Developing an artificial colour-sound association for musical composition

By Richard Abbott

Submitted to University of Plymouth
in partial fulfilment of the degree of

Research Masters

Interdisciplinary Centre for computer Music Research
(ICCMR)

School of Humanities and Performing Arts

Faculty of Arts

September 2017

Acknowledgements

I would like to thank all of my colleagues in ICCMR, my academic supervisors for their guidance, the other researchers for tolerating my incessant questions and my peer for his parallel panics:
Prof. Eduardo Miranda inspires great new questions and confidence in my practice as a researcher, our meetings have been invaluable and often promoted rich lines of enquiry.
Dr. Alexis Kirke has always held me to account for my methods, I know that an idea passed through his mesh of conceptual integrity is far the better for it.
Dr. Michael Mcloughlin, Nuria Bonet Filella, Aurelien Antoine, Pierre-Emmanuel Largeron, Jared Drayton and Dr. Edward Braund have each, at different times, given me excellent advice and fostered key analytical discussions from which I have greatly benefitted.
Alan Miles, my comrade, has been my peer and friend from the first, I was very pleased we could lean on each other in this process.

My parents have offered different and complimentary support throughout, as always, Dr V. J. Abbott and Mrs S. G. Abbott I owe you infinitely. My best friend and sage, Oliver Haines has been a creative and artistic guide as well as an incomparable mensch. Alice Eagle, Johnny Mitchel, John-lee Robinson and Sophie Etheridge are, in all things, the friends I needed and hope one day to deserve. Paul and Lauren Jackson with the recent addition of Edmund are the longest standing, firmest friends; source not only of support and sanity, but this inquiry began in no small part because of my conversation with Lauren about her magical, colourful brain.

Author's Declaration

At no time during the registration for the degree of Research Masters has the author been registered for any other University award without prior agreement of the Graduate Sub-Committee. Work submitted for this research degree at the Plymouth University has not formed part of any other degree either at Plymouth University or at another establishment.

Word count of main body: 19167

Signed ……

Date ……

Abstract:

Developing an artificial colour-sound association for musical composition

Richard Abbott

Some great composers - Messiaen, Scriabin, Liszt in exemplum - have been found to have an internal colour world that responds to music and characterises the way they experience and express music. Many of these artists, it could be strongly argued, had the neurological trait synaesthesia. The author, a non-synaesthete, creates a logical correspondence between colour and sound and uses it to explore the tonality of aesthetic colour combinations in nature and modern life. He argues that if the colour-sound practitioner is consistent in their colour-sound association, they can benefit in harmonic discoveries as the synaesthete does. It was found that the harmonies produced were strange, new tonalities that do not repeat in each octave but form something akin to macro-chords, shifting density in different registers. The author produced a series of short scores for small ensembles to explore the possible merits of drawing harmony in music from harmony in colour.

Contents

List of Figures

Introduction

There are a minority of the population who don't just hear music, but see it. The flow of electrical information that travels from their ears stimulates not only the temporal lobes –which process sound and speech -, but also the occipital – which processes light information. This can mean that music results in a wash of colour, not only beautiful to behold, but also a central function to the exceptional ability of these people to perceive precisely and find connections between seemingly unrelated phenomena. Many of them enjoy a perfect pitch perception and an understanding of colour far beyond the common person. They are called synaesthetes and they count among their number Kandinsky, Messiaen, Liszt and Duke Ellington.

I consider Synaesthetes to be somewhat superhuman, they have an unconventional approach to the sensory information around them that allows them to draw fascinating parallels and make bold harmonic choices in the moment, which the rest of us can only analyse afterwards. I wonder if I, a musician who desires to someday become exceptional, can borrow from the approach of these exceptional people and become deliberately superhuman. If so, I wonder how would this be achieved and if these methods – in replication of a trait – can be made available to the wider populace of *potential* superhuman musicians. With this in mind I have honed the following research questions to guide this enquiry. I will return to them towards the end of the project as a benchmark for any potential discoveries herein made.

Research Questions:

- Can a non-synaesthete create a colour-sound association for the benefit of music composition?
- What principles must be considered for this association to be viable?
- Will the product of said colour-sound association be tonal without excessive interference?
- What are the potential benefits of a colour-sound association methodology in art?

1. Background – the foundation of colour-sound

In my compositions, experiments and in the creation of this Methodology of Colour-Sound, I seek clarity as a fundamental virtue. I find myself moved by the sound world in strange unexpected ways and my hope is that by analysing these experiences, by cross-referencing them in colour I will discover what patterns most move me to compose. What are the commonalities, if any, between what is beautiful in sound and in light? Is it possible that there are universal principles of aesthetic to be discovered?

Certainly, the synaesthete, for whom colour and sound are different aspects of the same experience, can make associations, draw correspondences, across the stimulus divide that benefit their art. I am drawn to this experience and its apparent benefits to art. I want to emulate this artistic thinking in my Methodology for Colour-Sound composition.

I do not know if what I find beautiful in those of my compositions that I feel are successful, are the same elements which are beautiful to others, but if I find a more universal language for describing sound, perhaps a clearer discussion may take place. Although conventional, classical, western music notation is practical and pragmatic for instructing the instrumentalist, the idea of a semiotic language of discrete dots and lines is a detached vocabulary for a spectral, analogue experience such as music. At the very least I hope to add to the script, aesthetically. I began this research with a semi-formed composer's voice with existing preferences and an arsenal of harmonic vocabularies that I liked to draw on. I hope that in the pursuit of this research, that voice has been clarified and matured.

1.1 History of colour-sound and synaesthesia

> Eye music, or the use of compositional techniques which the ear cannot (or cannot immediately) register, is nothing new. From the cannons of Netherlands Renaissance polyphony to the time of J.S. Bach, the composer’s eye was always an adjunct to his ear.
> (Stuckenschmidt 1973)

In the course of my studies in music, I discovered that Olivier Messiaen, a favourite composer of mine, was a synaesthete (in particular coloured hearing, or chromesthesia), that he saw colours when he heard music. Digging a little further into synaesthesia yielded many discoveries about the way they perceive the ineffable sense, hearing, and that a great many musicians with perfect pitch are synaesthetes.

> Clearly, Messiaen's ability to associate sounds with colors in a way that maps formant space with color space demonstrates the unity of his perception with the two senses and the consistency of his sensory associations. (Dworak 2009)

This trait is a neurological condition based on unusual synaptic pruning in infancy that resulted in hyper-connectivity across sensory processing mechanism of the brain (Ramachandran 2001), it is innate and a true synaesthesia cannot, apparently, be learned.

I started to pursue the idea of an artificial synaesthesia, using the functionality of smart devices and 'sensory substitution devices' (designed for people with sensory loss) as a means to experience music as colour (and the inversion of the same). If it is true that synaesthetes are more likely to achieve artistic excellence, is it possible to discover what about this functionality that allows them insight in the arts and build that functionality into artistic practice?

Certainly, the proportion of the population with synaesthesia is higher in the arts than among the general population which would suggest the trait is of benefit to the creative process. Populations of artists have reported 23% synaesthetes as opposed to 1%-4% in the general population (Ramachandran, Hubbard 2001). This may be because artistic synaesthetes are more likely to self-report than non-artistic synaesthetes, or it may be that synaesthetes are more likely to be artistic, but certainly artistic synaesthetes use their synaesthesia in their practice.

There are other practical benefits to developing a cross referencing of senses, people with grapheme-colour synaesthesia have been shown to have enhanced memory on a range of tasks using both stimuli that induce synaesthesia (e.g. words) and, more surprisingly, stimuli that do not (Pritchard, Rothen, Coolbear, Ward 2012). This speaks

to the myriad possible benefits of working with synaesthesia as a model for broadening aesthetic connections. Although synaesthesia is an inherent perceptual condition, rather than a learned association, this dissertation experiments in using the *nature* of the condition as a framework to develop a better methodology for approaching art.

Synaesthesia may not be a learned condition, but that in itself does not rule out the possible benefits of a learned or artificial synaesthesia. It is the purpose of this research to form a musical practice that emulates the function of synaesthesia for the benefit of the composer. I will investigate and experiment with colour-sound association in order to form a Methodology of Colour-Sound of rules and practices that will enable the composer to draw harmony from the colour world for musical compositions and eventually to be submersed in the musical world of colour, inspecting flowers not just for their individual colours but for the harmony between their colours.

1.2 Types of colour-sound synaesthesia

> The types of synaesthesia related to music may be conveniently classified into four groups:
> (1) synesthesia based on compositional styles, (2) synesthesia based on timbre, (3) synesthesia based on pitch, and (4) synesthesia based on tonalities. (Peacock 1985)

My purpose in this project is to utilise those potential categories that offer the least to my purpose. Therefore, I will focus on categories 3 & 4 over the first two categories; 1 & 2 offer clarification on areas which most people would not need support in expounding, furthermore the categorisation required to describe to a computer the components of compositional style and genre would be so complex as that much time would be saved in simply explaining these details verbally to a student. The potential offered by category 3 & 4 differs in that the information clarified is of a simple category of information, but with vast computational needs. Herein lies the potential of a system of shorthand or computational divination as to the measurements of pitch and harmony. The result offered approaches the functionality of absolute pitch and a diviner of tonality.

> The third type of synaesthesia, that of color association based on pitch…
> …spontaneous association of individual colors with specific tones is in fact rare. Pedagogical systems, popular in the early decades of this century, whereby students acquired absolute pitch by associating particular colors and notes may actually be interjecting an additional step. (Peacock 1985)

Peacock tantalisingly hints at the potential for colour sound association for a more acute sense of pitch, but it begs the question further, would it stop there? Could an artist broaden their experience by teaching themselves absolute pitch and expand into a profound understanding of harmonic patterns?

> Assuming that aural key identification is actually achieved, then two basic psychoacoustic mechanisms can be conceived of as being involved. The first is based on recognition of individual notes. The subject first identifies one or several notes of a musical sample and subsequently infers therefrom the tonic according to the rules of conventional musical practice. (Terhardt & Seewann 1983)

1.3 An unnatural synaesthete

In principle, an unnatural synaesthete – although not possessed of the neurological faculty for synopsia – could consider music, or any sensory stimuli, with the same tendency to cross reference as a synaesthete. This might mean using a device that analyses the spectral qualities of the sound and gives a colour representation of what's happening or simply by virtue of a systematic association wherein qualities of one sense are consistently described in the other until an association becomes inherent. But even without a device, can a person make a choice to conflate their senses for cross modal thinking?

Either of these methods may be less elegant than having the process performed instantly and invisibly to others, there's nothing to stop the unnatural synaesthete from responding to a device, or my Methodology of Colour-Sound, just as a synaesthete responds to their own internal, deliberate, colour-association.

The fact that an association is deliberate allows it the advantage of being quantifiable, logical and chosen for logical reasons, explicable to others, where the natural synaesthete struggles to make their experience clear to 'neuro-typical' audiences or colleagues, as theirs is not chosen and logical, it is rather a function of their neurology. An explicable colour-sound association could be shared and explained.

The output of this research does not include a device for this process, though further research is ongoing. Rather, the Methodology of Colour-Sound of rules, practices and colour-sound compositions will form the corpus of research product, other than this paper and any compositions arising from experimentation.

At such time as a device is developed, natural synaesthete must edit the theoretical device to exactly match their internal experience but they might be satisfied to project that association outwards into the world. Similarly, the unnatural synaesthete who would build this association into their practice is better placed to collaborate with all parties and make them privy to the experience of the colour-sound association.

The difference between the colour-association of the unnatural synaesthete and any individual natural synaesthete – as each natural synaesthete has their own unique colour association rather than any uniformity across the population – would be considered a transposition function. In fact, a transposing function between one's own colour-association and that of a friend could be an inherent function of the device.

Whereas, each natural synaesthete has an idiosyncratic association, the unnatural synaesthete – if they accept the suggestions of this paper, rather than developing their own association – is afforded the potential to join a community of colour-sound artists who are working with an agreed colour-sound association; this consensus in turn offering greater communication of ideas.

1.3.1 Internal consistency

When testing for synaesthesia it was discovered there was little consistency of association across different individuals; that one synaesthete might perceive E natural as Blue, someone else as Red (Whipple 1900) and someone else might perceive an

association not necessarily between pitches and specific colours, but more across tonalities (Bernard 1986).

In fact, it is this apparent lack of consistency that led to a lack of serious consideration of synaesthesia in the academic world until relatively recently (Cytowic, Eagleman, Nabokov 2009) and it was Cytowic's discovery of the high level of internal consistency and subsequent experiments which led to the synaesthesia battery test that is the benchmark of synaesthesia testing today.

Within this test, the subject is asked to select the colour they associate with a particular stimulus. They are given a great many different stimuli and all of their responses are recorded. The synaesthete will have an incredibly high level of internal consistency and they can be tested years later and their responses with match those initially recorded with an astonishing level of accuracy and precision. Cytowic describes synaesthetes as colour experts, since it seems only to be their unusual synaptic pruning that defines their trait, rather than any additional neurologically divergent structures or habits, the implication is that an unnatural synaesthete might learn colour or harmonic expertise by way of cross referencing. The element common to all synaesthetes – from whose talent I wish to benefit – is the **internal consistency**, rather than a particular association, that will serve to highlight pleasant harmonic patterns within sound and music.

This will be a key feature of my proposed Methodology of Colour-Sound and, although I will propose my own logically selected colour-sound association, the principles of the Methodology of Colour-Sound should still apply should the reader wish to select their own colours. In fact, any supporting technology, developed in future, associated with colour-sound need necessarily be adaptable to the user's own colour-sound bias (should they have one pre-existing), especially those due to natural synaesthesia.

1.3.4 Colour organs and other things this project isn't

Scriabin's clavier a` lumie`res, a piano that featured coloured lightbulbs was in infancy a tool to convey his colour-association and at its height became a feature of planned performances. He wrote it into his score for the 1910 work Prometheus: The Poem of Fire. This was somewhat close to, and certainly influential of, this project. Scriabin treated colour and sound together, not as separate planes of experience.

> …the ‘colour crescendo’ at the climax of Arnold Schoenberg’s 1910–1913 opera Die Glückliche Hand. According to Percy Scholes’s entry on ‘colour and music’ in the 1938 Oxford Companion to Music, between 1895 and 1932 there existed at least a dozen devices that could simultaneously produce colour and musical sounds, and a book published in 2004 reproduces illustrated patent applications for no less than seventeen such devices. (Wierzbicki 2012)

It must be considered at least, that these works differed from Messiaen’s in that he wasn’t attempting to colour or light a performance – even if those examples included composers with a colour-sound association – but rather the piece itself was drawn often ab initio from outside of the sound world; from the colour world. That isn’t to say a colour-artist shouldn’t consider using coloured light and projection in their performances, but just that this isn’t the primary goal of a colour-sound association. That it is, rather, closer to Messiaen’s world of the boundless journey between the colour and sound experience throughout the artistic process. Colour-sound is focused on an association at the point of composition, that the material itself be drawn from a new, augmented, perspective.

This dissertation makes references to technologies used to illuminate or clarify colour-sound association. I have discussed how the association may be represented in performance. The outcome is that the association in the mind of colour and sound, and also in the practice of a musician, may offer a new way of considering harmony and be a better way of communicating it, not just in performance but in scoring – either graphic or in augmenting existing scores – and in education; introducing new musicians to colour and sound together so that confidence and familiarity blossoms.

Scriabin, synaesthete or not, expressed colour in his performances in order to share a glimpse of the rich internal experiences he had in considering his music. Messiaen didn’t include colour in performance, yet his association served his genius none the less. That which they have in common is the internal process of colour-sound association that drove their exploration of music and to propose, that the musician born without their neurology need not be dissuaded from their method. To stand on the shoulders of

synaesthetes and explore an associative sense, my Methodology of Colour-Sound has focussed not on the practices of technologists and stage designers, but on composers and composition and on creating a series of principles by which to operate.

1.4.1 Michael Poast

Composer Michael Poast (Poast, 2000) argued the case for colour-sound association in particular as applied to scoring. Poast, long established in the classical scene of New York, could see the virtue of an overlap of sensory play and certainly found a strong history for it among his heroes from Aristotle to Kandinsky (Poast 2000) but suffered from an unclear vision and a poor grounding in the mechanisms of both colour and sound.

> These waves range from long, red frequency waves through short, blue ones. Virtually all the colors we see are mixtures that take on the appearance of the brightest color in the mixture. (Poast 2000)

This of course, does not display a strong understanding of colour physics. My intention in this moment is not to undermine Poast, but merely to stress the importance of understanding the components of the association, their character and definition and also for any system developed therefrom to be rational and clear. Examples of his scoring, rather than enabling the musician, lowers the clarity of his scores and serves better to express his feelings about his music. They are works of art in themselves but not strong tools in the exploration of art as a score should be. Not everything colourful should be included in colour-sound association.

1.5 Colour sound composition

Composers often propose new genres of art based on the findings of their careers, consider Schoenberg's 12 tonality or the process music of the minimalists; to do so is not in any way limiting, it is a summoning to responsa, a hope for antiphony. Although I propose key principles for colour sound composition, I justify them and believe them to be the best course of action for colour-sound, it only becomes a genre if engaged with critically.

1.5.1 Messiaen

In particular what I romanced about synaesthesia began with an anecdote I heard from another compositional student (similarly to Dr Wiggin's apocrypha, it is the effect not the stimulus that is important here) about Messiaen listening to his favourite bird songs and, inspecting the colours their song produced in his vision, he replicated the feeling in his orchestral compositions.

In my composition 'Along the Dart', a response to my experience of the colours in this environment, I modified this approach; rather than responding to my colour association with the sounds of that environment, I responded directly to the colours of that environment. However, once I have trained my ear to associate colours with the sounds of the natural world – or undertaking the same process via means of a device – I will attempt a more direct copy of Messiaen's method here.

> Colours are very important to me because I have a gift-it's not my fault, it's just how I am-whenever 1 hear music, or even if I read music, I see colours. They correspond to the sounds, rapid colours which turn, mix, combine and move with the sounds. Like the sounds they are high, low, quick, long, strong, weak, etc. The colours do just what the sounds do. They are always changing, but they are marvellous and they reproduce themselves each time one repeats the same sound complex. (Messiaen & Watts 1979)

Contemporary classical composition, for me, is a largely abstract and ineffable experience, wherein I deal with large flowing sensations and replicated emotions, disembodied from narrative in its truest sense. The prospect of capturing real life sensory experiences from the sound *or* colour world of everyday life and, through the sound of those colours, or the colour of those sounds, immortalising them in orchestra, is tremendous. The bass of a passing bus or the shriek of a buzzard, analysed and noted in a familiar pallet of colour, condensed in note, carried home and reconstituted in church organ. This seems much more plausible in colour than in a series of pencilled letters and symbols, much more organic.

There is a certain amount of discussion of other synaesthete, or colour-sound, composers, but only is so much as the composers themselves discussed their internal world. Certainly, it is only recently that synaesthesia has been taken seriously within the

modern science of neurology. It would be fair to assume that there may be more well-known composers who, unbeknownst to us were synaesthetes. Discussions are only available for those artists who spoke openly about their strange internal sensory world. In the case of our first subject, even the validity of his colour-association is called into question within academia from the off.

1.5.2 Scriabin

According to Galeyev and Vanechkina (2001) Scriabin was not a natural synaesthete, yet he drew on his, perhaps voluntary, colour-association to make a bold impact on the musical world of his day, his work still echoing in the minds of modern composers for its scale and ambition as well as it's drama. His masterwork – begun in 1903 but left unfinished as the time of his death in 1915 - 'Mysterium', a colour-sound concert of astounding proportions, with considerations of smell and touch also, was yet unrealised at the time of his death. Triarhou (2015) would seem to make a solid case to counter Galeyev, but without a living Scriabin brain and a 'functional Magnetic Resonance Imaging machine' (fMRI) the question must remain unsatisfied. I can consider it possible, in the light of doubt and debate on his status as a true synaesthete, that as the product of his work is not in doubt, that, in itself, promotes the idea of the unnatural synaesthete composer. It has been implied that upon meeting Rimsky-Korsakov in his youth, Scriabin was inspired to work with colour. If this makes the case that his colour-association was voluntary, then his success makes the case for the unnatural synaesthete.

1.5.3 Rimsky-Korsakov

> All tonalities, modes and chords, at least in my personal view, can be found exclusively in nature, in the color of clouds or in the strikingly beautiful twinkling of colored columns and tinges of northern lights. There exist "C"s proper, and "h" and "A"s and anything you wish. (Rimsky-Korsakov in Yastrebtzev 1958)

Whether this is 'metaphorical thinking' or not, is incidental considering that the nature of synaesthesia is innately metaphorical – yet a real neurological experience – as it has been argued that the nature of metaphor is innately synesthetic in origin (Ramachandran, Hubbard 2001). Ramachandran postulates that metaphor, even speech,

may have their origins in synaesthesia; as the action of describing, with a vocal ejaculation, the experience of surprise or fear or frustration, certainly to eventually describe the action of a tool with words requires the societal consensus that sound can represent experiences that are not in the first case aural. Above Rimsky-Korsakov reaffirms this idea with his principle that he is ordering his experiences in music, not creating something new that does not exist in nature. There is a conceptual grounding in this idea, that seeks to recognise the source of inspiration for even abstract art forms, such as classical music, in experience.

Rimsky-Korsakov was a contemporary of Scriabin and it was their discovery of each other's colour-associations that inspired them both to write it into their music (Triarhou 2015), although with different stylistic results. The style, the response to the association is the composer's individuality. The clarification of principles is what I will pursue in this research.

2. Literature Review

This paper drew on a wide range of scholarly work as the foundation of colour sound association. Indeed, there was a necessity to define each area to be understood and then what work had been done previously on drawing them together. I offer some brief thoughts in many areas in the hopes that the whole will provide a guide to the diffuse world of colour-sound research.

2.1 Colour

In discussing colour it was important immediately to define colour; of course, the broad effect of colour is quite familiar to the general populace, after all we learn to categorise colours from infancy, but two questions are important to address from the outset, firstly do we experience colour in the same way and secondly what are the dimensions of colour i.e. is there an analogue continuum or a series of discrete steps and in either of these qualities what varies one colour to the next? Gravesen (2015) describes 'The metric of colour space'; a description of the parameters of colour in the language of both physical light and technological reproduction of colour. It was important to find a paper that describes the earliest theories in light of the newest understanding and Gravesen does this clearly and concisely in a manner accessible to the colour-laymen.

All papers I read referenced MacAdam. It appears that as early as his, 'Quality of Color Reproductions' (MacAdam, 1951) for International Commission on Illumination - adopted by the American Standards Association - seems to be the foundation for the majority of colour science today. In fact, the graphical representation of theoretical colour space is almost identical to those still used in Gravesen's paper 64 years later. MacAdam never professes to be an authority on individual colour bias arising from physiological conditions or the broader departure of human perception from mathematical colour but this is covered in Gravesen's work as the understanding of the physiology of the retina, by the new millennium, had progressed somewhat.

2.2 Sound

I drew on a variety of areas for my research on sound, I looked a paper on the development of a guitar tuner, both for its literal description of the parameters of sound

and also for its articulation of such parameters into a digital language for the processing of such data by computer. (Lourde & Saji, 2009, among others). As sound is a simple process of transverse compression waves, understood for some few hundred years, the process is taken as axiomatic – but secondary papers such as this one describe the process well secondarily for its translation to, in their eyes the primary process; in this case the definition of a tuner.

Seitz et al. (2010) discussed the relative merits of different methodologies of auditory training, this allowed an exploration of the process of music learning and by extension of post perception neurological processing of music as an experiential rather than physical process. Sound is in the ear of the beholder. In this regard, I am straying from the broader definition of sound and starting to describe the components of music, this is a meta-concept, not of sound veridical, but of conditions we apply to sound to encode and convey meaning. Along with Terhardt, & Seewann (1983) in their paper on 'Aural Key Identification' it assumed that I am now discussing a second category of sound wherein an agreed experiential system of tonalities exists.

Just as Lourde and Saji must define and describe the parameters of sound to translate it to a processor, Seitz, Terhardt and Seewann must discuss the parameters of tonality.

In Chen- Hafteck's (1997) paper, Music and Language Development in Early Childhood another stage further is afforded to this study, the characteristic relationship between the learning of language and the encoding of the musical system described by Seitz, Terhardt and Seewann.

If the colour-sound association described by this paper is to be internalised I must understand what is the natural process that one is proposing to augment. This is another storey on the house of musical understanding. The foundation of which is 'what is sound?', the ground floor is 'what is music?' and the first floor is 'how do we come to agree on that?'

Stuckenschmit (1973) touches briefly on the plumbing of this house, giving an overview of what technologies have been developed in music and in particular in the odd cousin of music, colour-sound. Most writing in this area discusses specific composers, their

processes and whether or not they were neurologically divergent. Stuckenschmit gives a brief overview of some of their works in a historical context.

2.3 Synaesthesia

The understanding of synaesthesia is relatively new, it has been observed as a phenomenon since at least Whipple's 'Two cases of Synaesthesia' for The American Journal of Psychology in 1900, but the term had been defined earlier in a description of an Albino patient who coincidently exhibited synaesthesia. As interesting as the history is, even as late as Whipple, only descriptions of the phenomena were offered. The physicians investigating it had assumed if it was real, rather than hallucinatory or psychosomatic disorder, there would be some congruence between the different subject's associations. It wasn't until Cytowic developed his ingenious, logical tests in the 1980s that all doubt about the subject was dispelled and the real science began. The best book to read for the development of this golden age of synaesthesia research is Cytowic's later work 'Wednesday is indigo blue: Discovering the brain of synesthesia' from 2009, wherein he is able to give an overview of the majority of discoveries and developments over those decades.

Ramachandran offers the other clearest voice in the field and, among others, his 2001 writing with Hubbard; 'Synaesthesia - a window into perception, thought and language', highlights his theories of synaesthesia's effect of the development of other neurological systems. This is essential for placing synaesthesia within not only neurology proper, but also in discussing how synaesthete tendencies are not alien to the neurotypical brain, rather that is an amplified version of a process common to us all. It is clearly written and enjoyable to consume, verified with data integrated beautifully to the writing. V.S. Ramachandran is one of the best known nuero-psychologists exploring synaesthesia. This article has been cited in 1160 papers. It is grounded not only in the work of Cytowic (2009) and Baron-Cohen (1994) but in Ramachandran's own innovative experiments that have quickly come to influence the technique of investigating psychological phenomena such as this. The focus is on grapheme-colour associative synaesthesia and it was this work that proved that synaesthesia operates on the level or perception not on memory association due to experiments that highlight a grapheme-colour associative synaesthete can perceive coloured graphemes crowded by non-coloured graphemes at a rate far in excess of non-synaesthetes, therefore they aren't

finding the graphemes and applying the association. Rather finding the graphemes *because* of the graphemes. This utterly affects the field of my project.
It is a key discovery that has affected the approach of all psychological researchers into this area. It is Ramachandran and Hubbard in this study who posited the origin connection between low level synesthetic connections and the origin of language, not just metaphor.

Bor et al (2014) in his, 'Adults can be trained to acquire Synaesthetic experiences' confirms that the project is rational. The essay cites well throughout and is drawing on results from the researcher's own experiments. It seems that their results are promising although they are working with small numbers of participants such that the results may seem too narrow for confidence in the scientific community.

Harrison and Baron-Cohen (1994) give an excellent, but brief view of synaesthesia in 'Synaesthesia: An account of coloured hearing'; not from the perspective of historical record of studies, as some have done, but glancing across some areas of its application in music, painting, poetry and concluding with a synopsis of testing methodologies current in 1994. It is a considered summary that would serve well to elucidate the condition and its various possible manifestations in traits. Baron-Cohen is best known for his work in autistic spectrum disorders such as Aspergers, but has ventured considerably into synaesthesia particularly in so much as the two impacts on each other, as it has been noted to do so, with a high concurrence of both traits in single subjects. It should be noted that this is not seen as causal in either polarity all though it is possible that there may be a third factor as acting as causal to both. In the author's comparison of possible investigative techniques, the following are considered and compared; behavioural observation, interview as both first-hand experience and also as clarifying patterns in description, finally concluding with neuro-imaging studies. The later could be considered to verify experience, but only when taken in unison with interview methodologies, as fMRI and positron emission tomography (PET) scan show areas of the brain activated but are not detailed enough to speak as to qualitative experience.

Leatherdale (2013) provides an overview of synaesthesia for the layman in Synesthesia: The Fascinating World of Blended Senses. It is brief, but dances across the condition in areas of application to mathematics and art (both traits of possible expertise in subjects

with synaesthesia), and how they are investigated. It briefly explains most of the current thinking. This is an excellent early resource for planning a study although, it seems, there is little new light or primary study here.

2.4 Colour-sound composers

Previous sections, defining colour, sound, music and even synaesthesia are elements to be drawn together for the benefit of composers, but in this section the papers discuss what work colour-sound composers, particularly synaesthetes have done so far in the field.

Bernard (1986) focuses on Messiaen's colour-sound association and delineates it for us to a greater
level of detail and clarity than even Messiaen (1957) did in his treatise 'My Musical Technique'. In Messiaen's own paper his focus was his use of harmony, counterpoint and rhythm but colour-association could be inferred. However, in this work Bernard has researched and written up the detail; tabulating for pitch, harmony, horizontal melody and counterpoint, how colour-associations would work in Messiaen's experience. Taken together with Messiaen's 'My Musical Technique' a whole picture is visible of his perspective: one voice from Messiaen's perspective explaining his technique when colour is assumed and one looking at the results when colour is explained. This is invaluable to the development of my Methodology of Colour-Sound. Bernard draws on Messiaen's own writings, on Samuel's conversation with Messiaen and on other academics work in analysing his scores. However, his sources are narrow as this is fundamentally an archival task, taking the time to unpack a specific text from the few detailed clues available. An important trait of synaesthesia highlighted here is its high level of internal consistency, which is now understood to be of much more importance than the previously expected societal consistency. This work clearly evidences Messiaen's internal consistency and, that he had achieved acclaim without the musical world's knowledge of his unusual internal processes they are highlighted here as a clear functional benefit and not, in any way, a novelty.

Dworak (2010) similar to Bernard's work (1986) elucidating Messiaen's colour-sound association, Dworak brings an even tighter focus in his analytical discussion of Messiaen's colour 'spaces' used in 'Couleurs de la cité céleste' or 'Colours of the

Heavenly City'. As one of his later works Messiaen's synaesthesia, or as he described it 'synopsie', was now known to him to be, not only an unusual sensory experience, but a fabulous tool contributing to the texture of his art in a way unavailable to non-synaesthetes. For this reason, Messiaen openly included notes on his colour-association with this score. Dworak need not reveal to us the various colours associated with each musical element, but annotates it for us.

Galeyev & Vanechkina (2001) challenge popular assumption with their paper 'Was Scriabin a Synaesthete?' with a focused discussion on Scriabin's colour-sound association, a comparison of natural synaesthesia and voluntary colour association. The Authors at times seem to imply doubt, not just that Scriabin was a synaesthete, but perhaps that synaesthesia exists as a phenomenon at all. This is problematic as a concept since fMRI scans of blind synaesthetes who show activity in the colour centre of the vision cortex has justified beyond doubt that the phenomenon is real. Such data was available before 2001. This prompts excellent questions and, as the counter argument to synaesthesia's testability, it calls me to justify the existence of the trait. 24 out of 44 of the authors references are their own previous writings, more than half. I see this as academically problematic. Although a good deal of original work was done in archives of Scriabin's work in Russia, I would expect a strong paper to draw on a larger pool than self. In either case the article is useful, in that if Scriabin was a voluntary synaesthete with a synthetic colour association, then his methodology is even closer to my own. Certainly, his colour associations are similar in colour to my choices. Apart from the question as to Scriabin's status as a synaesthete, though, there is a good deal of analytical work here on the nature of his colour association and this would be very beneficial to the formation of my Methodology of Colour-Sound.

Galkin, E.W., Messiaen, O. and Satterfield, J. (1957) 'The technique of my musical language', Notes, 14(4), p. 575) Messiaen's (1957) treaty, 'The technique of my musical language', is pivotal to my project; as a first-hand account of his compositional technique and colour association. Although the colour association is not the focus of this paper, seeing his description of techniques for compositions for which I know the colour association, from other sources, gives a stereoscopic view of his process. The citations are limited, as one would expect in an article on his own practice, this is not a problem at all. I rely, due to my own limited French on Satterfield's translation, but I have access

to French speakers and the original, should any part be unclear or in question. This paper works systematically through all aspects of music, rhythm, harmony, modality, citing influences and, as it is my intention to form my own Methodology of Colour-Sound; his framework is excellent for my own purposes.

Peacock (1985) brings the counter argument to Gayelev and Vanechkina, in ‘Synesthetic perception: Alexander Scriabin’s color hearing’, with an essay divided into two parts, the first lays a healthy foundation for an analytical study of Scriabin's synesthetic trait. A broad range of sources are drawn on from, including Vanechkina, but also Flournoy, who has been cited as the originator of the term synaesthesia. Citations range from 1881 to 1984, giving a complete overview of the developing scientific thinking on synaesthesia beginning in a time where no verification of experience was possible. Scriabin's synaesthesia is compared to Rimsky-Korsakov allowing us to observe the unusual level of systematisation of Scriabin's colour-association in comparison to the inarguable, natural synaesthete found in his colleague. The phenomenon of coloured-hearing in a musical context is broken down systematically, as did Messiaen, so that all of the components necessary to the formation of my own Methodology of Colour-Sound are made available. The essay draws on original scores with colour-association notes and on final directions for light projection in Scriabin's 'Luce'. This allows the comparison from Scriabin's internal colour-association and selective artistic choices relating to what he wishes to highlight in the music.

Galeyev (2007) ‘The nature and functions of Synesthesia in music’ It has been argued that low level sensory association of a mechanism similar to synaesthesia is the route of metaphor. Culture wide inter-sensory associations allow us to draw on language from one sense to describe another; sharp cheese, warm sound, loud shirt etc. This is because sensory conflation is more common is more, but more subtle than in the extreme cases of synaesthesia proper. This is the focus of Galeyev's essay. As with their 2001 text, when Galeyv and Vanechkina disputed Scriabin's synaesthesia, Galeyev hints at something between disbelief or disinterest in conventional definition of synaesthesia, but instead is interested in what aspects of the trait may be accessible to all, particularly in the context of music. In this case 6 of 16 citations - a fairly narrow pool - are drawn either from Galeyev or from Vanechkina, slightly over a third. What is being discussed for the most part is commonalities of experience for the population compared to

idiosyncrasies of experience in synaesthetes.

Watson, et al. (2014) offer ‘Synesthesia and learning: A critical review and novel theory’.

This is one of the most well-read essays I have found. It draws on the works of the most peer reviewed psychologists tackling the mysteries of synaesthesia; Cytowic, Ramachandran, Ward and Baron-Cohen. The study stretches to the origins of synaesthesia study in Calkin's work in the 1890s to modern work and discovery. Early arguments about synaesthesia tried to place it either in a category of genetic cause or one of environmental cause. This essay recognises not only that phenotype of synaesthesia-proper is a result of both, but also that the process is dialogic between systematising and learning. Environment helps those genetically predisposed to synaesthesia to codify their experience with more regular labels from another sense, then the regular labels from that other sense create mnemonic devices beneficial for good learning in abstract contexts. The essay considers problematic anomalous influences such as Asperger’s and draws confident principles from other scholars. When discussing the issue or learned synesthetic response in non-synaesthete adults, the study is systematic in its analysis of the fairness of each study, the authors are strict to the scientific method and thus result in a very fair delineation of the results, more so than the studies themselves, in part because it acts as a survey for all such studies.

3. What is colour & what is sound?

In any investigation we must first define our terms.

Light, visible light, are the only waves of the electro-magnetic spectrum perceptible to the human eye without prior treatment. At a later stage, the limits will be expanded. I will describe colour as that quality of light that conveys frequency. The finer dimensions of colour will be defined in the next section, but as a broad stroke, this definition is sufficient.

In equivalence, I can define sound as only those compression waves of a fluid body (gas or liquid) perceptible to the human ear, although at a later stage these boundaries may be broadened to include sounds perceptible to our colour-sound technology. The finer dimensions of colour will be defined in a subsequent section, but as a broad stroke, this definition is sufficient.

It will be immediately obvious to the reader that I am endeavouring to find close equivalency in all parameters of either colour or sound with its counterpart in the other.

As this investigation is in pursuit of understanding interaction and bias between our perception of our senses and the formation of art, it is of great importance that we are in agreement when we define our senses. There is, perhaps, more room for discussion than one might, at first, think.

For example in the case of vision there is an ever-shifting relationship between the perceived colour of objects and the source of light that acts upon them initially. A piece of white paper is, as white, a roughly even reflection of the light acting upon it at any one time. Therefore, at sunset it will be reflecting a pinkish light – rather than true white – at dawn that light might be bluer, yet to the observer is appears consistent (Gravesen 2015). This is one important consideration I must include when defining a colour response to sound. For shorthand, I refer to this principle hereafter as '**veridical light source**'. It is the bias incurred by the source of light in each environment. This can be considered in one of two ways; first to ignore its influence, focusing on the principle that the perceived or measured colour of the moment is the stimulus of focus and what the colour may be under differing conditions is irrelevant; the second is to provide a

balanced light source and measure veridical reflection from an even source. If the artist wishes to respond to the colours of an environment that inspire them, then the measurements of a veridical reflection from an even light source is inconsequential to the initial inspirational experience. Light source bias in this case can be ignored. However, if one is wanting to explore the trueness of colour environments, but through sound, the colour correspondence should be derived from an even light source.
A second bias to consider is that of the eyes of the individual.

The human retina has three types of colour photoreceptor cone cells, with different spectral sensitivities, resulting in trichromatic colour vision, i.e., a colour is described by three real numbers [...] The sensitivities of the colour receptors are not the same for all humans. It depends on the angle under which the colour is observed, but also on age and gender and there are individual variations. (Gravesen 2015)

This bias should not be as much of a problem when discussing colour, so long as the subject's experience of colour is internally consistent. The consideration of age in this instance is not too dissuading as I expect that any shift is so gradual so as not to interfere with the production or experience of art. Obviously, a colour blindness – to part of or the whole colour spectrum – would need consideration as would any sensory loss in an aesthetic pursuit. To afford us the ease of discussion later, I will define this factor as '**individual retina bias**'.

A macrocosm of individual retina bias would be '**human retina bias**' which is that bias away from veridical or mathematical colour that affects our species as a whole. Obviously, the outer limits of human visual sense are defined differently from animals, such as butterflies and birds, who perceive ultra violet light, but what may not be widely known is our bias *within* the visible light spectrum.

In *fig 1*, it is clear that there is an uneven arrangement of colour photoreceptors against the light frequencies that stimulate them. Longer wavelengths (lower frequencies), from 650 nanometres to 470 nanometres, stimulate red photoreceptors, green *and* contrast cones (the latter only feature as part of vision in low light conditions, providing roughly black and white vision at night). It is in this region of great overlap, particularly between red and green retina cells, that the vast majority of colour is perceived. These

frequencies of light include; red, orange, yellow, and green. This area of overlap allows the green and red photoreceptors to work antagonistically; rather than a single parameter of light that can range from 0%-100%, the overlap allows colours to be made up of two variables. When considering colour, I must consider that our perception of it is only one of many possible evolutional responses to the world of light. Does the colour sound composer wish to compose a symphony about his perception of a meadow of wildflowers, or the same meadow as the bee perceives it?

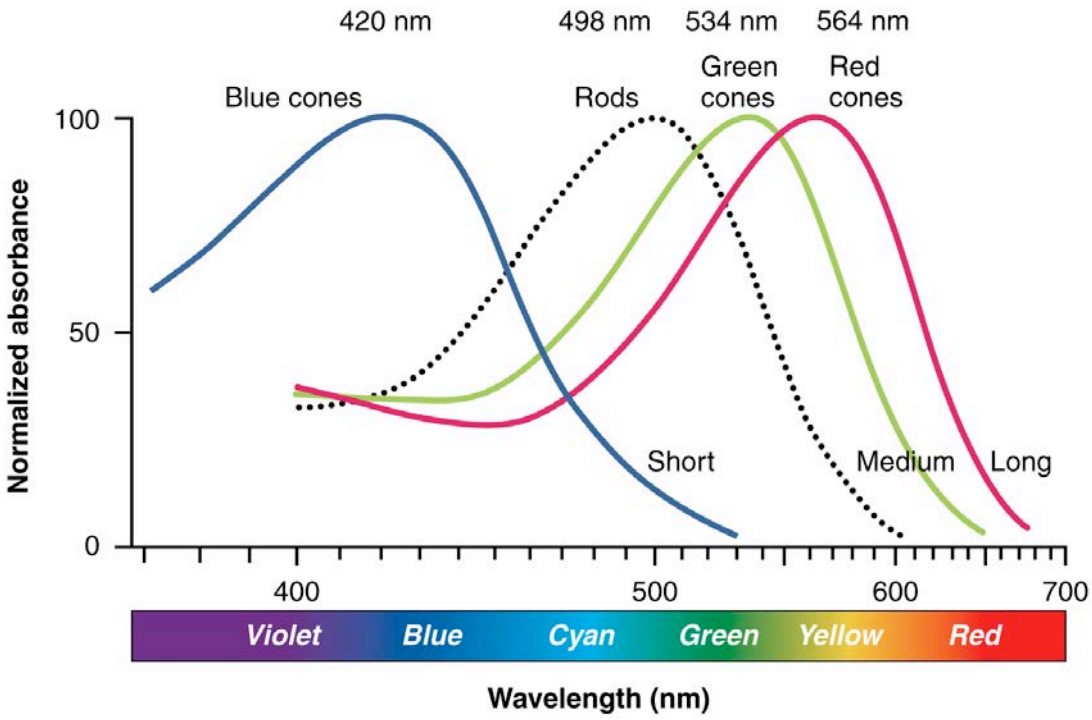


Figure 1 Human photoreceptor stimulation at varied wavelengths. (Openstax CNX website, vision derived from sensory perception http://cnx.org/contents/YPmMIA42@1/Vision, June 2017)

3.1 Dimensions of colour

> No elaborate experiments are needed to decide that color can vary in three, and only three, independent ways. We can realize this by noting that color sensations can differ only in hue, saturation, and brightness. If we adjust one color so as to produce the same hue, saturation, and brightness as another, the two colors are indistinguishable. (Macadam 1951)

The reader will notice that brown does not appear on the spectrum of visible light in *fig1*. If one seeks to arrive at brown one must begin at orange and lower the brightness. Taking this into account, if the colour-sound composer wishes to capture a significant brown from the colour world and express it in sound, they will need to navigate the less obvious dimensions. The obvious dimension of the spectrum can be subdivided into the 12 notes of the western spectrum and attributed sequentially to pitches, but those desaturated, overly lightened or overly darkened colours such as brown will need a correspondence also. So that these three dimensions of colour will need equivalent dimensions in sound. I discuss this in section 3.3 (Correspondence).
I define the Macadam's three dimensions of colour; **Hue**, **Saturation** and **Brightness**. HSB is sometimes referred to as 'HSL' (where L is luminescence – the same quality as described by brightness) and 'HSV' (where V is Value – an ambiguous alternative for brightness).

Hue ranges from 0° to 360°. Each increment of approximately 30 degrees represents a distinct colour. First there is the red hue (0°/360°) and then each colour in common parlance sits at approximately 30° hence; orange 30°, yellow at 60° etc. Saturation represents the amount of colour or, more exactly, its percentage; 0% represents no colour (white in appearance – at the centre of the colour space in *fig 2*), while 100% represents the full colour (the outer edge of the colour wheel). Brightness describes the percentage of light overall; 0% appears black, 100% represents full colour. The closer this value gets to 0%, the darker the colour is. The closer this value gets to 100 the Brighter the colour is. Every possible colour has a HSB value of three coordinate numbers (X, Y, Z,).

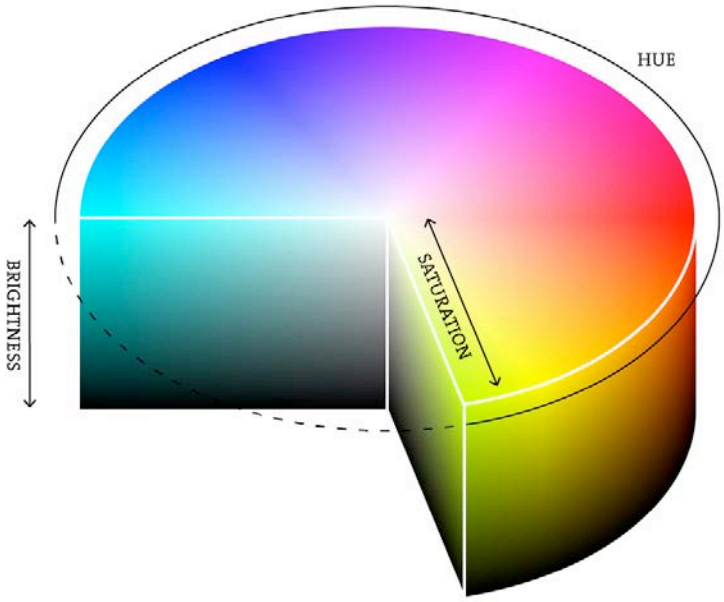


Figure 2 A representation of the HSB colour space: Hue is represented as degrees of the circle. Saturation is represented as percentage from the de-saturated centre of the circle. Brightness is represented as vertical percentage towards black
(Processing foundation Website https://www.processing.org/tutorials/color/ May 2017)

3.2 Dimensions of sound

At first consideration, the dimensions of sound would only consist of the dimensions of a wave; in which case, the considerations would merely be; **Frequency** and **Volume**. However, this is made more complex by the human experiential construct of harmony, wherein the Pythagorean framework of western tonality is applied to certain frequencies and relationships between frequencies as tonal, frequencies and relationships outside of the framework are considered atonal. This means that one is not merely navigating a pure spectral, analogue experience, but also to highlight these tonal moments and relationships. Dimensions of; **Note** within the octave, location of the **Octave** within the spectrum and **Interval** between notes vertically (chord or harmony) and horizontally (melody) in time.

A consideration of **Timbre**, that microcosm of harmony that gives the note shape, or voice (and tells us which instrument is playing), contains not just the fundamental

frequency, but also complimentary harmonics that relate to the harmonic series. It adds subtle qualities that transform a sine wave into a rich note of subtle complexity. Within the field of colour-sound, I consider timbre either as a small combination of colours, as I would a chord, or perhaps a shape in the HSB colour space. A third option would be to momentarily ignore the richness of the note and focus on the fundamental, but this feels like a loss of important textural information. The timbre of a note is also affected by how these harmonics 'attack' and 'decay' over time and again both these elements of timbre as microcosms of the initial two dimensions of sound **Frequency** – which are the pitches that form the harmonics? – and **Volume** – how do their shapely increase and decrease of volume? Bearing that in mind, whether I consider timbre or not I am only seeking to represent our initial two dimensions.
Both Timbre and harmony, then should be represented as multiple colours in space, perhaps with most space assumed by the fundamental in either case. I discuss this further in section 3.3 (Correspondence).

A meta-dimensional consideration for music that will not, necessarily, apply to sound is **Octave**.
Attributing each pitch of a scale to a degree of the hue circle, I assign each octave of C♮ a new colour moment on the horizontal HSB circle (*fig 2*) or consider the important link between octave notes and give over a different dimension of colour to the consideration of octave. As of yet I have identified only two dimensions of sound, but three dimensions of colour, I can afford to be generous with this meta-dimensional consideration.

3.3 Correspondence

If the visible light spectrum were to be distributed evenly across the whole audible light spectrum – there are approximately 132 semitones from the 1st to the 11th octave 16Hz to 32kHz) – each semitone of pitch would correspond to a colour indistinguishable from the last. The attributed increments of colour would be imperceptibly different from the other notes in each octave so that the only information conveyed by the colour correspondence would be roughly which octave was being observed. Certainly, nothing of particular pitch or harmony would be clarified.

It would be more useful to the colour-sound musician to form a correspondence of the whole colour spectrum to one octave so that in each octave a certain note has a relationship of intervals of colour to the notes around it. Each E♮ note would begin with the same colour (although I will go on to adapt this colour in view of clarifying octave with another HSB dimension).

In the absence of a colour bias, I argue that sequential pitches of the octave should correspond to sequential colours of the light spectrum, since there's no apparent benefit to the contrary and since I am looking for a harmonic equivalency to two spectral sensations. Furthermore, I argue in favour of representing the lower pitches with lower frequencies of colour, so that I begin our colours with the red end of the spectrum. Considering that each key begins with a different note, none of greater, universal importance to musicians, there are two rational candidates; beginning alphabetically at A, or beginning as the majority of music students will, with the 'natural scale': C natural (C♮). I argue in favour of the natural scale so that I may establish our spectrum clearly to future colour-sound musicians before having to tackle the concept of sharpened and flattened notes, which will be tackled with sharped and flattened colours.

This point, then, results in **C♮ as Red**; this is our anchor point for the rest of the spectrum in each octave.

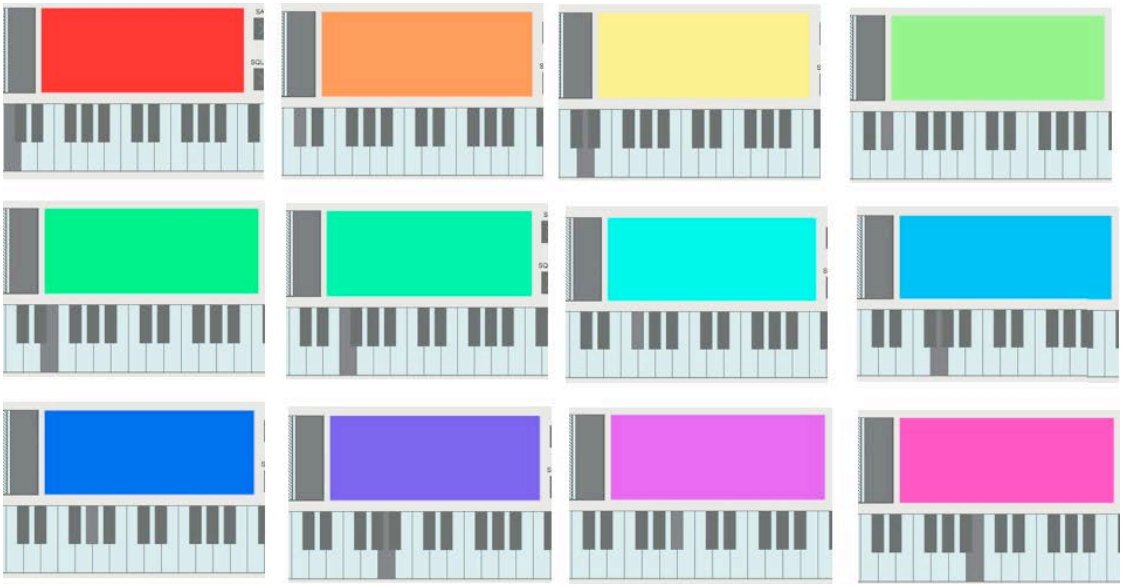


Figure 3: An early approximation of the colour correspondences of the twelve tones of the western chromatic scale.

In this step I have attributed hue, one of the three dimensions of colour, to pitch *within* the octave, one of the dimensions of sound. **Intra-Octave Hue**. I have temporarily suspended consideration of pitch within the wider macrocosm of the audible sound spectrum, other than how each pitch falls somewhere within one of the 11 octaves of audible pitch. If a pitch I am considering falls between two of the notes of the chromatic western scale, for example D and D#, what colour should be attributed? I address this in the section 0.5 (Chromatic and non-Chromatic sound).

If a composer wants to capture the experience of brown in a composition, what pitch should he attribute to brown? I can consider Brown a dark orange, in that if I lower the brightness of an orange hue, it will become brown. As of yet I have suspended the consideration of octave. It is reasonable then to consider a lower octave of a note in the same way we consider a darker moment of a particular hue. **Inter-Octave Bright/Sat**. In musical discussions, we often describe a bright tone as being one with a higher balance of tone and a darker or warmer tone as being one with a lower balance of tone. Considering this I propose to attribute lower octaves to darker colour and higher octaves to paler colour.

Brightness is given as a percentage, 0% being black 100% being full colour. Anything below 20% makes hue indistinguishable, therefore brightness range will begin at 20%. Also, increments of less than 15% are fairly unnoticeable from those either side by eye. This only gives us seven workable steps; 20%, 35%, 50%, 65%, 80%, 95% and 100% Brightness. But I offer an additional option in Saturation.

Saturation is roughly the inverse process of brightness. Decreasing brightness has the appearance of adding black to darken, decreasing saturation has the appearance of adding white to lighten. Therefore, our process can range from 20% Brightness and 100% Saturation, until the point of 100% Brightness 100% Saturation and then Saturation can incrementally decrease. Similarly, to the 20% Brightness threshold, Saturation shouldn’t decrease beyond 15% for reasons of hue distinction.

Table 1 give notes B and D# throughout the range of human hearing. They can be seen as a range of human skin tones.

Octave	0	1	2	3	4	5	6	7	8	9	10	11
Saturation	100%	100%	100%	100%	100%	100%	100%	90%	75%	60%	45%	30%
Brightness	15%	20%	35%	50%	65%	80%	95%	100%	100%	100%	100%	100%
hue: 330°/B												
hue: 0°/C												
hue: 30°/C#												
hue: 60°/D												
hue: 90°/D#												
hue: 120°/E												
hue: 150°/F												
hue: 180°/F#												
hue: 210°/G												
hue: 240°/G#												
hue: 270°/A												
hue: 300°/A#												

Table 1: An example of Inter-Octave Bright/Sat for Octave across all of the notes of the audible sound spectrum

> Take a note, any note, and there is a corresponding colour. If you change the note, even by a semitone, it's no longer the same colour. With the twelve semitones, the colour never remains the same. But once you reach the octave, you have the original colour again. It recommences with the high octaves and with the low octaves. In the higher octaves, it becomes progressively more diluted with white, and in the lower octaves, it is mixed with black so that it's darker. (Messiaen & Watts 1979)

At this point I would like to discuss the **dark & desaturated false paradox**, namely that though it may seem to be a paradox to say that a colour can be both dark and pale but, when colour space is defined by three coordinates that include brightness and saturation, one giving the appearance of darkness and the other giving the appearance of paleness it must be possible for these to coincide.

In the table below I have given examples of a single hue in various combinations of brightness and saturation.

Low brightness (dark) High Saturation (rich)	High Brightness (light) High Saturation (rich)	Low Brightness (dark) Low Saturation (pale)	High Brightness (light) Low Saturation (Pale)

Table 2: Compares various brightness and saturation combinations of the same hue (120° of E)

The first two columns are easy to place, approx. E1 and E5 respectively, but the third column is more difficult to assign. In attempting to broaden my colour range to meet the various 11 octaves I put the darkness of low brightness – low octaves are dark – and desaturation as paleness – high octaves are pale – I have created a gap for those notes that are, apparently paradoxically, dark and pale. In these cases, the hue is unproblematic as it represents a different plane, I will make a judgement call on the placement of the note within the octave range. It could be interpreted variously as a low dark octave or a high pale octave, so it will act as an ace card that could occupy either position subject to the bias exerted from its source material.

Fig 4 – from a series of photos take in the process of collecting colours for the composition ‘Along the Dart’ – various greens can be observed; the yellower greens of the ‘doc leaf’ are 90°/D# 120°/E, the grasses are majoritively bluer hue in the region of 150°/F. In particular some blades on the lower edge of the dark and pale. In the context of the yellower greens I would place these greens as dark, but they could easily be interpreted as light.

Figure 4: Image from 'Along the Dart' collecting colours for a composition

Previously I had attempted to use Brightness alone to represent Octave, but this gave too narrow a range. In *fig 4* an early representation of this idea of 'Intra-octave hue' and 'Inter-octave brightness' is given. The pitch, in this example, ranges from C3 to B6 and a moment of brown can be found C#3. Offsetting this model against Inter-Octave Bright/Sat offers not only a greater range of distinct note associations, but also covers a greater range of colours that may be appealing to the composer as inspiration.

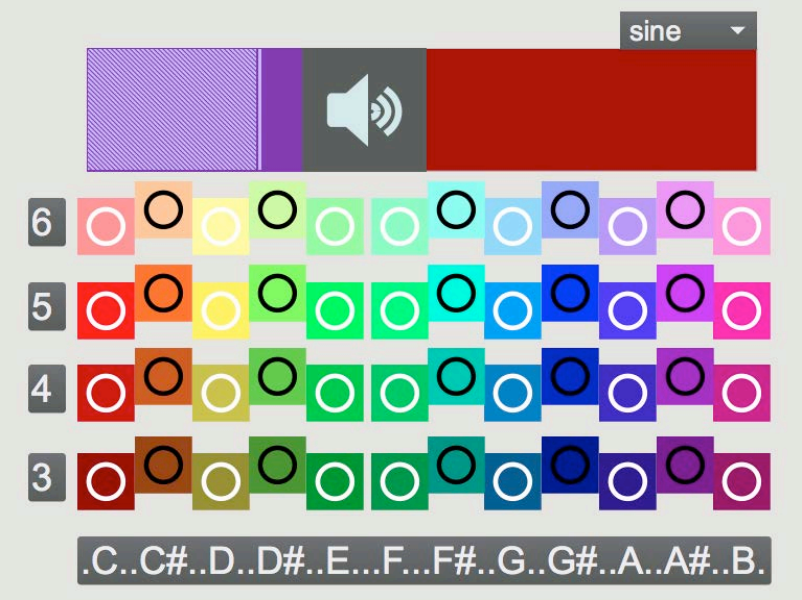


Figure 5: A synthesiser with Hue attributed to pitch within the octave and brightness attributed to octave.

Volume, or amplitude, is one of the more obvious or rather, more clearly discernible, dimensions of sound, but all the dimensions of colour all have been assigned a colour equivalency. Dynamics within a composition are a subtle element with great creative complexity, but I am happy, for now, to suspend their consideration in colour-sound. Since their appearance in sound is so obvious, I do not need support understanding or exploring what volume means to us in the same way that I am exploring harmony and tonality. Colour-sound is more a consideration for exploring harmony and tonality than a point by point musification of images.

I discuss later how timbre is made up of an attacking and decaying of harmonic overtones which, in this system, would be naturally be represented by different colour moments than the fundamental. It's important that the fundamental not be crowded out by representations of harmonics, especially in the case of chords, wherein I am already considering the colours of different fundamentals. However, it would be reasonable to expect the development of a shimmering texture of pixels representing the harmonics towards the edges of the fundamental colour. Even in a chord this could appear as, perhaps three or four areas of colour representing the fundamentals of each pitch contributing to the chords, and a mere hint of pixels representing their respective harmonics within each fundamental area.

Music is a **time-based medium**, photography is not, therefor when taking inspiration from a still image the temporal component must be added and so to any elements that are derived from time; rhythm, chronology of events, shifting dynamic, all of this is down to the composer's own artistic choice to infer from the context of the image or to construct. That therefor implies that when using a film or animation as a time-based score, the temporal and chronology of the moving image should be considered.

3.3.1 How correspondence is attributed

The dimensions of sound can be aligned to the dimensions of colour in the following manner:

'Inter-Octave Pitch = Hue': Pitch (in the form of frequency) is assigned a degree of the colour wheel. The 'Colour Wheel' (*fig 5*), as seen on the upper horizontal plane of the HSB colour space (*fig 2*.), is divided into the 360° of a circle, each is a '**hue moment**'

of the spectrum. The first, or lowest frequency, of the spectrum is red or 0°. As discussed this will represent C♮ as the fundamental of the natural scale. In *fig 5*, the example of C# at roughly 30° is highlighted as being orange. The interval 'θ' is a semitone. On this plane, it is apparent that a subject could – with training or practice – distinguish between microtones; consider the note at 15°, a quarter-tone higher than C♮ and halfway through the interval of 'θ'. It represents a 'hue moment' between red and orange and would have a marginally different colour reality from either.

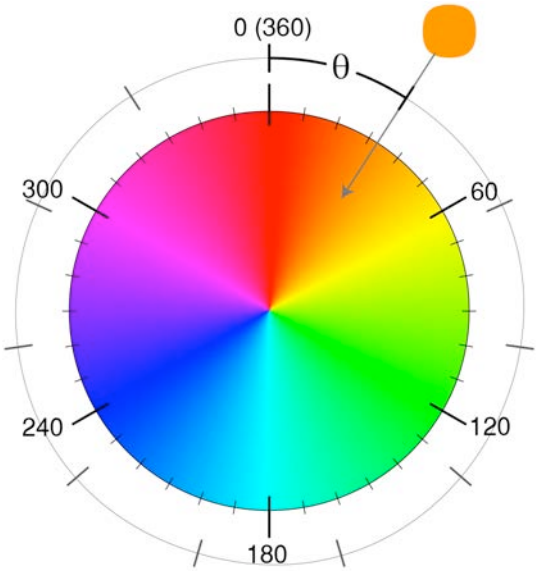


Figure 6 'The Colour Wheel' representing a cyclical colour spectrum by degrees (ModeLab website http://grasshopperprimer.com/en/1-foundations/1-3/4_domains-color.html June 2017)

Table 3 gives the degrees of the colour wheel that each pitch of the chromatic scale is assigned. Quarter tones are given in the unlabelled columns between each note position; distinguishing them would take training. A mathematical formula is needed that can transport the raw frequency of each note to the appropriate degree of the colour wheel, this will be developed in subsequent studies wherein a device will be developed rather than in this case where the focus is the composer's own response to colour.

C		C#		D		D#		E		F		F#		G		G#		A		A#		B
0°		30°		60°		90°		120°		150°		180°		210°		240°		270°		300°		330°

Table 3. Shows the equivalent degrees of the colour wheel for each of the notes in the chromatic scale.

By way of example, Table 4 gives the frequencies for natural notes C, D and E in octaves ranging from 2 to 8. The frequency at each point is a given, there is a doubling relationship between each octave of the same note and there is a relationship of 1:1.05946 from one note in the chromatic scale to the next (this is derived from a division of one octave into 12 chromatic semitones, each 100 cents). A function must be given that commutes each frequency of C to 0°, each frequency of D to 60° and each frequency of E to 120°. The same function must be applicable to all so that it may be applied to raw frequency to arrive at the appropriate hue moment.

Octave	2	3	4	5	6	7	8
Freq. of C	65.41	130.81	261.63	523.25	1046.50	2093.00	4186.01
Freq. of D	73.42	146.83	293.66	587.33	1174.66	2349.32	4688.63
Freq. of E	82.41	164.81	329.63	659.25	1318.51	2637.02	5274.04

Table 4. Examples of three frequencies in each octave from Octave 2 to 8 units in Hz.

3.4 Chromatic and non-Chromatic sound

This study sits between the scientific or measurable and the artistic or aesthetic. One can agree a numerical value for the frequency of a note or a co-ordinate for a colour in the HSB colour space, but the application of these in composition or visual art is a subjective pursuit. Two mediating considerations should be discussed regarding this principle before I explore any further into the assumed conventions of western tonality. Our tonality, of course, is not the only tonality and there should be room for the application of colour-sound within musical mindsets foreign to our own; both so that composers from other backgrounds may participate and convey their ideas freely within this artistic philosophy and also so that western composers are not limited by their own conventions. Already the consideration of this has begun in that I started my colour-sound association with a chromatic scale and not with a major, minor or any other particular mode. How, though, can a composer discuss equal temperament or tonalities that use microtones, or long slow glissandos for example? There needs to be some opportunity to divert from our twelve tones.

This is easily enough addressed by simply finding the colour moments between two

pitches. If the frequency of the note is a known element, as is the HSB coordinates of the notes around it, then it should be a reasonable step to find any frequency's colour, without the grid of 12 tones.

For the most part colour-sound composers will be looking for an appropriate note from the chromatic scale so, I focus my discussion on brightness and saturation variations of these given twelve hue moments. I only offer the user one of the colours that relate directly to the 12 notes of the chromatic scale. There should exist, however, an option to have '**No Tonal Frame'** allowing for a freely flowing pitch to colour correspondence. This would allow me to find the afore mentioned microtone midway through 'θ' in *fig 5*. Once devices are developed this must be a function of registering free pitch to a corresponding colour. The composer should eventually train their hearing and sense of colour to be able to do this. This should also apply to scanning a colour to hear a pitch in future devices and in the practice of the composer. With the tonal frame applied the device should offer the nearest tonal pitch, but with tonal frame disabled the device offers veridical equivalence.

4. A language for describing a spectral experience

Whether describing colour in sound and music, or describing sound and music; with coloured conventional scores, graphic scores, paintings or verbally – with use of colour related language to touch on aesthetic aspects of pitch, harmony, performance or experience – colour-sound is to be considered a tool to benefit the artist, not restrict them. It is a spectral language intended to describe spectral experiences. Thus, it may be considered for use in conjunction with or in place of conventional notation as the context, or preference, dictates.

In principle it is metaphorical, using one familiar experience to convey another less familiar one to the subject's audience or performer or another composer or to clarify for oneself or as a tool for learning.

Music is the abstract brother of speech. Speech may be just as artistic, it may even feature in music – as lyric or spoken word – and music may be designed to emulate speech or to imply meaning, but in nature it differs from speech in its inherent abstractness. That uncoupling from distinct meaning aside, it occupies in us a vital role, that is in some way tied to the intelligence required for, and functionality of, speech.

> Music and language are the two ways that humans communicate and express themselves through sound. Since birth, babies start to listen and produce sound without distinguishing between music and language, singing and speech. Thus, the close relationship between music and language development in early childhood is evident. (Chen-Hafteck 1997)

Chen-Hafteck (1997) argues that the first stage in the development of either process is the perception of sound. Later I encode meaning and categorise sound. To expand our expression of music, just as with speech, I must further my perception and understanding of sound, and extend my vocabularies.

I began with an anecdote that speaks to the virtue of encouraging all of society to feel entitled to music. In light of the idea that the development of musical understanding and vocal understanding are of the same foundation, that all society continues in their development of language – unless for some tragedy of neural disease or injury – then

nothing but a similar tragedy should exclude any from music.

> Languages differ in their phonetic repertoire, that is, in the set of speech sounds that are used to form words and thus to convey distinctions in meaning. Infants learn the speech sounds of their linguistic environment in their first year of life by attending to sound differences that are related to meaning differences and ignoring inconsequential sound differences (Seitz et al. 2010)

Seitz et al. (2010) explains that this leads to a better processing of speech sounds used in language and a poorer processing of other sound. Let us consider, then, the learning of colour-sound as a language, with an alphabet of pitch, words of chords and melodies, phrases and a written language of colour. Let us seek to understand the components of our coloured language of music, so that this develops for us as language does, as it should have done in infancy.

4.1 The coloured alphabet of pitch

The structure of our alphabet is different to English. Rather than 26 letters and a myriad of discrete symbols that imply grammar; I have twelve initial letters which can be uttered in eleven or twelve octaves, but are most commonly uttered in six (Octaves 1 – 6 inclusively which approximate from the lowest of a bass guitar to the top of a strong soprano voice). Drums and percussion punctuate and abstract meaning is found in antiphony, modulation and reprise.

5. Coloured harmony

The drive behind this project is the pursuit of harmony and tonality, both in vertical chords and horizontal in melody and tonality. A perfectly transposed tonality will have great mathematical similarity to the original, but an instrumentalist may have bias towards the comfort and playability of different keys or find different transpositions of the same intervals express different ways on different instruments and in different contexts.

A colour-sound composer might have a bias towards the appearance of certain keys, for their colours, even if they might have great mathematical similarity to other transpositions of the same intervals. This is not problematic, it encourages the composer to explore what is pleasing, it shifts their perspective on the relationships they observe.

5.1 Expounding a Harmony

Fig 5 is the photo 'b0' taken from the composition 'Self-Portrait on a Friday'. In this composition, I photographed all of the significant colours I encountered on a conventional Friday, I annotated them with patches of colour-picked significant colours and their corresponding notes and used the harmony of each image chronologically in a composition. The letter relates to the pitch within the octave and the number relates to the octave. I have not stuck strictly to the particular octave, rather I have used it as a rough guide as to which pitches should be higher or lower and if there should be large or small intervals in the harmony – as changing the order of notes drastically alters their intervals. C with an F above is a fourth, C with and F below is a fifth.

In this particular image, after I return from buying food at the supermarket, I photographed the frenzied colours of the packaging. *Fig 8* shows the notes I have assigned forming the tonality from this image.

Unlike 'Along the Dart' (Appendix B), wherein each image relates to a single bar of music, in 'Self-Portrait on a Friday' each image creates a tonality to be explored for some time. In the score for 'Self-Portrait on a Friday' annotations have been added noting when each photo's tonality begins. *Fig 6* is an illustration of the harmonic space is given, not a musical phrase itself and does not appear in this form in the score. It is helpful, though, when responding to the harmonic colour space of an image to see the

macrocosmic harmonic space it inspires laid out, especially when so much colour detail emerges from a single image (I will note this practice in the Methodology under the term **mapping the harmonic space**).

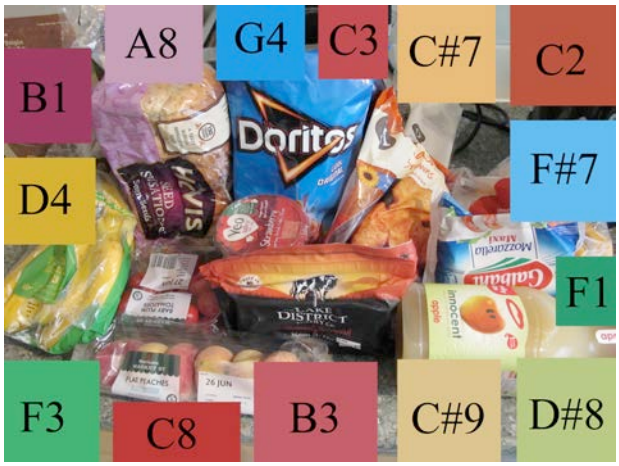


Figure 7: Annotated image (b0) from 'Self Portrait on a Friday'

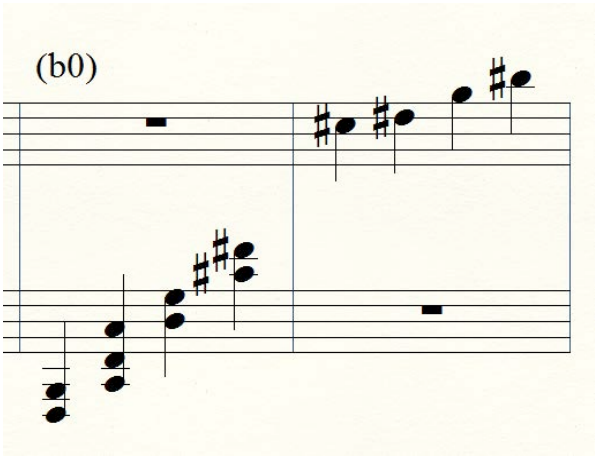


Figure 8: Tonality for (b0) displayed on treble and bass staffs

There are near infinite ways to respond to a tonality and in this way colour-sound association differs from sonification. Often sonification can operate like process music wherein a series of rules are created and then followed to the end. These rules form a process by which the presumably A-tonal output of a non-musical system is moved closer to the tonal, but I intentionally leave this open to the composer. Colour-sound association is a methodology for responding to inspiring aesthetics in an open and explorative way, not a prescriptive or reductive way.

In this response to image 'a5' from 'Self Portrait on a Friday' *fig 9*, the simple abecedarian colours of my tooth cleaning paraphernalia are responded to in a simple repetitive way. This pattern, *fig 10,* continues for four bars in total, creating a simple, pleasant tonal space – alternating between perfect fourths and fifths – but in a pattern, that is rhythmically cheeky, not a replication of the rhythm of my brushing pattern but a nod to it as a rhythmic event. If faced with a similar colour combination in another context I wouldn't respond in this same way as it is appropriate to this particular stimulus. That being said not every image warrants a unique rhythmic response, just that

when it does I need to be free to articulate it.

Figure 9: Annotated image (a5) from 'Self Portrait on a Friday'

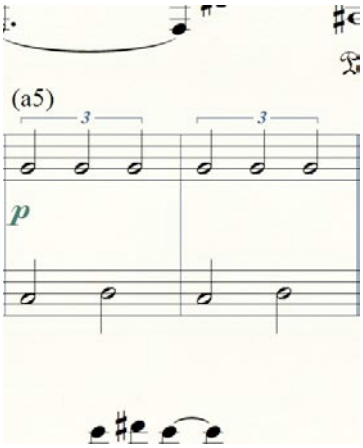


Figure 10: Tonality for (a5) displayed on treble and bass staffs

Often a location that a colour-sound composer might seek inspiration from will have a bias towards or away from darker or brighter colours. There is a danger that whole compositions might be lacking in some great region of the low, middle or high octaves. This will require further experimentation to discern, but this could be balanced by a clause in the Methodology that the composer retains the right to rearrange passages across octaves to their taste. Compositional licence – the risk here being that if a composer feels too comfortable to depart from the principles too readily, is there any conceptual validity to what they are doing? One will need to trust this to the judgment of the individual composer. For my taste, I would hope that an idiosyncratic quality of 'lacking' in a certain region of pitches would be part of the harmonic quality of the location and should be reflected as such in any composition about the colour harmony of a pleasing aesthetic location or point of inspiration. Perhaps it could be balanced in a subsequent movement by sourcing a location of inspiration with a different balance of pitch biases.

Experiments and Compositions

6. The harmony of great art

Here I have given some examples of experiments in testing my colour-sound association on the colour-harmony of well-known works of art. I have deliberately chosen those paintings whose colour pallet moves me; exploring their harmony in sound.

6.1 Son of Man – Rene Magritte - 1964

This tonality drawn from the sombre autumnal colours of Magritte's surreal 'Son of Man' is a lovely mournful melancholy chord.

A simple strong interval of a major 6^{th} - between D# and C - with high, glancing overtones of C# and G#. Clearly the colours of focus in the painting are the greens of the apple and the red of the tie, set against the background of the dominant blue sea and the pervasive extremely pale orange clouds. A passage from this painting should reflect that. A melody could borrow Cs, C#s, D#s and G#s from other octaves but the large interval between the source colours should be apparent. The lonely broad, sparse quality of colour here is influential in its implicit mystery. I spent about ten minutes experimenting with

these notes on the clarinet looking for combinations that sat well with my feeling of the painting. I would add into a score a direction to a clarinettist to play with a loose embrasure, lots of breathiness to address the soft misty clouds and vague sea, especially in those high, glancing overtones that represent those natural elements.

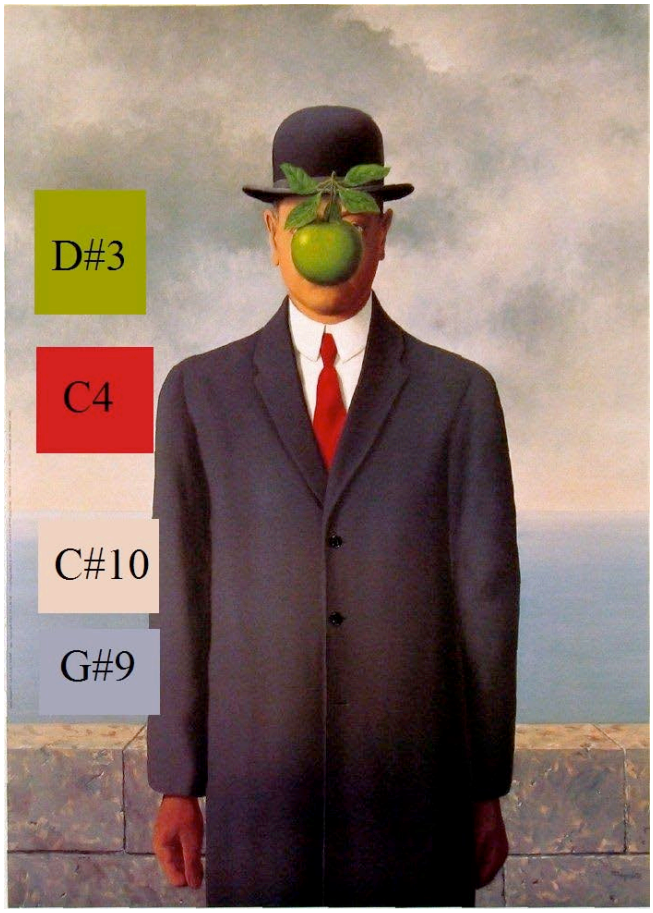


Figure 11 Son of Man, Rene Magritte (1964) annotated with key colour tonality

6.2 Café Terrace at Night – Vincent van Gough - 1888

I really enjoy the tonality of this painting as viewed through my colour-sound association. In colour, it is rich and bold, in sound it is also. The tonality changes as it ascends through the octaves, sitting on a low subtle F in the first octave, I think the F should remain in the low octaves. The feel of this painting is not predicated on sparseness – as in the case of 'Son of Man' – rather it is a loud drumming of colour, crowded and busy so I can afford to bring some of these notes together into the same octave. But clearly, the lower octaves are dominated by the blues and greens, and the higher octaves are dominated by the oranges, reds and yellows. Therefore, bass instruments should focus on a foundation of D#, G, F and treble instruments speak out B, D, and C#. A little room needs to be given between the voices of the dark and of the light to avoid clashing, but therein lies the fun of the tonality.

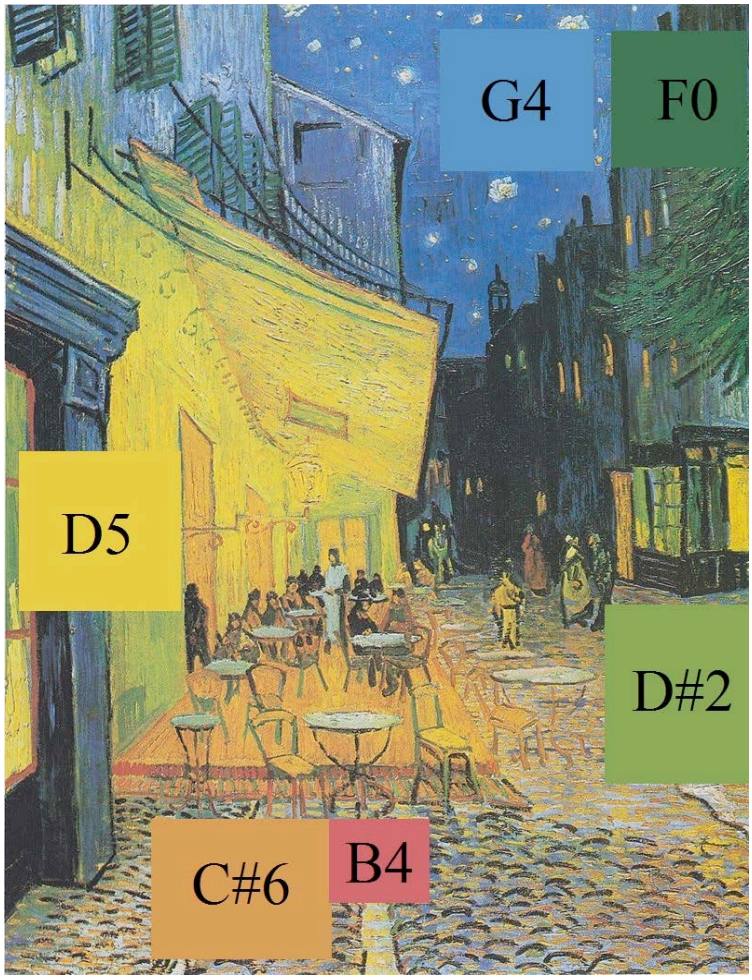


Figure 12. Café Terrace at Night, Vincent van Gough (1888) annotated with colour tonality

6.3 The Dance – Henri Matisse 1909

This is an interesting painting for its narrow and wilfully flattened colour harmony, virtually only three colours have been used and any subtle variation is due to brushstroke and articulation, not hue.

It makes for a limited, close phrase, quite different from the richness and depth of van Gough's Terrace. I would want to write some antiphony, some cannon, to reflect the dance, but I couldn't sustain a passage of music for very long drawing harmony from this painting. It could, however be part of a wider narrative. Considering this painting I would like to string a series of works by unrelated painters together, perhaps some bold and brash landscapes and woodland scenes that led to this secret little event of

womanhood. Perhaps the narrow tonality of this image would provide respite in an otherwise dense piece, drawing attention to the covert incident.

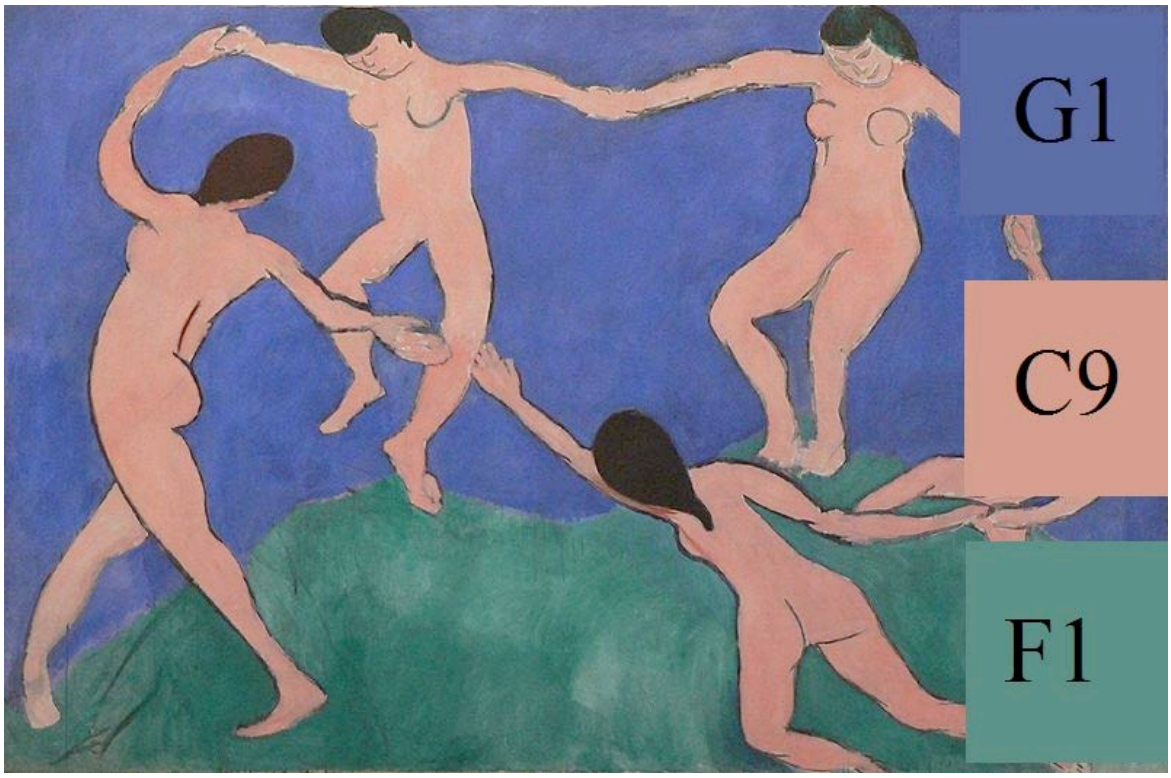


Figure 13 The Dance, Henri Matisse (1909) annotated with colour tonality

6.4 The Persistence of Memory – Salvador Dali 1931

The musical harmony of this painting feels very close to me feeling about it in the visual spectrum. The persistence of the C#s and Gs in each octave and the intervals between these is so haunting and foreboding. A semitone and a tritone, fantastic! I'm very glad this is what the painting sounds like through my colour-association. The apparent vast richness of this stunning work is built all on different tones of three colours – just as in the case with the Dance, but with but with far greater breadth in result – one cannot immediately know what is so strange about the colours.

Although it also rests on only three colours – just as did 'The Dance', I feel like I could take much more time exploring them.

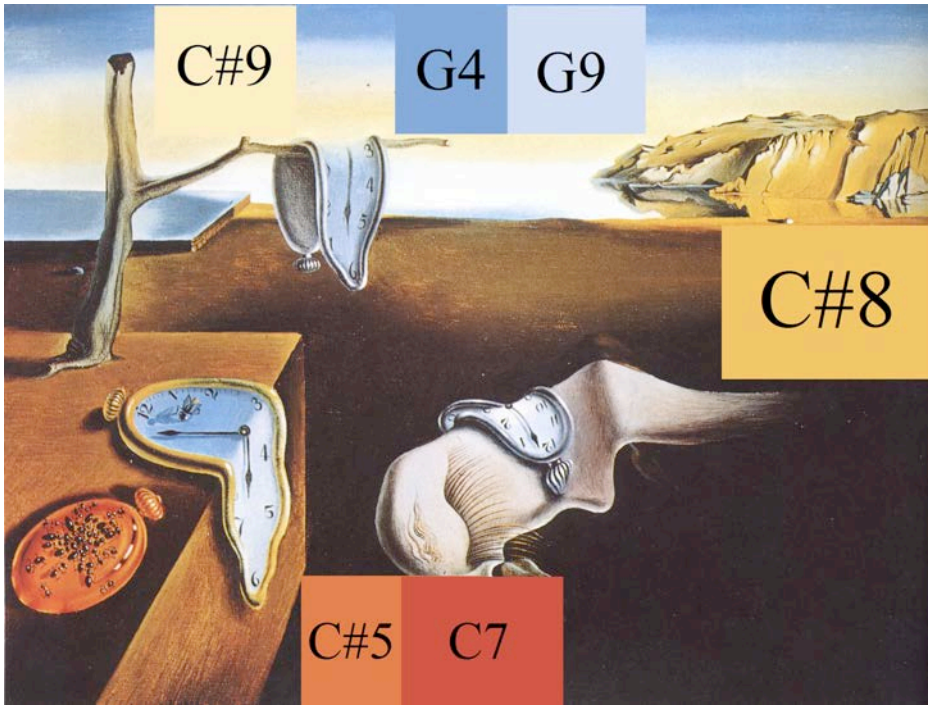


Figure 14 The Persistence of Memory, Salvador Dali (1931) annotated with colour tonality

7. Colour-Sound Walks

The process of collecting colours to inspire compositions is a physical exercise with practical concerns and unknowns, more than the normally intellectual process of conventional composition. One must venture into the colour-world and inspect exactly what colours exist there. I had ideas about what I would find in each of my locations, but it was only on exploring them with colour at the fore of my mind that I discovered what harmonies I was working with. I adapted my colour collecting practice with each investigation. I began with a walk along the River Dart.

7.1 The Colours of Life and Fiction

'The Colours of Life and Fiction' is a composition designed to respond to the Peninsula Arts Festival title for next year, 'Life', I saw colour sound as a good venue for an exploration of this very open theme. I decided to take a walk through two natural spaces – along the River Dart from Totnes to Staverton Bridge and across Dartmoor. The focus was to be on the colours on those colourful examples of nature I found. The Fiction element in the title was that I intended to use medium format slide film for this walk, double expose and cross process (C41 as opposed to E6) some of these images, so that the early frames are natural, but the later images become more distorted and unreal. Film photography is a slightly temperamental medium, prone to exciting mistakes and bursts of colour originating from accidental or unknown origins. I relished the potential for these unnatural moments while exploring a natural space. Upon experimentation, I found 120 E4 film to be cumbersome and expensive, if the slide was the end of the exercise this would be fine, but merely as a vehicle for collection of colour it is inappropriate, thus I will continue these exercises with a Cannon G11 DSC.

7.1.1 120 Slide Film Along the River Dart

The first thing that struck me on this walk was the vast amount of green. I undertook the journey on a sunny day in May and the plant world was at a peak of bloom. I was aware of roughly what plants I would encounter as I traversed the area, but I was surprised by how much repetition of colour I found. Firstly, there were the various greens, which I would interpret as various octaves of D#, E and F (see section 3.3 Correspondence) but also there was a particular yellow that showed up in many different, unrelated flowers. The particular yellow, found on buttercups and dandelions, I would attribute to a particular octave of D, resulting already in a cluster of chromatic notes from D to F as a

significant feature of my harmony. A dense area of chromatic notes like this makes for an unusual tonality. There was also a great prevalence of a particular blue and pink, the pink being, in my colour-sound association, to A# or B. I found that animals were difficult to capture and yielded less colour than plants in this location, so I focussed my attentions on flowers, lichen and leaves. It would be very interesting to trace the same walk
in different seasons for different musical movements in different colour tonalities.

Tonality (with intervals) of; A#, (1) B, (3) D, (1) D#, (1) E, (1) F, (1) F#, (1) G, (3) A#
9 note octave with areas of chromaticism and large steps

Although the mystery of the 120 slide-film was exciting and the potential for indeterminacy appealing, it was slow and cumbersome, and I am now faced with a wait until they are developed and delivered by post. It also poses a further consideration of colour bias; in the Methodology, I discussed 'Veridical Light Source', 'Individual Retina Bias' and 'Human Retina Bias' as factors affecting one's perception of veridical colour. Adding the dimension of film chemistry indeterminacy, I add another layer for consideration. I will consider the slide film walk as a reconnaissance mission, I will redo the walk on a day with similar light and try to recapture the same hue moments and tonality with a digital stills camera.

7.2 Digital Along the River Dart (Appendix A)

My second attempt at a River Dart colour walk and subsequent composition was very informative in terms of practice. I set about trying to pin down what it was I was capturing, I was able to edit the photos easily to highlight the colour moments involved and to reference them easily when composing.

Immediately, using a digital stills camera stood out with the advantage of being able to check how the photograph had come out in the moment. I could assess if the image I had taken matched my veridical experience in the moment. If the angle at which I had taken or the settings of the device were off I could immediately adjust and retake under the same conditions, whereas with chemical photography I would need to wait until

after the processing by which time light conditions would have changed, so there would be no chance to retake.

I was able to focus my attention on the task of ‘colour hunting’. The environment was dominated by a limited number of greens from all of the foliage, the blue of the sky and of the same reflected on the river. I wasn’t interested in a bi-tonal piece of music and so, although I made sure the greens and blues were represented, focused my attention on those colours that diverged from this. I found a reoccurrence of certain reds, yellows, blues and pinks in the flora and this gave me the mainstay of my harmony throughout the piece. Yellow flowers of differing species seemed to present the same exact tone as a buttercup, this particular hue of ‘D’ featured often. Fauna was much more difficult to capture; I saw, but was not able to photograph, butterflies and a kingfisher, and although I was aware intellectually that the buzzards were brown, they appeared black when viewed from below. This walk, then, became a tonal catalogue of the plant life of the Dart. In other seasons larvae would offer other varieties of colour and in other geographical locations a wholly different colour-harmony would be on offer. I considered recording and transcribing the birdsong I heard on the walk but at this stage it was practically complex and conceptually muddy to split my focus this way. The resultant harmony didn’t sound like the hot, pleasant and overall jolly afternoon, but I had not expected it to. After all, those elements which conditioned my mood on the afternoon were multifaceted and not overarchingly related to colour. The regularity with which the colours related to each other did, however relay a regular tonal sound experience that I was most pleased with.

The main influence on the colours present were the environmental influence over which plants may thrive, including what minerals where present in the soil, the presence of water and cow dung and sunshine. These factors affected the entire environment and so resulted in a similar harmony. If, along my journey, I had changed to an urban environment, or the brackish or saline environment of the coast, I could well expect the tonality of the plant life to change, perhaps dramatically as a key change. As it was, the result was a pleasant, albeit a harmonically static composition.

7.3 Descending Totnes High Street (Appendix B)

Whereas the main influence over the colour-tonality along the Dart was the environmental influence on flora, the key factor on colour, while descending Totnes High Street was the choices of the shop owners there. Once might expect this to result in an almost random scattering of unconnected colours but actually that community of business must exercise some influence over each other in some way – either deliberate as part of some business community agreement, of simply trends emerging from fashion or from observing pleasant colours in their environment. Either way the resultant colours available in this environment were regular but not repetitive. There was a clear harmony with some harmonic movement during the piece. I operated in the same manner as 'Along the Dart', photographing, picking out the major colours of influence in each case and then notating tonal phrases, freely into a notation software. Afterwards my editing of dynamic, ornamentation and expression was led by my own aesthetic choices.

7.4 Self-Portrait on a Friday (Appendix C)

For this composition, I collected colours I encountered, with a digital camera, over the course of a normal Friday. This included my bed, soaps and shower gels used, my breakfast (like a hipster on Instagram) and books I read over the course of the day. I included Shabbos candles and a period of silence as the sun went down. As I was working from home there were fewer photographs with richer ranges of colour in each case than those that made up 'Along the Dart' and 'Descending Totnes High Street', so instead of attributing one photo to one bar of music, each photo outlined a harmony to be explored for an indeterminate number of bars – more for more tonally rich images, less for those too simple to sustain a motif for long – I found this a more satisfying methodology than the previous compositions. Certainly, the option to reflect the chronology of the day in the chronology of the harmonies was satisfying especially when it came to the unusual period of silence at the end of the piece. To underline this feature, I included an instruction for the performer to light two candles during the silence having the dual intention of raising an enigma about the event and also giving

the audience something to focus on when experiencing the quiet. Often an audience faced with quiet will assume the piece has ended and applaud, but on seeing the pianist stand and light two candles they will likely wait for a further signal as to the end of the piece. This is of great importance as a composer is not often able to use silence greater than is proportional to the patience of those listening. A further benefit is that I am able to tie the conceptual impetus for the silence into the silence of the performance.

8. Discoveries and Principles

The purpose of these early colour-sound experiments is to test methodologies, while under scrutiny, that will evolve into an art practice for use while I, and those compelled by it, are composing in the future. I have attempted in the Methodology below to note the practices most pertinent to the future colour-sound composer. Core principles of purpose and method are implied from the successes and failures of experimentation. They are the 'laid table' of colour sound. They are all either derived from my experiences writing colour-sound scores for this project or from the work and principles of influential composers affected by colour-sound association in one form or another.

8.1 Practicalities Derived from Experiment

The colour score: Would colour help the composer convey tonal and experiential ideas to the performers? If not, if it is not beneficial, do not include it. If the performer wishes to participate in the colour-sound experience, do so. Teach them what the colours mean, add as many sensory clues and queues as would benefit the performer and no more. Clarity is of paramount importance.
If the performer is a synaesthete, or if they have their own colour sound associations, endeavour to transpose the score to meet their association, just as you would do with a transposing musician such as a clarinettist or euphonium player.

The colour performance: A colour-sound musician, when constructing a performance from a colour inspiration source, should try and build in performative elements that imply the original conditions. There is great room for interpretation in this. If the original environment explored was cold and wet, could the air conditioning be adjusted to convey this experience? If many photographs were used to capture the original colours of the inspirational environment, could they be projected, or wall mounted in order to help the audience experience a fuller knowledge of the composer's experience? If recordings were taken, will they feature in the performance also?

The colour audience: share colour tonality with the audience to the extent that it will improve their experience and understanding of your composition and no further. If,

artistically speaking, you feel it would only serve to irritate or confuse a new audience, then feel free to exclude them from your process. However, if their experience would be enriched by any of the parallel-sensory elements of your practice, include them. Of course, any audience is not monolithic and any decision is a risk, but you're the artist, your choices are your art.

8.2 Hopes for future work

The next stage of this research will be to create a system for using colour-sound as an educational tool, introducing a colour-sound association at the beginning of a person's musical education so that not only are they as familiar with each as with the other, but also that their daily colour experiences will be constantly reinforcing their musical sensibility. Once indoctrinated with a colour-sound frame of mind they won't help but know the musical key of their cereal packet or the flowers in their back garden. Every walk in the country will be a musical journey – as is the case with natural synaesthetes – so that the subject becomes both a colour expert and a sound expert.

9. Methodology for Colour-Sound

The process of investigating the merits of colour-sound evolved into a methodology itself. Beginning from the visual and taking aesthetic, silent colour material, passing it through the composer's ear and responding to it in musical composition is the primary methodology that resulted. If this were to become a manifesto of a new art, it would require respondents from different practices to argue and add their versions of colour-sound or at least methodologies more applicable to, say sculpture, painting and film.

But for my part, the primary composer's methodology includes the formation of a colour-sound association and its application to colour stimuli:

- Design new colour-sound association or describe and existing one
- Map and test this association, justify it and explore it in a comfortable environment
- Explore contrasting environments using the same colour-sound association and compare the results from each. What is to be discovered.
- Submerse yourself in the association.
  a) Try to note aural experiences in colour and
  b) when struck by dramatic colour experiences try to replicate them in sound.
  the former will require a notebook and colour pens or paints (available always)
  the latter will require some sort of portable instrument – even an instrument app will suffice – to allow yourself to hear the notes in the moment.
- In turn, this will require the memorisation of the association. In my association, for example, all bright yellows are D natural. Every time I see a yellow I am compelled to experience and appropriate D natural aurally. It should become pavlovian, and hopefully, eventually internalised so that the mind may imagine the note without tools.
- Even if you do not discuss the association, consider it in all artistic pursuits. Know what the association of each artistic expression would be, even when you choose not to share that information.

There are principals, perhaps a culture of ideas and expressions that should inform the colour sound artist and I consider these to be part of the methodology. The

following ideas are philosophies of the colour-sound artist.

Multidirectional artists

The colour-sound artist is concerned with the border between the sound experience and light experience. They may be a visual artist drawing inspiration from the world of sound, a composer drawing inspiration from the world of colour or a mixed media artist drawing both together. They establish a correspondence between elements in each, and create art by moving information between the two.

Choice of language

Their colour-sound association may be that which I have provided, or their own – based on internal biases or experience – but the association is to be logical, considered and internally consistent. Once they have established their association they are to be loyal to it.

Conceptual integrity

The colour-sound artist considers the association at each stage of the artistic process; inspiration, concept, experimentation, implementation, performance or installation, and the experience of the audience. Even deciding to exclude colour-sound from any or many of these stages is a consideration. But it is only a work of colour-sound art if the consideration clearly guides or defines at least one of these stages.

Tools and senses

The colour-sound artist may develop tools or technology to help them explore their colour-sound association; programmes, apps or devices, but they should also endeavour to internalise this process – either through ear and eye training or by becoming a cyborg – so that it effects the way they work, think and experience the world even when they are not actively engaged in art. It is to become a part of their experience.

Internal consistency

The colour-sound composer can use the colour-sound association presented here or form their own, but once formed they should remain faithful to their association, not changing their own rules to suit a certain piece or movement. Internal consistency is one

of the essential, non-negotiable, principles of colour-sound as derived here from synaesthesia. If the composer takes time to form their association, with iterative experiments and evolutionary formation of a colour language this is perfectly acceptable, of course, but once they form a system acceptable to them, they should be faithful to it.

Inspiration not musification

The colour-sound composer takes inspiration from the harmonies of the colour world, or perhaps transcribes colour environments into music, but they are not confined to the truth of the situation. This means that if their environment is skewed by dull or offensive sounds they should feel free to ignore these in favour of those colours and harmonies that attracted them to the environment in the first place. That being said, they should not invent colours, tones or motifs but adhere to what is available to them from the pallet of the colour world. This could poetically be described as 'telling the truth, but not necessarily the *whole* truth'. Whereas the *sonifying or musifying composer* must create rules of translation to convert data into palatable sound or music and then adhere to the behaviour of the data, the *colour-sound composer* goes hunting for harmony in strange new frontiers and capturing them. They are less bound to a certain source or to include the ghastly.

Mapping the harmonic space

When transcribing the colours of the inspirational material – be they sourced from an environment or a painting or any other text – the colour-sound artist should map out the harmonic space and consider it. For example, if the source image contains mostly dark greens and one extremely pale red; does one need to stick to the exact octave of the source colours, or is it enough to have a colour space grounded in low D#s, Es and Fs with some high C. Perhaps it is the shape of the colour space here that is important rather than the exactness of the dimensions. Does the frequency of each occurring note matter; does the order if they are not chronological at the source? The colour-sound artist will need to answer this for themselves in each case, but it should be an important part of their practice to consider the harmonic space offered by the source of inspiration.

Colours of 'life' and 'fiction'

When drawing inspiration from the colour world, the composer should consider the two

categories of source material as being ‘the colours of life and fiction’. In the immediate sense, it might appear that the colours of life refer to the colours of nature, and fiction refers to those colours emerging from human influence, but it would be better to consider these categories as referring respectively to those colours occurring naturally in an environment or those occurring due to deliberate choice. Exceptions to the rule of nature versus human influence will prove the rule:

Whereas plants growing wild on a heath may be considered ‘life’, those chosen deliberately for a manicured garden may be considered fiction. Whereas packaging designed to appeal to a consumer and chosen for a supermarket may be considered ‘fiction’, sea glass scattered on a beach may be considered ‘life’. Whereas a colourful bird in a dull nest of sticks and down may be considered ‘life’, and a bowerbird who designs his display with agency may be considered ‘fiction’ (in that it has been constructed deliberately by someone other than the composer with aesthetic in mind).

The composer should decide, before they begin to collect the colours that will form the basis of their work, whether they will collect colours of ‘life’, ‘fiction’ or both and in this decision, what will be the conceptual effect of their choice.

Practices of a colour-sound composer:
Colour and Sound as inspiration: In an inspirational environment, any inspirational sensory experiences should be considered, be prepared to take notes, recordings, photographs. Notice the sounds, sights, smells and location, even the time of day and year and of the weather. The colour-sound composer is not trying to recreate in the environment in any *realist* manner, but is trying to convey the feeling, the sensation of the moment of inspiration. The primary factors of influence are colour and sound, as the two overwhelmingly spectral experiences, but do not limit yourself to these.

The experience of the composition in the performance: The colour sound composer is endeavouring to communicate abstract ideas and experiences to the audience. If the composer is taking inspiration from their senses, they need to understand what they are experiencing. The perfect colour-sound performance will convey the state of mind of the composer in the moment of inspiration, all performances are an imperfect attempt to approach this. The colour-sound composer must decide if they want to involve the

initial colour in the performance or just the sound it inspired, after all the audience's response to such a colour may differ from that of the composer and so convey an inaccurate experience to the audience of what the composer felt.

To a finer degree, but in a similar ilk there are terms, definitions and considerations the colour-sound artist should be familiar with when describing their practice or communicating with other colour-sound artists. The following are a glossary of terms that evolved from the research of this paper. I consider them also to be a part of the methodology of the colour-sound artist. The following ideas are the language of the colour-sound artist.

Internal Consistency; Once established the artist should maintain a consistency in their colour-sound association. The integrity of their colour-sound is based on the consistency of their association more than their reasoning for their association – although both are important.

Veridical Light Source; The artist should be conscious of how the environment affects colour – in particular the effect of the colour balance of the light source. They should not assume colour is a constant and make their colour choices in their inspirational environment or from their source material in the knowledge that at a different time of day or under different lighting the colours will be other.

Individual Retina Bias; Different people experience colour slightly differently; the artist should recognise their audience or peers will have a differing experience of colour.

Human Retina Bias; Colour is not a mathematical truth and the architecture of the human eye does not process colour as other animals do. The artist should consider that 'true', 'veridical' or 'mathematical' colour is hidden from the human experience.

Dimensions of colour;
Hue; colour disregarding brightness and saturation, the frequency of light produces hue.

Saturation; The density of hue as offset by white, paleness, ranging from saturated (full colour) to desaturated (white)

Brightness; The density of hue as offset by black, darkness, ranging from bright (full colour) to dark (black)

Hue Moment; Actual colour, the result of all three of the Hue Saturation Brightness values.

Dimensions of sound;
Frequency; number of oscillations per second as described in Hertz. A mathematical description rather than musical.

Amplitude; loudness.

Timbre; the resultant shape or quality of a note as described by the 'attack', 'sustain', 'decay' and release of not only the fundamental pitch, but also of its overtones (from the harmonic series). A colour sound composer should be conscious that any note other than a sine wave is a chord of related pitches. They should decide if they want to convey this in their work.

Note; The musical reference to frequency as limited to one of the twelve tones of the western scale or to one of the named notes of other tonalities.

Interval; The space between two notes. As an individual note derives a quality from its timbre, two or more notes derive their effect from their relative positions to each other. The colour-sound artist should consider how the intervals between colours relate to the intervals between notes.

Octave; Notes have a special relationship to those other notes that are multiples of, or factors of, their frequency. They share the same name and, in colour sound, the same hue. Frequencies of 65.41Hz, 130.81Hz and 261.63Hz are all described as 'C' and in colour sound are all variants of the hue of red.

Considerations of correspondence;

C♮ as Red; If the colour-sound artist uses the association suggested in this paper, or creates a *sequential* association for themselves – rather than using an internal association that results from synaesthesia – they need to choose a start point for their scale. C♮ is the logical start-point as the most common first scale for a new musician. This paper argues that if it is the starting note and most musicians learn to ascend a scale before descending one then C♮ should be associated with the lowest visible light frequency – Red. The colour-sound artist is welcome to argue for their own association here but it is a common and logical association.

Intra-Octave Hue; Notes within an octave – ranging from C to C, are signified by colours ranging from red to red. Each 12^{th} fraction of the octave is a 12^{th} of the colour wheel.

Inter-Octave Bright/Sat; if a note is signified as C by its red hue, it is signified in its respective octave by its balance of brightness and saturation:

Dark saturated colours represent low octaves,

bright, saturated colours represent middling octaves,

bright, desaturated colours represent high octaves, and

dark, desaturated colours are placed by the bias of the composer.

Considerations of concept;

Compositional Licence

No Tonal Frame; The assumption is that, for the most part, the colour-sound composer will operate within the 12 notes of western tonality. At those times when they diverge from this system this is signified as having 'no tonal frame'. They are working with frequency rather than notes, with sound rather than music. They should be clear about this in the presentation of the work. They will have a free, spectral use not only of sound but also of colour.

Life; source material which is naturally occurring rather than deliberate. This might include colours from nature, chance coincidence of disparate elements such as colourful refuse in inappropriate contexts, food which has not been planned with colour in mind, any situation wherein the colour has come about without deliberate agency or design.

Fiction; the counterpart to life, responding to the colour of the agency of others be that elements where colour has been a primary factor – such as paintings or the work of any designer or artist – or a secondary one - such as informal clothing – even from a standpoint of non-human agency – such as bowerbird displays or AI design.

10. Conclusions from Colour-sound

Participants in a study (Lindborg & Friberg 2015) were asked to match colour patches to varying example sine waves. The results confirmed a hypothesised correspondence between light intensity and pitch, and between colour hue saturation and loudness. There was a response common to all participants about what intensity of light should match a pitch, and that the intensity should increase as pitch increases. There was not, however a particular common association with hue. Hue, it could be argued, is free to be assigned to specific pitch.

I established that the colour association of synaesthetes may have a lot to offer to artists in general, not just in terms of source material for inspiration, but also there is a possibility that long term categorisation of one sense via a second may result in expertise in navigating harmonic relationships. As a longitudinal study requiring many participants, that was outside of the scope of this project. However, in the duration of this project it was possible to investigate what a logical association might look like, what would be required of a colour-sound association, as a precursor to a more profound study. This study found that the element common to all colour-sound synaesthetes was not the particular association they exhibited, but rather a high level of internal consistency. Therefore, when constructing a colour-sound association, the subject may create an association which is logical to them, if not to others, so long as once created they remain faithful to it.

Certain principles emerge naturally for a genre of art inspired by synaesthesia, certainly the idea of submersion in sound by an association with colour encourages the exploration of new strange harmonies in a way that would be commonplace to synaesthetes but new to neuro-typical musicians. For a clear scientific theory to emerge fair tests will need to be developed, but there is a roadmap for that in this project. This was an opportunity for me, as a composer, to consider the existing research on synaesthetes and, at the same time, but in a different channel, the work of colour sound composers and artists. Considering this I developed principles to explore through composition.

Different source materials produced differing tonalities, certainly unlike conventional

classical tonalities, but a tonal harmony space that could be explored musically to pleasant musical result. In so much as the number of colour tonalities used as source was too narrow, finer principles could not yet be derived as to how differing sources produce differing tonalities. For example, if a forest space changed harmony over the seasons, or simply key – i.e. did the pitches shift evenly, leaving the intervals a constant or where the intervals warped by the shifting colours? - or if natural spaces vary in a regular way from environments wherein all the colours are selected by human design. If submersion in colour-sound association did result in colour and sound expertise these subtler ideas of varying harmonies in varying environments may be further clarified by the increasing perception of the subject. As to the benefits of further submersion in a combined colour-sound world, by means of device or programme, this would need to form a larger study with multiple participants and a control group.

The study yielded a strange new pattern of tonalities with form and shape, but one which doesn't repeat within each octave, instead it often yielded wide open intervals in some ranges and dense or even chromatic clusters of notes in other areas. Certainly, I can conclude that what I find beautiful in music does not directly resemble what I find beautiful in colour when the two are translatable. But it does yield harmonies which are aesthetically rewarding in new ways. I am keen to explore these new tonalities further and will be composing for a small exhibition of music at Plymouth University next spring with the results of this project.

These new tonalities are not necessarily a-tonal – or chromatic – but rather are macrocosms of harmony across the whole of the audible spectrum. Of course, a person who develops a different, perhaps even less systematic colour-sound association would yield different exact tones of association, but the shape of these larger harmonies would be similar in differing associations in that their irregular and unbalanced tonality would still be present in very similar forms.

As these tonalities are quite new to the ear conditioned by Northwest European tonality, this calls for patient, spacious compositions at first – as with the work of Morton Feldman – wherein the harmony itself is the subject of consideration, until such time as these harmonies would become so familiar, a short hand of colour-sound, that they could be danced across with pace and subversion. Just as Jazz, in its inception, needed

first to establish its rules and then bend and erase them, I have found, for myself, a new area of music I am eager to pursue.

In my next study of colour-sound the focus will be on pinning down methodologies most pertinent to submersion in colour-sound association. I will be working with cyborg artists to develop colour-sound as an artificial sense or synergy of senses, so as to reap the benefits that the synaesthete does. I will explore those technological tools hinted at in this project and develop the fair testing mentioned in this conclusion. Considering these patterns of colour-sound association has opened a new realm of artistic philosophy, but without constant reinforcement at point of sensory experience I do not foresee the subject would ever fully integrate the association into their practice. I am, though, at a stage of technological development wherein this might be achieved.

Research Questions:

- Can a non-synaesthete create a colour-sound association for the benefit of music composition?

In section 1.5.2, I discuss how there is some debate within musical academia as to whether Scriabin was a true synaesthete or simply undertaking a deliberate colour-sound association of his own design. Further, I make a brief case in section 1.3 for the unnatural synaesthete. On the whole, I found the product of this project, the scores to be performed in Spring 2018 in Plymouth, to be a case in favour of a non-synaesthete colour-sound association. In these brief, practical experiments I was able to make tonal products of a silent source.

- What principles must be considered for this association to be viable?

For my own benefit, I wanted the association to be sequential and perhaps spectral where possible to emulate the nature of analogue sound. It is my understanding, however that this is not as integral as internal consistency of association. In section 1.3.1 I discuss how this is the main unifying component to all synesthetic experience and that synaesthetes benefit artistically from their association regardless of whether they agree what particular colour should be result from a certain sound. Even within families of synaesthetes – even amongst twins – associations can be quite different, but

a highly acute sense of both hue and pitch awareness will likely result. Although this colour and sound expertise has not yet resulted in the immediate for me, my suspicion is that constant exposure to colour-sound association would result in increased pitch and hue expertise. This will be the basis for a subsequent investigation.

- Will the product of said colour-sound association be tonal without excessive interference?

The product of my experiments was tonal, but not a tonality we are generally familiar with. For example, 'Along the Dart' (which can be found in appendix A.a in score form or on the accompanying CD as a midi representation) was drawn from the colours occurring naturally along the river dart. Photos were taken where interesting colour combinations stood out. Certain colours occurred often, due to environmental factors, and resulted in a reoccurring harmony in certain areas. The resultant tonality did not resemble the major or minor scales of European classical music, yet there was a clear enough pattern of familiar intervals that the audience could easily become accustomed to the movement of the notes. This piece is discussed in 7.2 and the rest of the compositions are discussed more widely in section 7. as a whole. There is also a discussion of the tonalities resultant from paintings in section 6.

- What are the potential benefits of a colour-sound association methodology in art?

Within this project I found myself constantly evaluating the relative key and tonality of environments I was in, it encouraged me to be thinking musically even when no apparent music was present and in turn that allowed me to produces a series of compositions for small ensembles very naturally. Once I had established a methodology to follow, the process of composing the music of an environment flowed well. I see this new field of inspiration as being of direct benefit to the composer. To any musician who develops a colour-sound association there is the potential for being submersed in music as much as they are submerged in light. There are two questions, prompted by this project, that will guide the next stage of my research. The benefits of a real aural response to colour and a real colour response to sound. Throughout this paper questions were raised about the potential of a portable computing system that could act as colour translator. I was also conscious that constant submersion in sound might be a factor in the synaesthetes mastery of colour and sound expertise. Therefor my two questions for the next stage of my research will be:

- Would a portable or wearable device that translates between colour and sound be of benefit to the colour sound composer?
- Would a constant, artificial colour sound association – by way of portable device – result in the same cognitive benefits for the non-synaesthete as a neurological synopsia does for the synaesthete?

References

Bernard, J.W. (1986) ‘Messiaen’s Synaesthesia: The correspondence between color and sound
structure in his music’, Music Perception: An Interdisciplinary Journal, 4(1), pp. 41–68

Bor, D., Rothen, N., Schwartzman, D.J., Clayton, S. and Seth, A.K. (2014) ‘Adults can be trained to acquire Synaesthetic experiences’, Scientific Reports, 4, p. 7089

Cytowic, R.E., Eagleman, D.M. and Nabokov, D. (2009) Wednesday is indigo blue: Discovering
the brain of synesthesia. Cambridge, MA: MIT Press.

Chen- Hafteck, L., (1997) Music and Language Development in Early Childhood: Integrating Past Research in the Two Domains, Early Child Development and Care, 130:1, 85-97, DOI: 10.1080/0300443971300109

Dworak, P. E., (2009) “Color Harmonies and Color Spaces Used by Olivier Messiaen in Couleurs de la cité céleste” University of North Texas Press

Galeyev, B.M., Vanechkina, I. L., (2001) Was Scriabin a Synaesthete?, Leonardo, Volume 34,
Number 4, August 2001, pp. 357-361 (article) MIT Press

Galeyev, B.M. (2007) ‘The nature and functions of Synesthesia in music’, Leonardo, 40(3), pp.
285–288

Galkin, E.W., Messiaen, O. and Satterfield, J. (1957) ‘The technique of my musical language’, Notes, 14(4), p. 575)

Gravesen, J., (2015). The metric of colour space. Graphical Models 82 77–86

Harrison, J. and Baron-Cohen, S. (1994) ‘Synaesthesia: An account of coloured hearing’, Leonardo, 27(4), p. 343

Lindborg, P., Friberg, A., (2015) Colour Association with Music Is Mediated by Emotion: Evidence from an Experiment Using a CIE Lab Interface and Interviews, PLOS ONE, December 7, 2015, creative commons

Lourde, M, R,. Saji, A, K,. (2009) A Digital Guitar Tuner, International Journal of Computer Science and Information Security, Vol. 6, No. 2, 2009

MacAdam, D. (1951) Quality of Color Reproduction. Proceedings of the I.R.E., 39(5), pp.468-485

Messiaen, O., Watts, H., (1979) Canyons, Colours and Birds: An Interview with Oliver Messiaen, Tempo, New Series, No. 128, pp. 2-8 Published by: Cambridge University

Press Stable URL: http://www.jstor.org/stable/946059 Accessed: 11-07-2017 10:13 UTC

Peacock, K., (1985) Synesthetic Perception: Alexander Scriabin's Color Hearing, Music Perception, Summer 1985 vol. 2, No. 4, 483-506 University of California

Poast, M., (2000) Color Music: Visual Color Notation for Musical Expression, Leonardo, Volume 33, Number 3, pp. 215-221 (Article) Published by The MIT Press

Pritchard, J., Rothen, N., Coolbear, D., Ward, J., (2012) "Enhanced associative memory for colour (but not shape or location) in synaesthesia", Cognition 127 230–234

Ramachandran, V.S. and Hubbard, E.M., (2001). Synaesthesia - a window into perception, thought
and language. Journal of consciousness studies, 8(12), pp.3-34.

Seitz, A.R., Protopapas, A., Tsushima, Y., Vlahou, E. L., Gori, S., Grossberg, S., Watanabe, T., (2010) 'Unattended exposure to components of speech sounds yields same benefits as explicit auditory training' Cognition 115 pp.435–443

Stuckenschmit, H., (1973) Twentieth Century Music, New York, NY: World Univ. Press Library p. 229.

Terhardt, E., Seewann, M., (1983) Aural Key Identification and Its Relationship to Absolute Pitch, Music Perception, Fall 1983, Vol. 1, 63-83 University of California

Triarhou, L., (2015) 'Scriabin For Neuroscientists'. Constantinos. 1st ed. Print.

Whipple, G.M. (1900) 'Two cases of Synaesthesia', The American Journal of Psychology, 11(3),
p.377.

Watson, M.R., Akins, K.A., Spiker, C., Crawford, L. and Enns, J.T. (2014) 'Synesthesia and learning: A critical review and novel theory', Frontiers in Human Neuroscience, 8.

Wierzbicki, J., (2012) 'Shedding Light on the 'Colour Music' of Sydney 's Alexander B. Hector', Musicology Australia, 34:1, pp. 81-99, DOI: 10.1080/08145857.2012.681622

Yastrebtzev, B. B., (1958) 'Nikolai Andreyevich Rimsky-Korsakov: Reminiscences', Vol. 1, p. 176 (in Russian). [Translation found in Galeyev, B.M. (2007) 'The nature and functions of Synesthesia in music', Leonardo, 40(3), pp.285–288]

Images

Anon (2017) A representation of the HSB colour space: Hue is represented as degrees of the circle. Saturation is represented as percentage from the de-saturated centre of the circle. Brightness is represented as vertical percentage towards black. Web. Accessed from [https://www.script-tutorials.com/demos/404/hsb.jpg] on 12/05/2017 at 12:48

Anon (2017) 'The Colour Wheel' representing a cyclical colour spectrum by degrees.

Web. [http://grasshopperprimer.com/en/1-foundations/1-3/4_domains-color.html] Accessed 16th May 2017

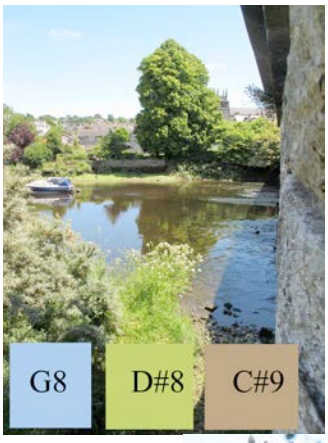
Author (2017) An early approximation of the colour correspondences of the twelve tones of the western chromatic scale. Author's own screen capture from MAX MSP patch

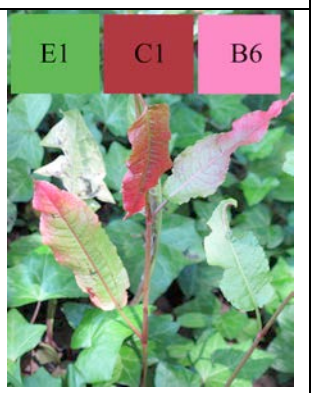
Author (2017) A synthesiser with Hue attributed to pitch within the octave and brightness attributed to octave. Range is from C3 to B6. Screenshot from Author's own Max MSP patch

Telleen, S. Comparison Of Color Sensitivity Of Photopigments. 2016. Web [http://cnx.org/contents/YPmMIA42@1/Vision]. Accessed: 10th May 2017.

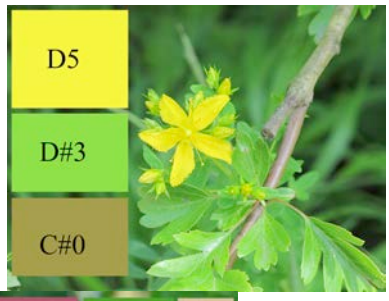
Appendices

A.a. – Along the Dart (annotated images)

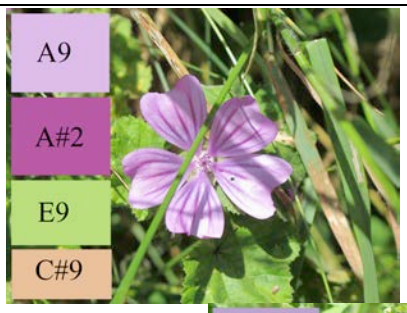


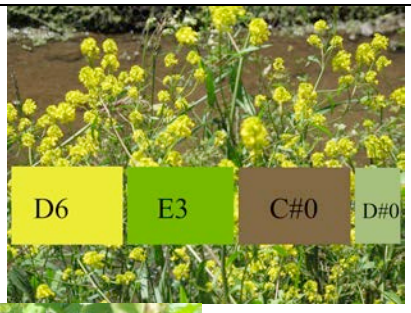



E1
D3
B1


D5
D#3
C#0


D#8
B2
E1
C#9

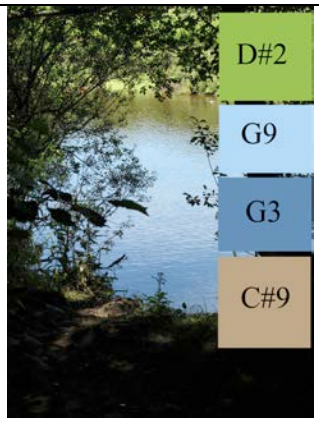

A9
A#2
E9
C#9

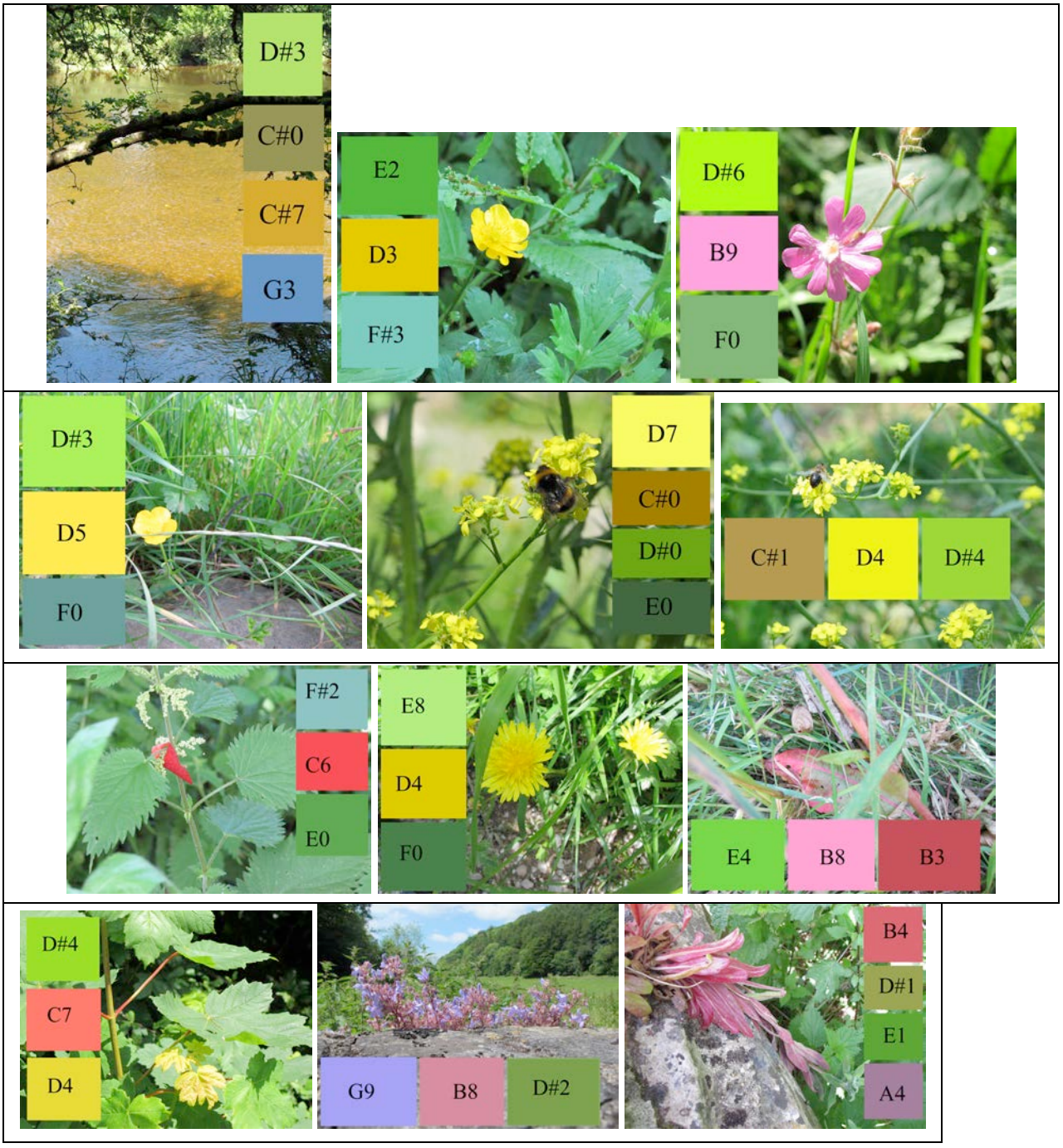

D6
E3
C#0
D#0

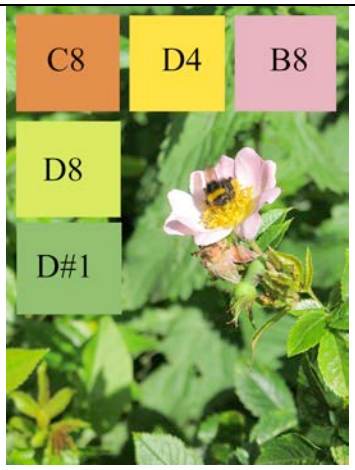

A8
B3
D#1
D2

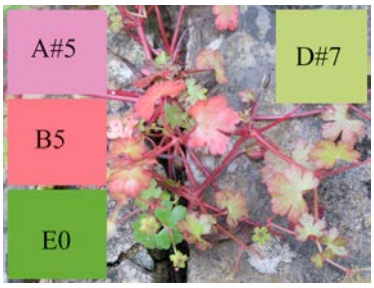

B5
D#4
F0

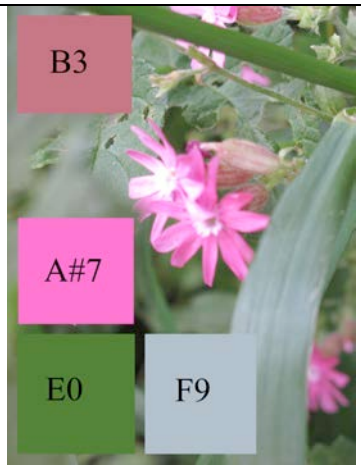

G4
B0
D2
D#0


D#2
G9
G3
C#9

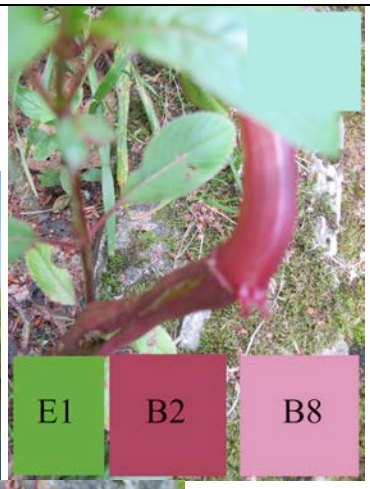

D#3
C#0
C#7
G3
E2
D3
F#3
D#6
B9
F0
D#3
D5
F0
D7
C#0
D#0
E0
C#1
D4
D#4
F#2
C6
E0
E8
D4
F0
E4
B8
B3
D#4
C7
D4
G9
B8
D#2
B4
D#1
E1
A4


C8
D4
B8
D8
D#1


A#5
D#7
B5
E0


B3
A#7
E0
F9

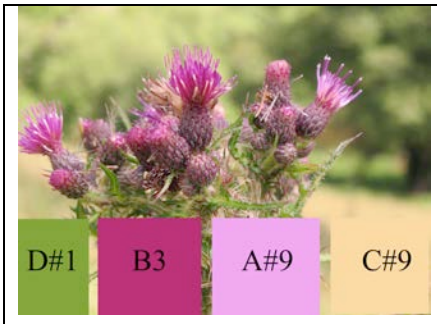

G5
D#3


E1
B2
B8


D#8
A#7
D#1
A9

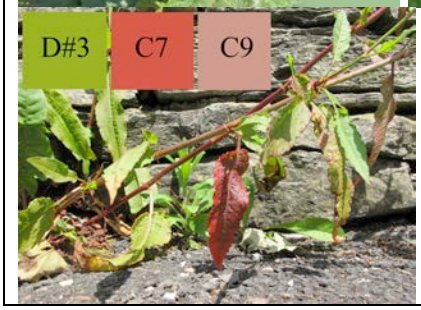

D3

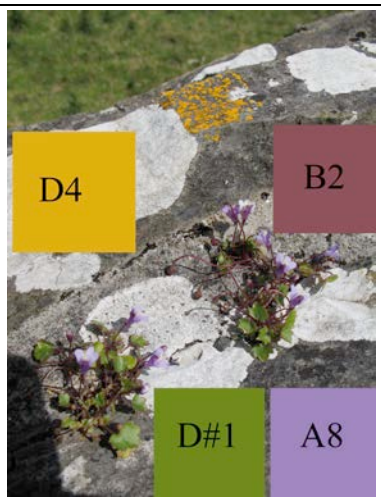

D#5
F0
A#7

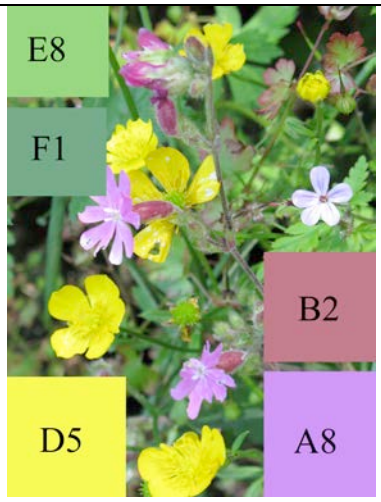

D#1
B3
A#9
C#9


D6
C#1
D#6
F7

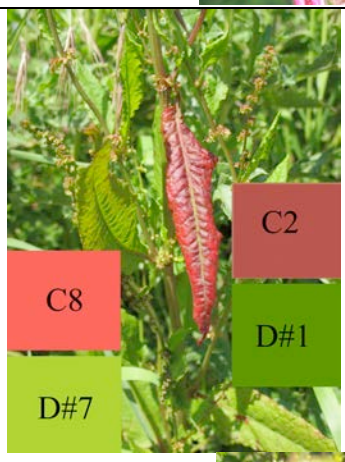

D#0
D#3
C#6
B9


D#3
C7
C9

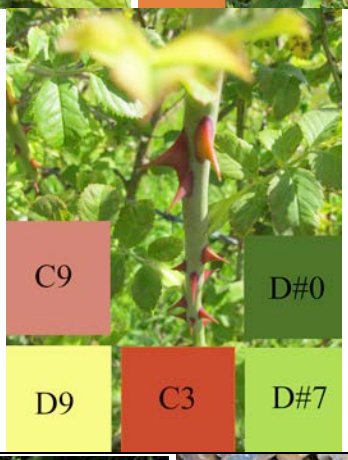

D4
B2
D#1
A8

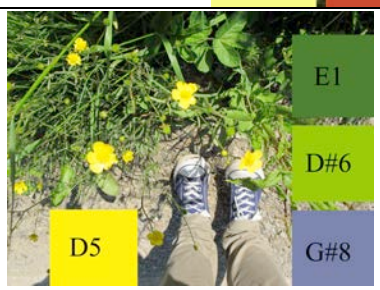

E8
F1
B2
D5
A8


D#5
E0
A#8
B7

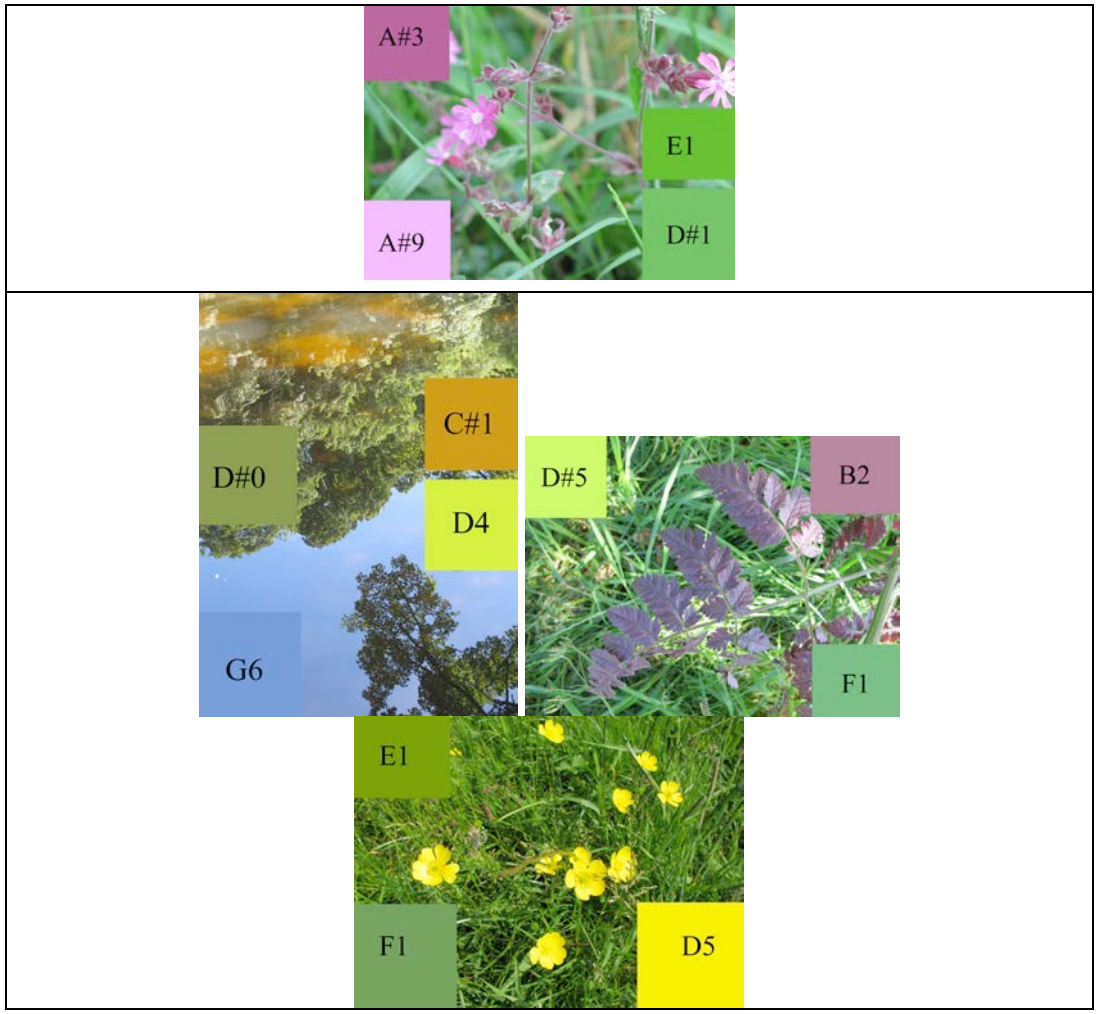

C2
C8
D#1
D#7

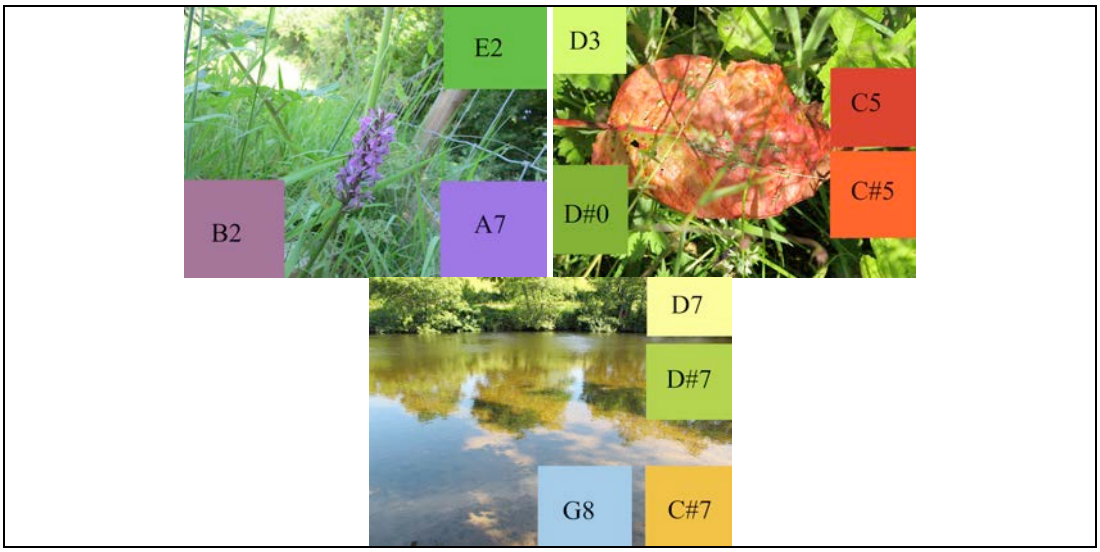

D#3
C7
C#5
D4

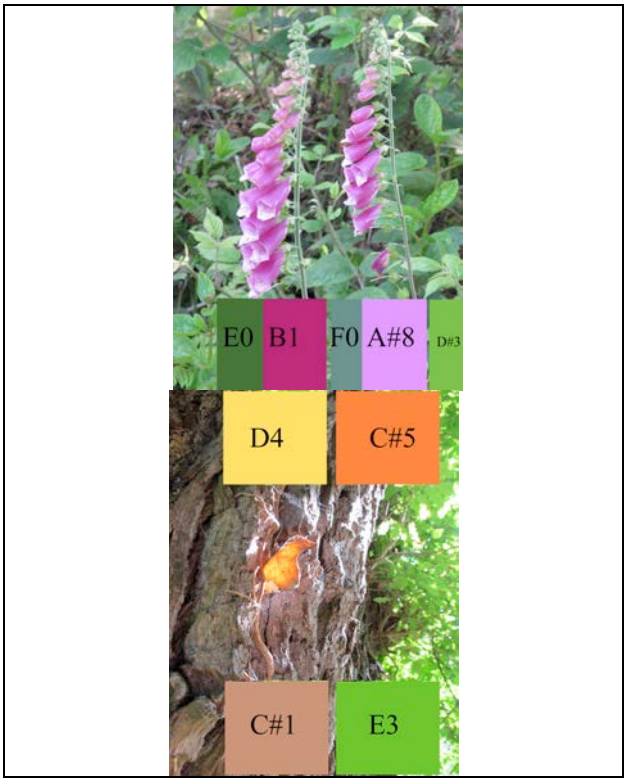

C9
D#0
D9
C3
D#7


E1
D#6
D5
G#8

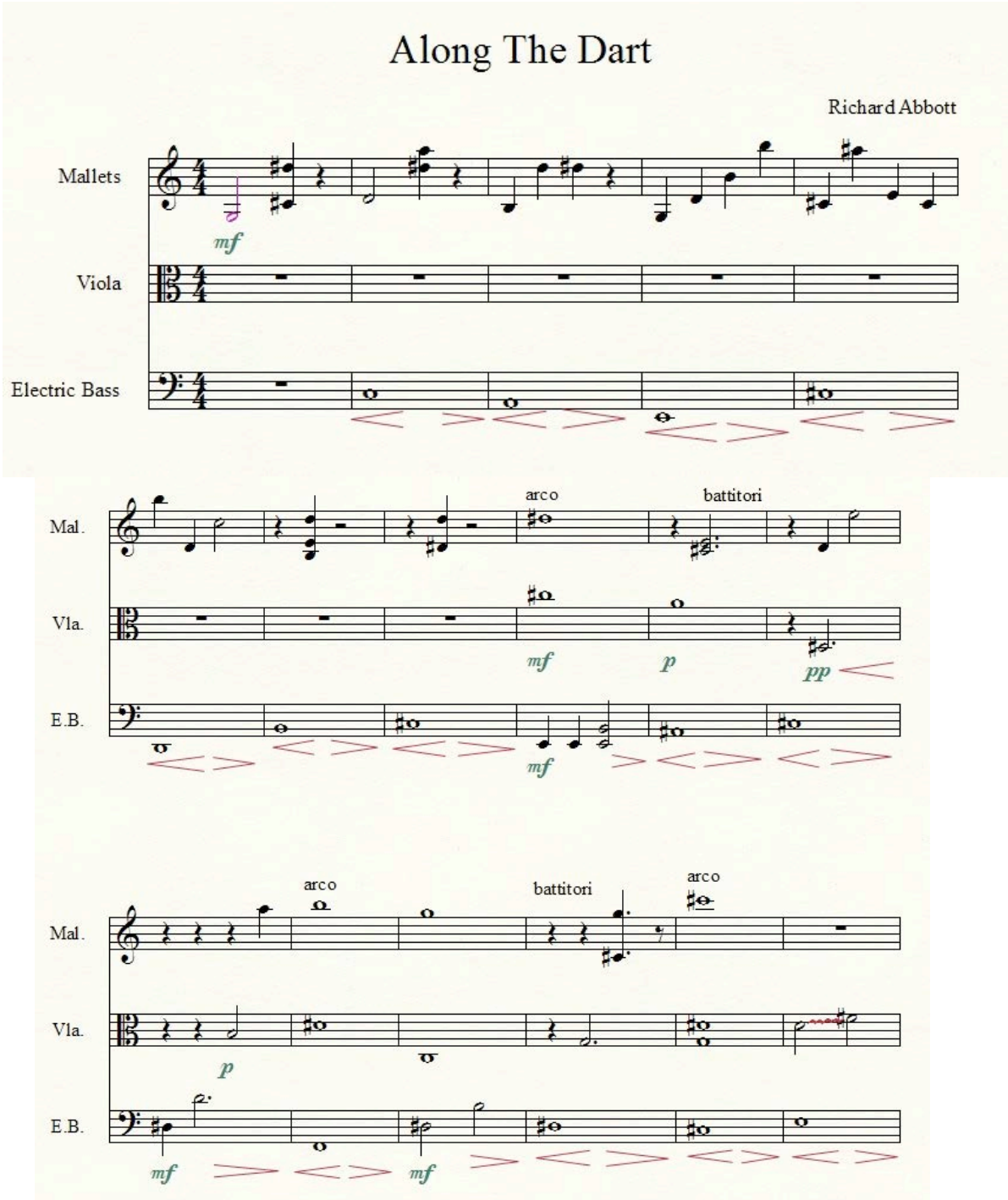

G#8
E1
C#7
F#7

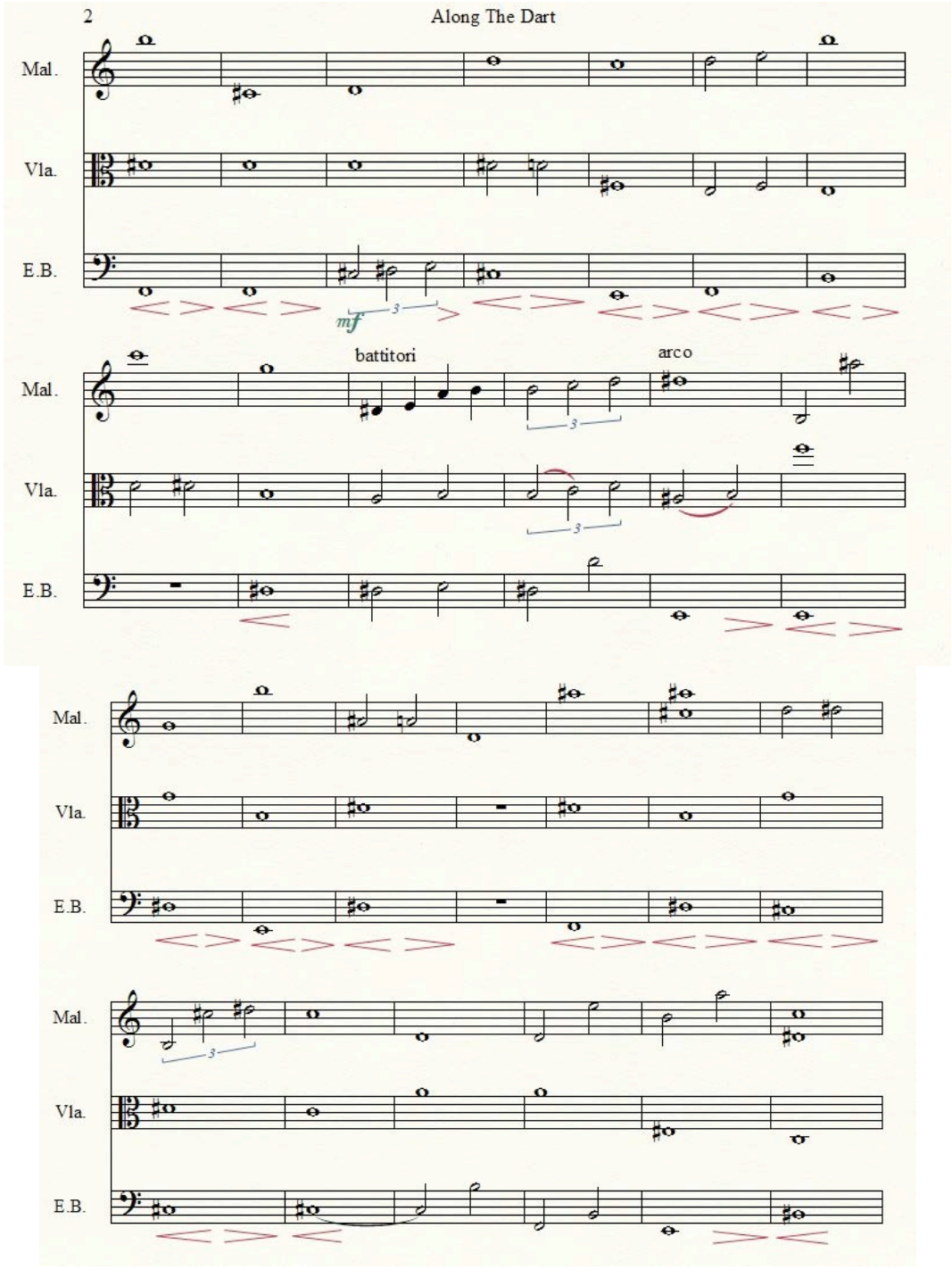

A#3
E1
A#9
D#1
C#1
D#0
D4
G6
D#5
B2
F1
E1
F1
D5

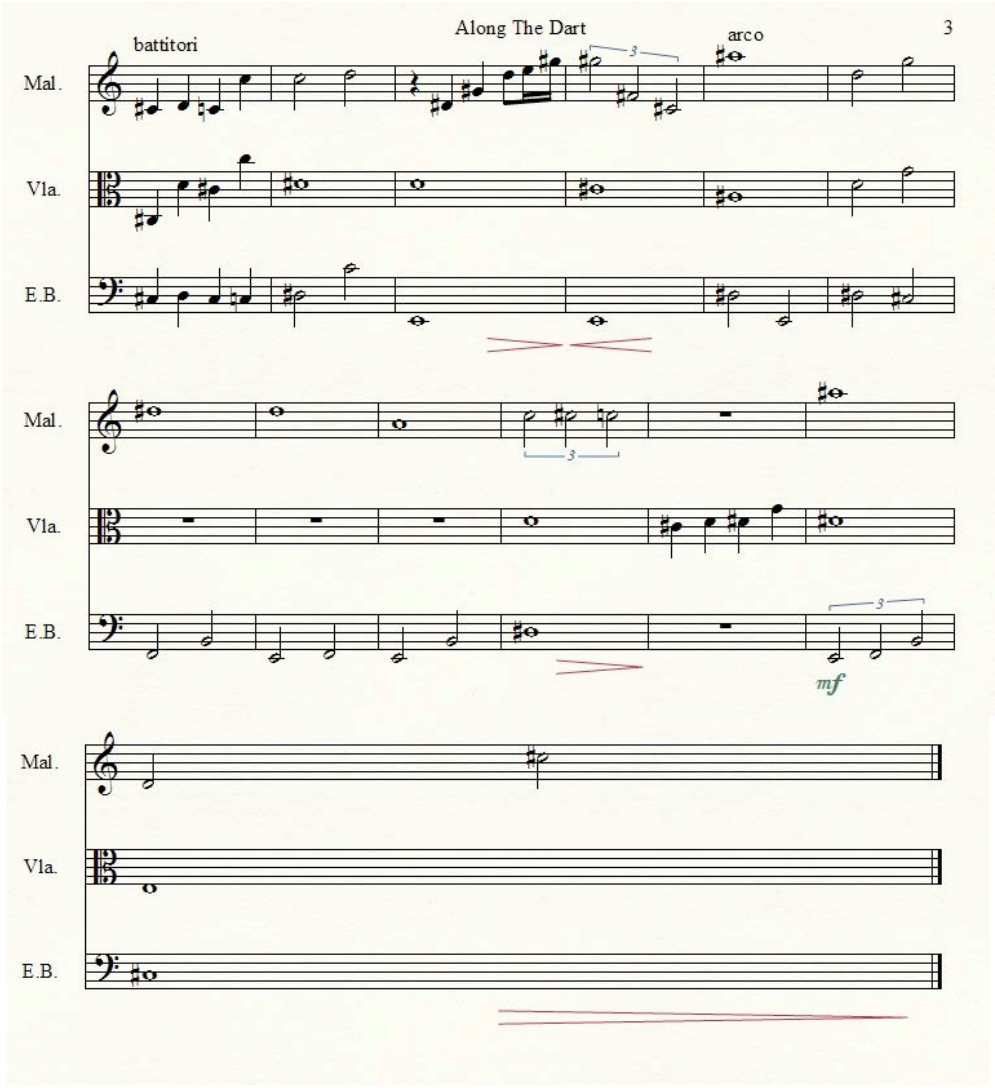

E2
B2
A7
D3
C5
C#5
D#0
D7
D#7
G8
C#7


E0
B1
F0
A#8
D#3
D4
C#5
C#1
E3

A.b. – Along the Dart (Score)




2
Along The Dart
Mal.
Vla.
E.B.
mf
3
battitori
arco
Mal.
Vla.
E.B.
Mal.
Vla.
E.B.
Mal.
Vla.
E.B.


Along The Dart
3
battitori
arco
Mal.
Vla.
E.B.
Mal.
Vla.
E.B.
mf
Mal.
Vla.
E.B.

B.a. – Descending Totnes High Street (images)

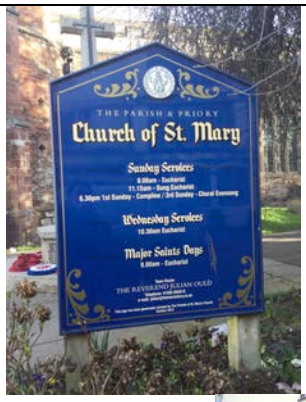

Riverford Farm Shop


Cupboard
The Totnes Wine Centre


British Heart Foundation


WELLINGTON.


Children's hospice South West


THE PARISH & PRIORY
Church of St. Mary
Sunday Services
Wednesday Services
Major Saints Days


The Loft

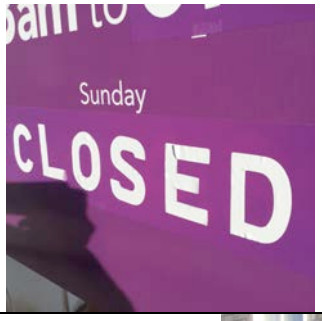

THE ARMY SURPLUS STORE
BINOCULARS TELESCOPES ASTRONOMY


moshulu


Narnia
TIMEHOUSE TOTNES

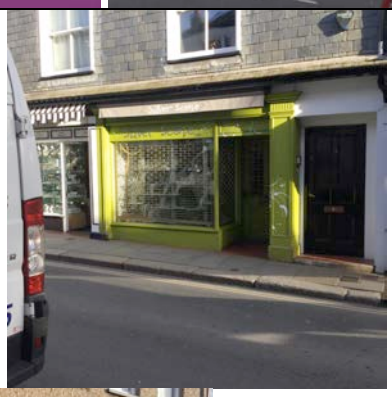

THE KING WILLIAM IV


ARCTURUS BOOKS


Sunday
CLOSED

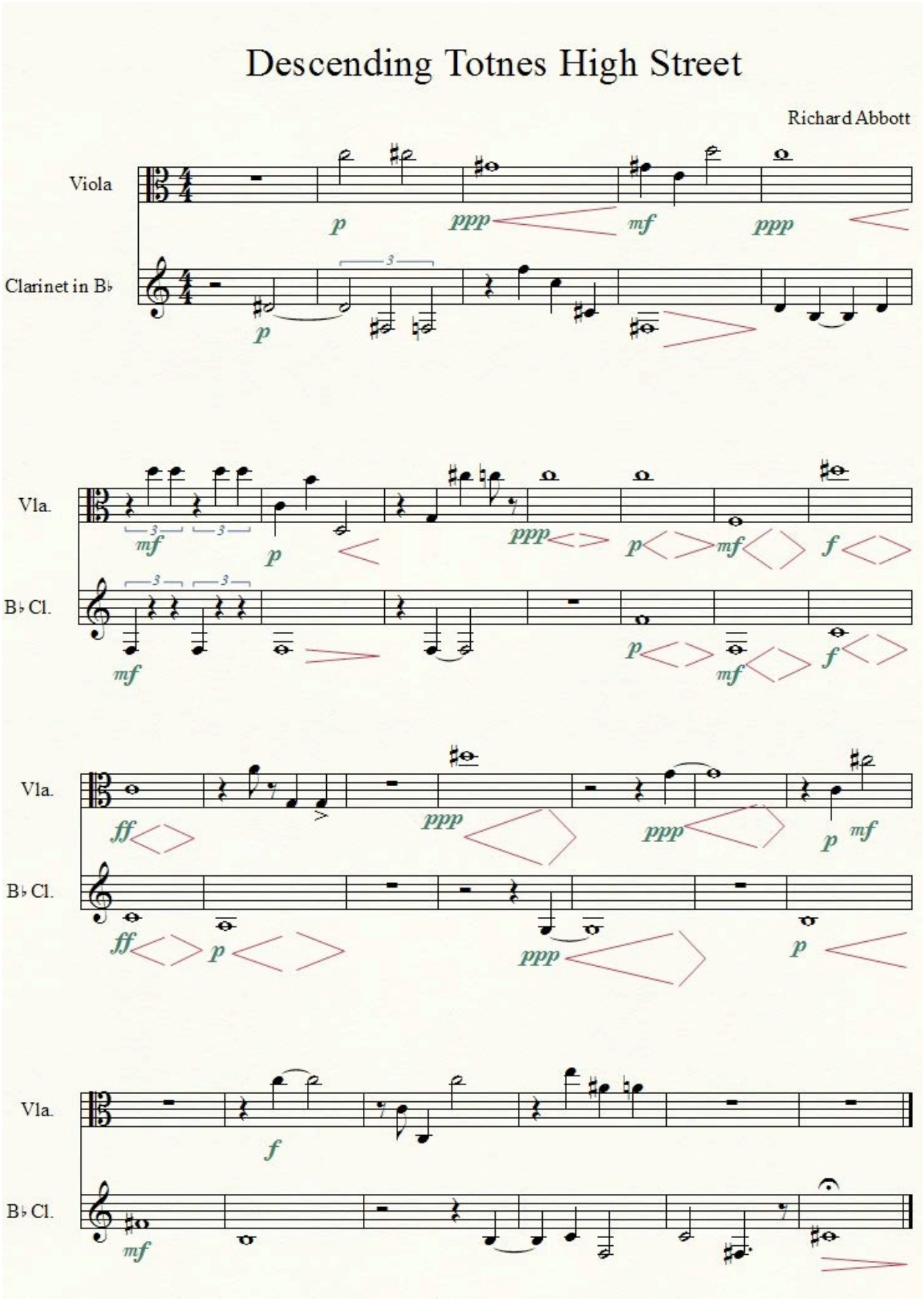

HOLLAND & BARRETT
37


Scope

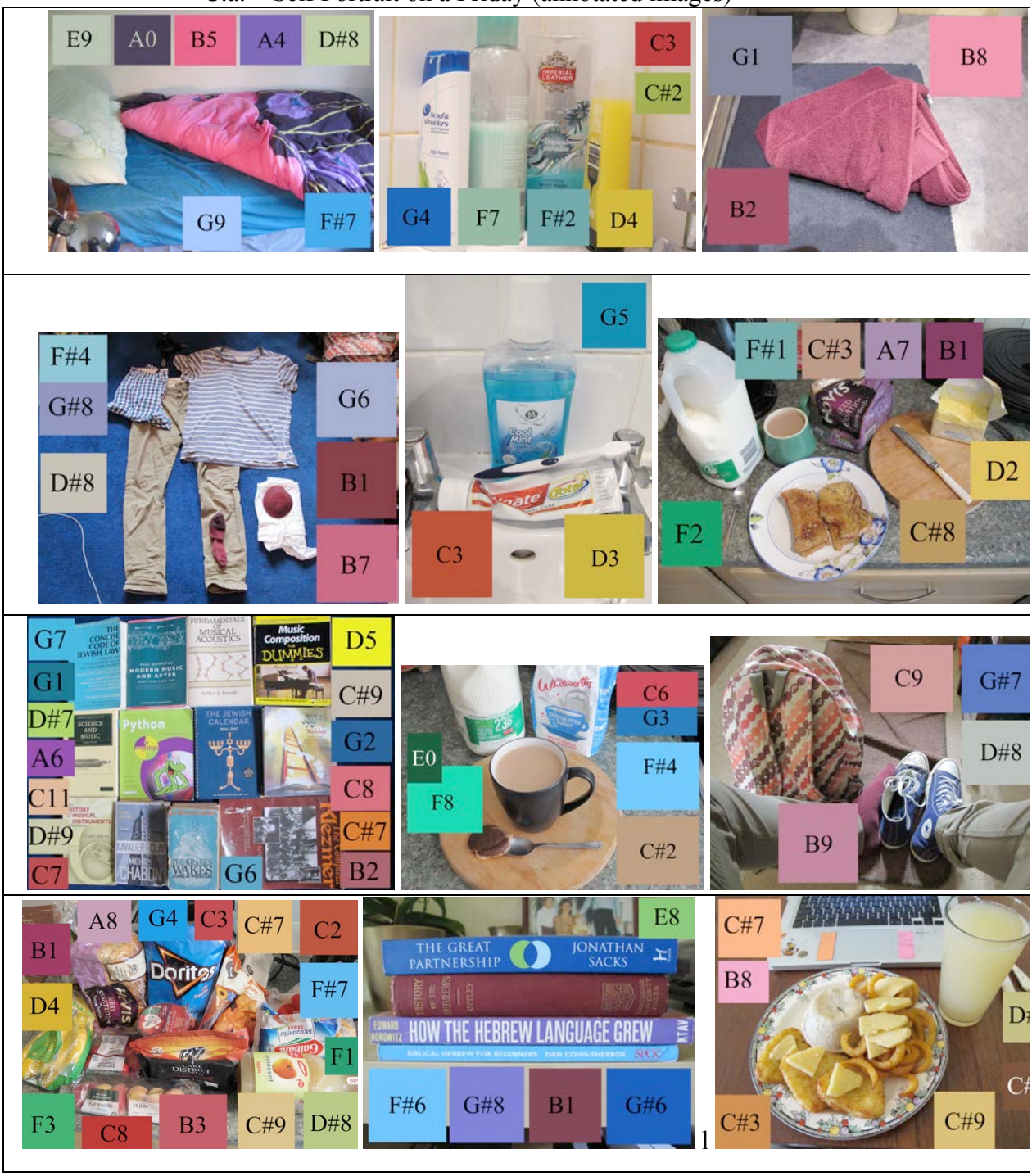


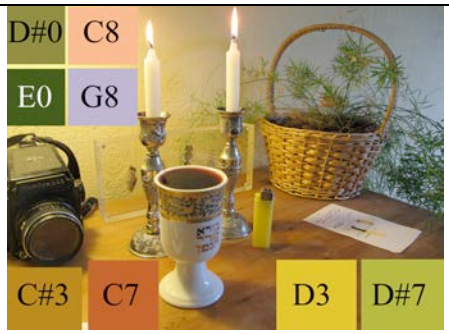

Electrical
CANCER RESEARCH UK

B.b. – Descending Totnes High Street (Score)

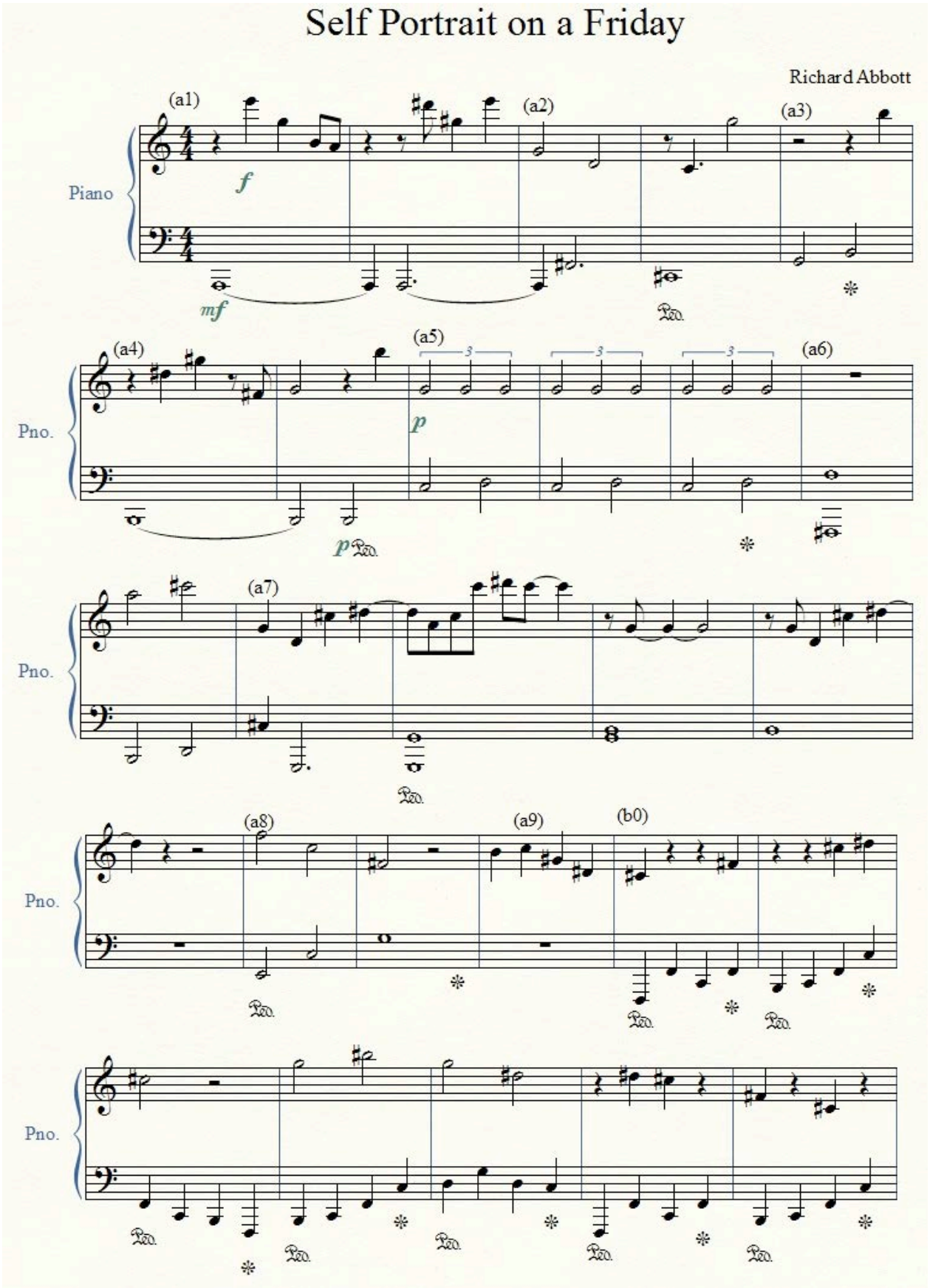


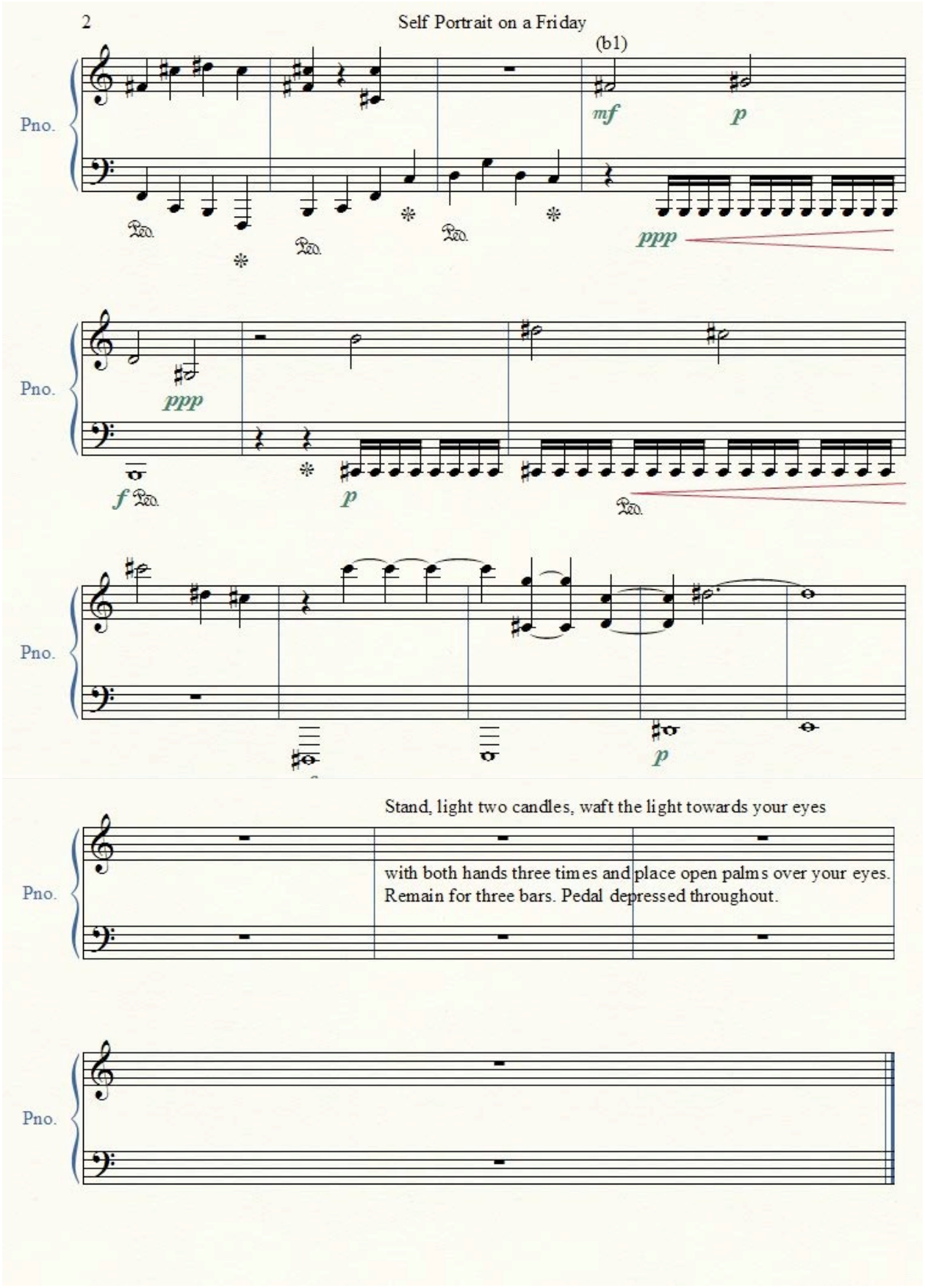
C.a. – Self Portrait on a Friday (annotated images)




D#0
C8
E0
G8
C#3
C7
D3
D#7

C.b. – Self Portrait on a Friday (Score)




2
Self Portrait on a Friday
(b1)
Pno.
mf
p
ppp
ppp
f
p
p
Stand, light two candles, waft the light towards your eyes
with both hands three times and place open palms over your eyes.
Remain for three bars. Pedal depressed throughout.