and grapheme (Hubbard, et al., 2011). Analysis of the timing of neural activations may indicate whether synaesthetic experiences are mainly governed by top-down (late conceptual) or bottom-up (early perceptual) processes (Jäncke, 2013).

Although not addressed by Grossenbacher and Lovelace (2001), Brang, Hubbard, Coulson, Huang and Ramachandran (2010) identify that because of later top-down processing in disinhibited feedback, there should be an observable time lag between the processing of the inducer and the concurrent. In a case of the hyperconnectivity/hyperbinding theory, the direct connections between the inducing and concurrent areas of the brain should occur without delay, as processing in both areas should occur almost simultaneously. Yet neither theory has been categorically proven to be better than the other, or that they cannot exist side by side (Cytowic & Eagleman, 2009). Although some support for the neurological basis of synaesthesia has been observed in the activation of the V4 colour area in grapheme-colour synaesthesia (Nunn et al., 2002), a limitation of most neuroimaging studies is that they focus on grapheme-colour synaesthesia alone. Nunn et al. (2002) considered the activation of the V4 area as proof for the existence of synaesthesia and the presence of hyperconnectivity, but it cannot necessarily be assumed that it is directly translatable to other forms (Zamm et al., 2013). For example, Neufeld et al.'s (2012a) study found that there was no activation in the V4 areas for music-colour synaesthetes. The next section compares the results of eight neuroimaging studies (Table 1) conducted on synaesthetes with forms of coloured-hearing to examine the evidence for the presence of disinhibited feedback or hyperconnectivity. The studies comprise three functional studies (Goller, Otten, & Ward, 2009; Jäncke, Rogenmoser, Meyer, & Elmer, 2012; Neufeld et al., 2012a) and five structural studies (Banissy et al., 2012; Hänggi, Beeli, Oechslin, & Jäncke, 2008; Zamm et al., 2013; Jäncke & Langer, 2011; Neufeld et al., 2012b).

3.2 Neurological Studies

3.2.1 Functional

Goller et al. (2009) carried out a study of 10 coloured hearing synaesthetes and 10 controls to see if there was a stronger activation in the visual cortex for synaesthetes compared to controls. Of the synaesthetes, five were identified as projectors: two seeing colours in front of them and three from where the sound originated. Of the remainder, three were classed as associators, seeing colours in the mind's eye, and two were a combination of associator and projector. An Electroencephalograph (EEG) study was carried out during which all participants heard five pure tones. The purpose of the study was to investigate whether early differences in auditory event-related potentials (ERPs) existed in the synaesthetes, which might indicate that sound processing differences in coloured hearing synaesthesia involves the auditory cortex and superior temporal regions. Although there were differences in auditory ERPs in the synaesthetes suggesting the involvement of auditory cortex and superior temporal regions, the results did not support a visual potential. The authors consider the results to be complementary to the disinhibited feedback theory, rather than to a suggestion of special direct connections between visual and auditory pathways in the brain. It should also be noted that a difference was found between two particular synaesthetes: SL, who was identified as an associator, and, JL, a projector. The authors suggest that earlier processing in projectors (Dixon et al., 2004; Ward et al., 2007) might be an explanation for JL's greater size of visual P1 (an early visual related ERP component) of 80-120 msec, compared to SL's negative later deflection of 230-270 msec. Later Jäncke et al. (2012) tested 11 coloured hearing synaesthetes and 11 controls with a more intricate test, again to see if there was an involvement of the visual area in the synaesthetes. EEG signals were measured whilst participants watched a silent movie and attempted to ignore presented tones: 440Hz 60% of the time, and 4 deviants (438Hz, 422Hz, 416Hz and 264Hz) each presented 10% of the time. Mismatch negativity (MMN) was observed for both groups but the MMNs were larger in synaesthetes for the two largest deviant tones (416Hz and 264Hz) suggesting that the larger deviance was due to the synaesthetic colour being processed early and pre-attentively. A LORETA source reconstruction suggested the possible involvement of visual areas in this group. However, Hupé and Dojat (2015) comment that a limitation with this study is the absence of MMN readings for tones that did not produce a synaesthetic response. It cannot be certain whether this group, particularly, just had a better MMN for stronger deviants irrespective of the presence of their synaesthesia.

No further clarity was produced from Neufeld et al.'s (2012a) fMRI study that compared the blood oxygenation level deviation (BOLD) responses in 14 tone-colour synaesthetes and 14 controls to different sounds played by different instruments. The authors found that the only difference was a stronger activation in the synaesthetes in the left inferior parietal cortex and no difference was found in the ROI (regions of interest) analysis at the V4 colour area nor any other visual area. The increased activity observed in the parietal cortex of the synaesthetes lends support to the hypothesis of its role in 'hyperbinding' in synaesthesia (Hubbard et al., 2011) as a sensory hub between auditory (inducer) and visual (concurrent) information. The results do not support direct connections between auditory or visual areas in the brain as predicted by the hyperconnectivity theory.

3.2.2 Structural

Hänggi et al. (2008) carried out a single case study on a professional flute player, ES, who had tone-colour, interval-taste synaesthesia and absolute pitch, compared to 17 musicians and 20 controls. Both groups were tested for diffusion tensor imaging (DTI) and T1 weighted differences in both fractional anisotropy (FA) and white matter (WM) in the auditory area of ES. As in Goller et al.'s (2009) study, Hänggi found differences in the auditory areas. Banissy et al. (2012) examined 9 synaesthetes and 42 controls. The synaesthetes all reported grapheme-colour synaesthesia and 8 also had tone-colour synaesthesia. Voxel-based morphometry (VBM) was used to observe whether there was an increased volume of grey matter (GM) in the synaesthetes compared to controls. ROI analysis revealed a larger GM in the left posterior and less GM in the left anterior part of the fusiform gyrus of the synaesthete group. However, no difference between the two groups was observed on whole brain analysis. Furthermore, how much the overall results may have been influenced by the presence of grapheme-colour synaesthesia as well as tone-colour is not clear. It is noted by Zamm et al. (2013) that whilst certain functional MRI, EEG and MEG studies have found activation in the V4 area in synaesthetes (van Leeuwen, Petersson, & Hagoort, 2010; Weiss, Zilles, & Fink, 2005; Brang, Edwards, Ramachandran, & Coulson, 2008; Sagiv & Ward, 2006; Beeli, Esslen, & Jäncke, 2008), most of these studies have concentrated on grapheme-colour synaesthesia. Because the areas of inducer and concurrent in grapheme synaesthesia may be adjacent to one another, Zamm et al. (2013) remark that the results may not be translatable to other forms of synaesthesia. Encouraged by the studies of Goller et al. (2009), Jäncke et al. (2012) and Hänggi et al. (2008), Zamm tested the hypothesis that there might be increased connectivity in WM pathways passing through the temporal and occipital regions in music-colour synaesthesia. In a study that compared 10 controls to 10 synaesthetes with tone-colour, chord-colour and instrument-colour (as defined by the subsets in the Eagleman Battery, 2007), Zamm used DTI to trace WM tracts in these areas and found that WM integrity within the right inferior fronto-occipital fasciculus (IFOF) was significantly greater in synaesthetes than controls. Zamm considers these results to suggest a likelihood of an increased connectivity in visual and auditory areas in music-colour synaesthesia. In contrast, instead of using structural or functional measures, Jäncke & Langer (2011) focused on resting state electroencephalography (EEG) to test the role and connectivity between the parietal cortex, auditory cortex and fusiform gyrus in coloured-hearing synaesthesia. 12 coloured-hearing synaesthetes and 13 non-synaesthetes were tested. The results showed that there was no increased connectivity in the fusiform gyrus and that there was no difference in general connectivity between the two groups. Although still lacking in direct evidence, higher values for synaesthetes in the parietal cortex led to the suggestion that more highly interconnected hubs might exist in the parietal regions in coloured-hearing synaesthesia thereby lending support to the hyperbinding theory (Hubbard et al., 2011). Finally, Neufeld et al. (2012b) performed a functional connectivity analysis on fMRI data collected from 14 tone-colour synaesthetes and 14 controls. The study found no increased connectivity in synaesthetes between the visual and the auditory cortex, but they did detect increased connectivity between the right auditory cortex and the left and right motor cortex, as well as between the left inferior parietal cortex and both the left primary auditory cortex and the right primary visual cortex. The authors consider these findings to be further support for the disinhibited feedback theory. A point of note is that all 14 of the synaesthetes were classed as associators, which van Leeuwen (2013) suggests might strengthen the theory that associators tend to rely more on top-down processing.

3.2.3 Summary of Neurological Studies

In summary, the results of the eight studies were largely inconclusive. Only Goller et al. (2009) and Neufeld et al. (2012b) considered that their results supported the operation of disinhibited feedback, whilst Neufeld et al. (2012a), and Jäncke and Langer (2011), favoured hyperbinding. Zamm et al. (2013) identified structural differences in increased white matter tracts between visual and auditory areas in synaesthetes that could suggest hyperconnectivity, which was also largely supported by Hänggi et al. (2008) Banissy et al. (2012) and Jäncke et al.'s (2012) studies. However, there are some limitations. It cannot be certain how Banissy et al.'s (2012) results might have been influenced by grapheme-colour synaesthesia, as all but one of the synaesthete group possessed both grapheme and tone-colour synaesthesias. Hänggi et al.'s (2008) subject, ES, also possessed absolute pitch. Consequently, it is not possible to be sure that the differences found were because of synaesthesia alone, as the comparisons made with musicians with absolute pitch were not conclusive (Hupé & Dojat, 2015). Furthermore, it should be noted that although both Banissy et al. (2012) and Zamm et al. (2013) found structural differences in synaesthetes, it is difficult to categorically say whether there are differences in the brain anatomy of synaesthetes, per se, or if the differences have developed because of years of synaesthetic activity (van Leeuwen et al., 2015). Lastly, as acknowledged by Jäncke et al. (2012) the small size of the synaesthete group in this study meant that it was not possible to distinguish between individual differences in synaesthetes, particularly with regard to whether synaesthetes might be associators or projectors. The detection of difference in the very early stages of processing may have been effected by a large proportion of lower synaesthetes in the group. One important finding is the identification of the role of the parietal cortex (Neufeld et al., 2012a, 2012b and Jäncke and Langer, 2011) as a potential hub in both the disinhibited feedback and hyperconnectivity/hyperbinding theories.

	Participants	**Synaesthesia Type**	**Modality**	**Results**
Functional				
Goller 2009	10 synaesthetes 10 controls	Coloured-hearing 5 projectors 3 associators 2 mixed	EEG	Differences in auditory ERPs but no visual potential.
Jäncke 2012	11 synaesthetes 11 controls	Coloured-hearing	EEG	MMNs larger for two largest deviant tones suggesting early pre-attentive processing.
Neufeld 2012a	14 synaesthetes 14 controls	Tone-colour 14 associators	fMRI	BOLD differences in left inferior parietal cortex only. None at V4 or other visual regions.
Structural				
Hänggi 2008	1 synaesthete 17 musicians 20 controls	Tone-colour Interval-taste Absolute pitch	DTI	DTI and T1 weighted difference in FA and WM in auditory areas.
Jäncke 2011	12 synaesthetes 13 controls	Coloured-hearing	EEG	No increased connectivity in fusiform gyrus, and no general difference in connectivity.
Banissy 2012	9 synaesthetes 42 controls	Tone-colour and Grapheme-colour	VBM – GM	GM larger in left posterior and less in left anterior of fusiform gyrus. No difference in whole brain analysis.
Neufeld 2012b	14 synaesthetes 14 controls	Tone-colour 14 associators	fMRI	No increased connectivity between visual and auditory cortex. Connectivity between right auditory cortex and left and right motor cortex, and left inferior parietal cortex and both left primary auditory cortex and right primary visual cortex.
Zamm 2013	10 synaesthetes 10 controls	Tone-colour and Music-colour	DTI	WM greater in right IFOF

Table 1 | Summary of the results of eight coloured-hearing neuroimaging studies

4 CONCEPT, MEANING AND QUALIA

4.1 The Role of Concept and Meaning in Music-Colour Synaesthesia

Although research over the last twenty years has predominantly concentrated on attempting to explain the cause of synaesthesia in perceptual terms, there is evidence to show that in some forms of synaesthesia a concept alone may be enough to induce the condition (van Leeuwen et al., 2015). Of the dominant theories positing a neurophysiological basis of synaesthesia, the disinhibited feedback theory offers the more compatible mechanism for the role of conceptual-level information promoting top down processing, but direct evidence is lacking. Several behavioural studies have suggested that synaesthesia is influenced by the conceptual representation of the inducer rather than its low-level characteristics (Chiou & Rich, 2014). It has been shown that the same physical shape can be interpreted as a ‘5’ or an ‘S’ depending on context and will result in a different concurrent experience in each case (Dixon, Smilek, Duffy, Zanna, & Merikle, 2006; Myles, Dixon, Smilek, & Merikle, 2003). Also, Dixon et al. (2000) demonstrated with grapheme-colour synaesthesia how a synaesthetic experience can be triggered without a sensory stimulus. Synaesthetes were presented with written numerical additions, such as 5 + 2, followed by a colour patch. The colour patch was either congruent or incongruent with the synaesthete’s colour for the correct answer. Results showed that reaction times were faster when the colour was congruent with the synaesthete’s colour for the correct number, demonstrating that synaesthesia could be activated conceptually and that the physical presence of the inducer was not necessary: the semantic knowledge of the system was sufficient (Meier, 2014). Synaesthesia associated with days of the week or months, one of the most commonly studied forms of synaesthesia, has also been shown to be conceptual in nature (Simner, 2009). Colours and spatial layouts are associated with the position of the day in the sequence of a week, or its meaning, rather than because of the letter the name of the day begins with. Indeed, the synaesthete, Smilack’s photograph entitled, *Weekends are taller than Weekdays* illustrates Saturdays and Sundays as being taller than other days of the week. The meaning of ‘the weekend’ is represented in the way both days occupy a graphically larger, or elevated, position in space (Smilack, 2012).

4.2 Ideaesthesia

These findings have led to an alternative theory of ‘ideaesthesia’ (Nikolić, 2009; Mroczko-Wąsowicz & Nikolić, 2014) and a replacement definition: ‘Synaesthesia is a phenomenon in which a mental activation of a certain concept or idea is associated consistently with a certain perception-like experience’ (Nikolić, 2009, p. 28). Ideasthesia has its foundation in the theory of ‘practopoieis’ that states that concepts are applied and learned as nerve cells quickly adapt to external stimuli (Nikolić, 2015). Although at first glance ideaesthesia would appear to be similar to the earlier described associative synaesthesia, what sets it apart is the way semantic associations may be translated from a physical synaesthesia-inducing stimulus (van Leeuwen et al., 2015). The assigned meaning to the stimulus then serves to mediate the perception-like concurrent synaesthetic experience. In theory, ideasthesia would not preclude perceptual stimuli from inducing conceptually mediated concurrents (Mroczko-Wąsowicz & Nikolić, 2014; van Leeuwen et al., 2015). The speed at which some synaesthetic associations are able to be made also support ideasthesia. In a study conducted by Mroczko-Wąsowicz, Metzinger, Singer and Nikolić (2009) grapheme colour syaesthetes were able to transfer their synaesthetic colours to an alphabet of Glagolitic graphemes (an ancient Slavic writing system) within as short a time as ten minutes. This would be far too fast for new low level connections between brain areas to form as suggested by the hyperconnectivity theory of Ramachandran & Hubbard (2001a, 2001b). The authors explain the speed of the transfer by the activition of mental processes that recognise the meaning of the letter, rather than its form or shape, in so far as a grapheme in either the Latin alphabet, or in its Glagolitic equivalent, might represent the abstract concept of the letter 'A'. (Mroczko-Wąsowicz et al. 2009)

Nikolić, Jürgens, Rothen, Meier and Mroczko-Wąsowicz (2011) also demonstrate the importance of purely semantic representations in synaesthesia in a study examining different swimming styles. Two known grapheme colour synaesthetes who were also semi-professional swimmers were found to associate four swimming strokes (breaststroke, crawl, butterfly and backstroke) with distinct synaesthetic colours. In a laboratory situation using a Stroop-like task, it was shown that it was not necessary for participants to be swimming in a pool to induce the corresponding colour experience. Both synaesthetes only had to think about practising the different strokes, or to think about the concept of each swimming style to induce synaesthesia. Each synaesthete reported that they had always had this experience with swimming styles and that the colours had remained consistent throughout their lives.

The role that semantic knowledge may play in some forms of music-colour synaesthesia is similarly suggested in an unpublished case study by De Thornley Head (1985) in which a tone-colour synaesthete, MH, without absolute pitch, self-triggered tones on a synthesiser and noted down each colour response. The synthesiser was then transposed, without MH's knowledge, and the task was re-performed. There was no change in the responses. The colours noted down were in reaction to the tones the synaesthete thought they were hearing rather than to the actual pitches. Ward et al. (2006c) also presents a first empirical study supporting synaesthesia for musical notation which suggests that this type of music-colour synaesthesia may be linked to conceptual rather than perceptual processing. Case studies were carried out on three participants who had synaesthesia for written musical notation, graphemes and heard music. All three had a high level of musical ability and could read music. None of them had absolute pitch. The synaesthetes were shown to be slow at playing musical notes when they were notated in colours incongruent to their synaesthetic colour, and Stroop interference was observed when they were required to name the synaesthetic colour of the written musical note and ignore the veridical colour. This type of synaesthesia was not affected by the shape of the musical note in the way that the shape of a letter or number has been shown to affect grapheme-colour synaesthesia (Ward et al., 2006c) The results of the study suggest that the synaesthetic experience in this case was elicited at a conceptual level: at the time the pitch of the note is required to be processed. As the name suggests 'ideaesthesia' may mean that synaesthetes are not pre-disposed to synaesthesia as previously thought, but may learn to assign meanings to certain stimuli to strengthen their knowledge and understanding of abstract concepts (van Leeuwen et al., 2015).

Stemming from this, Jürgens and Nikolić (2012) posit that certain types of synaesthesia may simply be a useful method a child may develop to more easily process its first encounter of abstract concepts, such as music unfolding over time. Such studies should not be taken to dismiss the existence of purely perceptual forms of synaesthesia. However, extending research to music affords the opportunity to study the causes of different types of synaesthesia in a form other than the more frequently examined grapheme-colour (Nikolić, 2009).

4.3 Music-Colour Synaesthesia and Musical Qualia

In a later study, Nikolić (2016) continues to explore ideaesthesia developing an 'ideaesthesia balance theory' with a view to formulating a 'theory of art'. Nikolić states that at the heart of the theory lies a relationship between concept (or meaning) and sensation (or experience) as the two forces of ideaesthesia. Although the relationship between ideaesthesia and art is beyond the scope of this review, Nikolić identifies sensation and its relationship to phenomenal experiences in terms of our understanding of what is known as 'qualia'. Qualia is the term used to describe the qualities of subjective experience associated with certain sensory stimuli (e.g., Jackson, 1982) such as the difference between seeing a red rose and yellow rose or, in musical terms, the difference between a melody played on a piano and the same melody played on a French horn. Music offers a rich variety of experience and such properties form, often ineffable, differences between one person's experience and that of another's.

Synaesthesia has been described by Wager (1999) as an 'extra qualia' that manifests itself differently from synaesthete to synaesthete. So, what do the different types of 'concurrent qualia' (van Leeuwen et al., 2015) synaesthetes experience on hearing music illustrate about individual consciousness? Eagleman (2015) posits that synaesthesia is '… a reminder that from person to person – and from brain to brain – our internal experience of reality can be somewhat different' (p. 59). Indeed, there are different kinds of synaesthesia in music, and together with the different categories of synaesthete, the assumption that there is a unity between all types of synaesthesias and that each operates by means of similar mechanisms is questionable. Auvray and Deroy (2015) argue that it might be better to regard each form as a separate condition and that defining synaesthesia remains an area for further research. Indeed, synaesthetic experiences may best be described as suggested by Auvray and Deroy '…as richer unified experiences where additional sensory info (or qualia) get hosted in the content of perception' (p. 12). Yet the phenomenal experience of music-colour synaesthesia, indeed of synaesthesia as a whole, presents a challenge to established philosophical theories, three of which are discussed in the next part of this review: functionalism, physicalism and representationalism.

4.3.1 Functionalism

The debate about qualia began in the 1960s and 1970s surrounding discussions about functionalism. The theory of functionalism states that 'the function of a mental state is its defining feature' (Kind, n.d.). There are different types of functionalism but their common thread is the understanding of a mental state from the position of its functional role instead of in terms of its physical set up (Block 1990; Chalmers, 1996). For example, the function of pain is not the firing of C fibres (as a physicalist view might uphold, as discussed below) but the avoidance of the cause of pain itself. In theory, functionalism allows for creatures with quite different physical set ups, to experience the same mental state (Smart, 1959).

However, functionalism has been the target of opposition for its limitation in accounting for qualia (see Shoemaker, 1984; Block, 1990; Tye, 1996; Chalmers, 1996). Functionalism does not attempt to explain qualia per se but, as described by Gray and colleagues (2002), looks for an understanding of the mechanisms behind the behavioural responses an individual may display as a ‘function’ of qualitative experience. Well known objections to functionalist theories have been presented in the form of the following thought experiments:

i) the *inverted qualia argument* (Block, 1990) where two systems may be functionally identical but each experience very different qualia
ii) the *absent qualia argument* (Block & Fodor, 1972) where two systems are functionally identical but one experiences no qualia at all.

‘Synesthetic experiences can be defined as richer, unified experiences, where an additional sensory attribute (or qualia) gets hosted in the content of perception’ (Auvrey & Deroy, 2015 p 12). The difficulty presented to functionalism by synaesthesia arises when the same mental state produces green on hearing an ‘A’ but also on seeing grass and trees (Auvrey & Deroy, 2015). In this case the same kind of mental state ‘seeing green’ emanates from two separate streams, both auditory and visual, not just from vision. In music-colour synaesthesia two quite different functions, that of hearing and vision, produce the same experience of colour and from this position Gray argues that synaesthesia provides a counter example to functionalism (Gray, 2005). However, Gray’s argument only holds for strong versions of functionalism that add the condition that not only should any difference in function correspond to a difference in experience, but for any difference in experience there must also be a corresponding difference in function (Macpherson, 2007). Macpherson (2007) also notes that Gray’s premise is based on the acceptance that the experience of synaesthesia is perceptual and works the same way as non-synaesthetic experience. For this to be true both the inducer and the concurrent would need to be normal experiences of sound and colour, and to be entirely independent of each other. However, evidence from neuroimaging studies is lacking in support of this assumption (van Leeuwen et al., 2010; Hupé, Bordier & Dojat 2012) and Eagleman and Goodale (2009) have demonstrated that coloured synaesthetic experiences are very different to non-synaesthetic colours, often including other elements such as texture and movement. Furthermore, the behavioural studies discussed earlier in this review support the importance of the role of conceptual rather than purely perceptual processing in some forms of synaesthesia. Consequently, Macpherson’s challenge to Gray’s ‘dualist model’ account of synaesthesia would appear to allow functionalism to hold its ground.

4.3.2 Physicalism

If it can be considered that two people might be in identical mental states in functionalism, so might it be that they could have physically similar brain structures but very different phenomenal experiences on hearing music (Kind, n.d.). Physicalism is the very general view that everything supervenes on the physical (Smart, 1959). In the philosophy of mind, this has been sometimes treated with the following claim: there is no difference between physical implementation and mental states (Gray et al., 2006; Block, 1997). Accordingly, physicalists are inclined to explain synaesthesia through a direct correlation between phenomenal experience and brain activity (Ramachandran & Hubbard, 2001a, 2001b). This is, however, not an easy task: as previously discussed, experimental results are still highly inconsistent. So, while some maintain that future advances in neuroscience will eventually allow us to explain all mental phenomena in neural terms (e.g., P. M. Churchland, 1994; P. S. Churchland, 1989) we currently lack epistemological and methodological tools to fully capture most of the properties of our mental life. And this is not the only problem. Some aspects of mind may be more easily explained than others. As we learn more and more about the brain, phenomena that might be explained in terms of computational or neural mechanisms, the ‘easy problems of consciousness’ (Chalmers, 1995, 1996) are expected to be solved at some point in the future. The problem of how we account for qualia, instead, presents a far more difficult challenge. Although it may well be likely that a physical system is responsible for qualia, we do not know what kind of mechanism that might be, nor have we any idea about what kind of biological law is involved in transforming electrical signal in the brain into consciousness. Consequently, the ‘hard problem’ of consciousness, that which accounts for qualia, remains.

Chalmer’s ‘hard problem’ also has a similarity to Levine’s earlier identification of the ‘explanatory gap’ (Levine, 1983). Levine states that an explanation of such phenomena as the transfer of heat may be given from our scientific understanding of the motion of molecules. Having discovered this, no further explanation is necessary. However, even when endowed with considerable knowledge about how a certain experience is due to a neural or functional state, something is still left unexplained. For example, understanding that pain is the function of the firing of ‘C’ fibres does not supply us with an explanation of why pain feels the way it does (Kind, n.d.).

4.3.3 Representationalism

Wager’s (1999) description of representationalism is that it is ‘the view that the phenomenal character of an experience supervenes on its representational content’ and offers some clarification of this statement in ‘the way an experience seems to its subject is […] the way the experience represents the world as being’ (Wager, 1999, p. 263). Arguably, the strongest version of representationalism is the view that phenomenal character is identical to its representational content (Tye, 1998) and in this way, representationalism attempts to explain qualia.

However, representationalism has been challenged by work on synaesthesia (Wager, 1999; Rosenberg, 2004; Brogaard, 2016). Musical qualia might be described as the experiential difference between hearing a piece played on a ‘cello and the same piece played on a flute'. However, it might also include the synaesthetic experience of seeing green on hearing an 'A'. The latter is not immediately explainable from a representationalist's standpoint as the phenomenal experience is at odds with reality: experiencing a note as green does not mean the note is actually green, or that the person is experiencing 'green-ness' (Auvray & Deroy, 2015). Adapting Schiavio and van der Schyff's (2016) inverted qualia example (Block, 1990) as further illustration, a synaesthete might hear a glissando but also experience purple, whilst a non synaesthete would just hear the glissando. It might be argued that both experiences have the same representational content (the glissando), but have shared and very different phenomenal characters. From this standpoint Tye's theory cannot account for such synaesthetic experiences. Wager (1999) suggests an alternative and describes synaesthesia as an 'extra qualia' one in which, 'two states with the same representational content share some but not all of their phenomenal content' (p. 264). On the face of it this might seem reasonable. For example, the colours, shapes and textures experienced in music-colour synaesthesia contribute as much to the qualitative experience of music as the more common subjective qualities experienced by non-synaesthetes.

However, a representationalist might offer a straightforward argument in response. The challenge to representationalism only holds if it can be argued that the additional synaesthetic experience does not instantiate the inducer. The representationalist might argue that the synaesthetic experience does in fact represent something. In the case of a synaesthete experiencing 'green-ness' on hearing an 'A', R. Gray argues that the concurrent does differ representationally in that it 'misrepresents' green-ness (R. Gray, 2001). Instead of saying that the green-ness is attributed to an 'A', why not attribute it to the misrepresentation of green triggered by the auditory stimulus?

Yet Rosenberg (2004) argues against misrepresentation using an example from grapheme colour synaesthesia. The fact grapheme colour synaesthetes are still able to recognise the veridical colour of the printed letter as well as their synaesthetic colour would suggest that the association of a colour with a letter is not a misrepresentation of surface reflectance at all, but is in fact an accurate representation of the letter. Alter (2006, p. 6) does not agree and asks why we should not instead conclude that the synaesthetic experience both accurately categorises the letter as, say, a letter 'D' whilst also inaccurately representing it as being green? Even though the inducer, be it a letter 'D' or a sounding note 'A', does not have the property of the concurrent, if the synaesthete believes that the experience represents it as having such a property, then there is no real argument against representationalism.

Brogaard (2016) identifies a lack of empirical evidence as a problem with synaesthesia based arguments against representationalism to date, and calls for a different approach. Brogaard posits that some forms of projector synaesthesia might be considered as examples of where the phenomenology of the visual experience does not flow directly from the representational content. Such a case is given as in 'M' a projector who experiences a terracotta brownish-orange volume in front of the letter R. The veridical colour of the letter is black and it never appears to 'M' that it is anything other than black. The letter R itself does not appear to 'M' at any time as terracotta brownish-orange. Hence the colours projected out into the world do not represent the mind-independent, physical object, R. In this case it can be argued that the phenomenology of visual perception is not exhausted by its representational content, and that representationalism is false (p. 312). Brogaard acknowledges that a representationalist might still attempt to dismiss synaesthesia by explaining the nature of such experiences as non-perceptual. However, Brogaard rejects this position by arguing that some forms of projector synaesthesia are a ‘kind of perceptual experience’ (p. 313) based on results relating to grapheme colour synaesthesia such as the Stroop effect (Mills et al., 1999; Mattingley et al., 2001) visual search paradigms (Ramachandran & Hubbard, 2001a) and brain imaging (Simner, 2012). Brogaard’s view is that from this standpoint a representationalist may not simply respond by arguing that projector synaesthesia is not a perceptual experience.

However, there are clearly difficulties in explaining some forms of music-colour synaesthesia in terms of musical qualia. Perhaps as suggested by Schiavio and van der Schyff (2016) an alternative embodied approach to the understanding of musical experience that does not seek to ‘reduce experience to inner mechanisms, representational recoveries, or neural firing’ (p.375) would lead to a better understanding. Indeed, Schiavio and van der Schyff’s argument that engagement with music involves not just internal cognitive processes but real-time interactions between the individual and their environment is equally relevant to the phenomenal experiences presented by music-colour synaesthesia.

5 Conclusion

This review has examined the current literature concerning a form of coloured-hearing, or chromesthesia, associated with music. It was found that music-colour synaesthesia has a broad scope encompassing not only tone-colour synaesthesia elicited on hearing individual tones, but a complex and idiosyncratic mixture of phenomenological experiences often mediated by timbre, tempo, emotion and differing musical style. The importance of the role of individual differences from synaesthete to synaesthete has also been highlighted. Without consideration being given to the distinction between the differing experiences of associators and projectors or higher and lower synaesthetes it is not possible to fully understand the mechanisms at work and experimental results may be misinterpreted.

The traditional view that synaesthesia is fundamentally a perceptual phenomenon has also been challenged here. The examination of eight neuroimaging studies were found to be largely inconclusive in respect of confirming the perceptual nature of music-colour synaesthesia. However, it should be noted that not all the studies distinguished between associators and projectors or higher and lower synaesthetes amongst their participants. Nonetheless, neither the hyperconnectivity (Grossenbacher & Lovelace, 2001) nor the disinhibited feedback theory (Ramachandran & Hubbard, 2001a) currently holds as a single categorical explanation for synaesthesia. Furthermore, comparisons made between cross-modal correspondences in non-synaesthetes and synaesthetes in respect of pairings made from colour, music, emotion, pitch-height and pitch-size suggest that non-synaesthetes employ similar mental processes to synaesthetes. Synaesthetes may not be pre-disposed to synaesthesia, per se, but may have developed a method of processing abstract concepts such as music unfolding over time afforded to them by the ‘extra qualia’ (Wager, 1999) of their synaesthetic experience. Theories promoting the notion of ‘ideaesthesia’ (Nikolić, 2009) have highlighted the importance of the role of concept and meaning in the understanding of synaesthesia (van Leeuwen et al., 2015) and have pushed for the move away from the purely perceptual sensory to sensory explanations for its cause and towards further research into the role of concept as inducer.

Music-colour synaesthesia demonstrates that a single mechanism is not sufficient to explain the phenomenological experiences that arise on hearing music, either from a sensory musical stimulus, or from a non-sensory musical concept. Stemming from this arises the need to reconsider the elevated position of consistency as the primary measure in synaesthesia studies. It has been shown in this review that inconsistency is not uncommon in music-colour synaesthesia and that the failure of a consistency test might result in the exclusion of a subject that may be able to reliably demonstrate synaesthetic experiences otherwise, such as through self-report or other behavioural tests. Whilst such batteries as the Eagleman Battery (Eagleman, et al., 2007) are very useful in determining grapheme-colour forms of synaesthesia, there is a risk that certain types of music-colour synaesthesia may be unnecessarily overlooked. If certain forms of synaesthesia can be discounted using current measures, alternative methods may reveal synaesthesia to be more prevalent in the general population than previously believed.

Finally, the difficulties in reconciling the phenomenological character of music-colour synaesthesia with established philosophical theories have also been discussed. The problem of the ‘extra qualia’ (Wager, 1999) presented by music-colour synaesthesia remains and cannot be satisfactorily explained by the theories of physicalism, representationalism or functionalism. In his theses, ‘What is it like to be a bat?’ Nagel (1974) states that because the way we perceive the world is so very different to that of a bat, we who are not bats cannot know what it is like to be a bat. Perhaps in the same way those who do not have synaesthesia just cannot know what it is like to experience colour on hearing music, illustrating further the difficulty in fully understanding the phenomenon.

Music-colour synaesthesia highlights the need for future research to extend to other forms of synaesthesia other than the more commonly examined, grapheme colour synaesthesia or tone-colour synaesthesia. However, a full understanding of the mechanisms underlying synaesthesia may not be possible if researchers continue to attempt to contain the phenomenon within a distinct set of rules (Simner, 2012; Cohen Kadosh & Terhune, 2012) and do not reject a ‘one for all’ explanation for its cause (Auvray & Deroy, 2015). Together with the recognition of the difference in experience between associators and projectors and higher and lower synaesthetes, and the similarities with cross-modal correspondences in non-synaesthetes, music-colour synaesthesia offers an opportunity to gain a better understanding of the processes of general cognition and consciousness from person to person.

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