Artistic and Psychological Experiments with Synesthesia

Crétien van Campen

Synesthesia refers to the phenomenon in which stimulation of one sense modality gives rise to a sensation in another sense modality [1]. The term “synesthesia” originates from the Greek syn (together) and aisthesis (perceive). The most prevalent form of synesthesia is known as audition colorée, the phenomenon of seeing colors when hearing music or vowels. Synesthetes experience this phenomenon more strongly—for instance, they see light spots in front of their eyes—than others who may experience only an inner feeling of color. Other forms of synesthesia result in “tasting” visual shapes and “feeling” warm and cold colors [2].

Synesthesia has played an important role in a recent neuropsychological debate on the organization of the senses [3]. Two positions can be distinguished. The oldest, most accepted and common-sense view (the modularity thesis) holds that humans possess five independently functioning senses [4]. The other view (the unitary thesis) holds that human beings have one integrated sensory organ with five suborgans [5].

The history of the arts shows a comparable debate. Are the visual and musical arts distinguished disciplines that work with separately perceived stimuli? Or are these disciplines part of a larger organ that unites the different arts in the ideal of the Gesamtkunstwerk (Total Work of Art)? Since the nineteenth century, the Gesamtkunstwerk has been an important motivation for numerous artistic experiments with synesthesia [6]. In recent times, new digital technologies of image and sound production have brought theoretical issues concerning the unity of the arts to the foreground once again [7].

It is remarkable that both the symbolist and the early abstract art movements’ interest in the Gesamtkunstwerk was synchronic with a boom of psychological publications on synesthesia in the years 1880–1930 (Fig. 1). After the second world war, the interest of psychologists seemed to disappear almost completely and has only been revived again in recent years—all the more reason to consider the current debate in the historical perspective of artistic and psychological experiments. In this article, I discuss a number of prototypical experiments of important art movements and psychological schools of the late nineteenth century and the beginning of the twentieth century and consider their contributions to the knowledge of synesthesia.

ARTISTIC EXPERIMENTS

Interest in color hearing goes back to classical Greece, where it was argued that color, like pitch, could be considered a physical quality of music [8]. Pythagoras discovered the mathematical order of musical harmony by relating the length of strings to successive octaves. This led to the idea that colors and sounds also could be related, following mathematical rules. However, the first known experiment that tested this hypothesis was undertaken in the sixteenth century by the Milanese artist Arcimboldo, well known for his vegetable and fruit portraits. Because he lacked a mathematical system of color harmony, Arcimboldo inferred a scale of gray values from the Pythagorean system of sound intervals. He translated the gray scale to color hues and persuaded a musician in the court of Rudolph II of Prague to install painted paper strips on his gravicembalo [9].

Still, one theoretical problem was not yet solved. One needed not only a system of color harmony related to a system of musical harmony, but also a correspondence scheme to integrate the two systems. Newton attempted to solve the problem by assuming that musical and color harmonies are related by means of the frequencies of light waves and sound waves. On the basis of Newton’s theory French Jesuit Louis-Bertrand Castel started to develop a color harpsichord (clavecin oculaire) around 1720. In collaboration with the instrument maker Rondet, Castel drafted a harpsichord with colored paper strips that appeared on top of the instrument when a key was pressed. The paper strips were lit by candlelight [10].

If one compares the descriptions by Arcimboldo and Castel, one can observe that the solving of musicological and mathematical puzzles contributed to the mathematical refinement of theories of color/sound correspondences. However, putting these refined ideas into practice in a performance proved to be technically challenging.

The discovery of the gas lamp provided new possibilities. Around 1870, Frederick Kastner developed a gas-lamp organ called the Pyrophone, which consisted of 13 foil-covered gas jets that lit crystal tubes. The term “color organ” was first used in a patent application by Alexander Wallace Rimington in 1893. His 3-m-high color organ resembled a customary house organ with a cabinet of 14 colored lamps on top. The light of the colored lamps could be adjusted to obtain certain gradations of hue, brightness and saturation. This system showed tremendous progress over the paper-strip harpsichords of earlier centuries. Like most color organs, Rimington’s instru-
ment did not itself produce musical sounds. The color organ had to be played simultaneously with an organ that produced musical sound [11].

**Scriabin’s Color Music**

The first synesthetic performances of color organs in concert halls were realized at the end of the nineteenth century after a number of technical problems were solved. At this level, psychological questions came into view concerning the effects that synesthetic performances had on the senses of the public. Russian composer Scriabin was particularly interested in the psychological effects of the simultaneous experience of color and sound. Scriabin started with a system of color-key correspondences (rather than color-note correspondences, as contemporary psychologists do), investigating the emotional aspects of synesthetic experiences of color during the change of one musical key to another.

According to Scriabin the presentation of a color that correctly corresponds to music works as “a powerful psychological resonator for the listener” [12]. Invited by experimental psychologist Charles Myers, Scriabin presented his ideas in London. He explained to Myers that whenever the tonality of a musical piece changes, the color also changes: “color underlines the tonality; it makes the tonality more evident” [13]. Sometimes Scriabin perceived a change in color before a change in key. The addition of color to music intensified both auditory and visual effects simultaneously, according to Scriabin [14].

Unlike previous performances by color organists, Scriabin’s synesthetic compositions were based on color-key correspondences rather than on color-note correspondences. Scriabin changed the colors only when the tonality changed, as in his composition Prométhée, Poème de Feu (Prometheus, Poem of Fire), in which the light experience was designed to be intense and enigmatic. For Prométhée he wrote two separate parts for the *tastiera per luce*, a color organ that was probably based on the design of Rimington’s color organ [15].

Scriabin’s first opportunity to test his synesthetic hypotheses in a concert in Moscow in 1911 failed, due to a defect in the light projector. A few weeks before his death in 1915, Prométhée was performed in New York with a color organ called a chromola that projected 12 colors onto a small screen. However, the performance was not appreciated by the public. One critic compared it to a “pretty poppy show” [16]. It was unfortunate that Scriabin’s conditions for the performance of this piece were not met: there was no “flood of light” in the concert hall, but merely a projection onto a small screen, and the chromola was used merely as one of the instruments, rather than playing a role equivalent to the entire orchestra.

A second path that was explored by Scriabin and contemporary artists such as Kandinsky and Schoenberg was the application of synesthetic dissonants next to consonants. Until the beginning of the nineteenth century, color harmonies had been tuned to musical harmonies. Scriabin composed two lines for the tastiera per luce: one consonant line and one dissonant line to accompany the musical lines of the symphony [17]. Scriabin aimed to create an auditory sensation accentuated by the matching and contrasting colors of the tastiera per luce. He concluded that colored light would act as “a powerful psychological resonator for the listener that intensifies musical perceptions” [18]. Later, Messiaen continued Scriabin’s synesthetic experiments by formulating more accurate transposition schemes for the translation of musical pieces into color sequences [19].

**Synesthetic Dissonance**

Symbolist painters of the late nineteenth century also explored synesthesia [20]. Their interest in synesthesia had two main motives. First, many visual artists regarded music as the highest step on the ladder of the arts, because of its universal and ethereal quality. Second, the influential idea of the Gesamtkunstwerk proposed by Wagner assumed that visual, auditory and other sensory elements were attuned in one Gestalt experience. The experiments by symbolist visual artists ranged from whistling during the act of painting (Delacroix and Mengs whistled to create the right atmosphere for their paintings) to rules of thumb for translating musical notes into colors. Van Gogh maddened his music teacher by stubbornly testing his ideas on tone-color correspondences during piano lessons [21].

The artist group Der Blaue Reiter executed the first synesthetic experiments by a group composed of painters, composers, dancers and theater producers. The group focused on the unification of the arts (by means of Gesamtkunstwerk), freedom of expression (abstraction) and spirituality (the ideal of a music-like immaterial art). Kandinsky’s theory of synesthesia, as formulated in On the Spiritual in Art [22], shaped the ground for these experiments. He described synesthesia as a phenomenon of transposition of experience from one sense modality to another, as in the sympathy of musical tones. In his Bauhaus lessons, he compared human nerves to the strings of a piano: if a note is struck on one of two pianos standing next to each other, the same note on the second piano will resonate. Kandinsky was well acquainted with the scientific debates on direct versus associative perceptual processes in the academic psychology of that time and explicitly defended his theory of direct synesthesia against the arguments of associationist psychologists [23].

Two essential problems were investigated in the Blaue Reiter experiments and later at the Bauhaus academy, i.e. dissonance and temporality. Kandinsky and Schoenberg were interested in the problem of synesthetic dissonance, which also had intrigued Scriabin [24]. After Schoenberg published the atonal theory of dissonant harmony, Kandinsky wanted to make use of these principles in painting and theater [25]. In his theater piece Der gelbe Klang (The Yellow Sound), he experimented with the opposition of three types of movement: visual movement (film), musical movement and physical movement (dance).

Duplicating the resources of one art (e.g. music), however, by the identical resources of another art (e.g. painting) is only one instance, one possibility. If this possibility is used as an internal means also (e.g. in the case of Scriabin), we find within the realm of contrast, of complex composition, first the antithesis of this duplication and later a series of possibilities that lie between collaboration and opposition [26].

Like Scriabin, Kandinsky wanted to alternate dissonance and consonance in order to intensify synesthetic perceptions so they would, in his own words, have a “deeper inner impact” [27]. Along with the composer Thomas von Hartmann and the dancer Alexander Sacharoff, Kandinsky experimented with synesthetic relations between three kinds of movements:

I myself had the opportunity of carrying out some small experiments abroad with a young musician and a dancer. From among several of my watercolors the musician would choose one that appeared to him to have the clearest musical form. In the absence
of the dancer, he would play this watercolor. Then the dancer would appear, and having played this musical composition, he would dance it and then find the watercolor he had danced [28].

Schoenberg experimented with similar relationships in his 1913 theater piece *Die glückliche Hand* [29]. Compared to researchers of cognitive schemes of color-note correspondences at that time, these artists cared more about the emotional and dynamic aspects of synesthetic perceptions. Their work predated the psychological studies of Gestalt processes in synesthetic perceptions in the 1920s and 1930s [30] and more recent research into emotional aspects of synesthesia in the 1980s and 1990s [31].

**TEMPORALITY IN SYNESTHESIA**

Many modern artists during the first decades of the twentieth century (e.g. futurists, members of *De Stijl* and *Der Blaue Reiter*) were interested in temporality [32]. Painting was considered a static art form, and some modern artists wanted to add to their two-dimensional paintings not only the third dimension of depth but also the fourth dimension of time by means of visual suggestions of movement [33].

Mondrian studied the visual perception of movement in his apparently static compositions. His first paintings with grids, completed around 1920, were a milestone in his oeuvre. However, according to Mondrian these first presentations of universal proportions were lacking the important characteristic of rhythm. The perception of reality was chained in forms dictated by the classical art of painting, he wrote [34]. To liberate it from its chains, visual form had to be destroyed and rhythm be given its freedom. Mondrian discussed the attempts of the futurists and the cubists to give space to rhythm in paintings, but concluded that they did not succeed in expressing rhythm [35]. It should be noted that Mondrian, an enthusiastic dancer, was very fond of jazz music and valued highly the prominent role of rhythm in this type of music [36].

Mondrian’s *Composition with Gray Lines* (1918) was an early attempt in this direction. The rhombus painting contained a grid of squares and planes that crossed each other in the corners. Mondrian systematically varied the thickness and the gray tones of the lines, giving rise to the perceptual effect of a rhythmic movement. Since the beholder’s eyes were disposed to follow lines of equal thickness and gray tone, his or her gaze was led through the painting in a movement resembling a quickstep dance. Visual rasters that elicit perceptions of movement—a type of synesthesia of visual images and musical rhythms—remained a central theme in Mondrian’s experiments, culminating in the paintings *Broadway Boogie Woogie* and *Victory Boogie Woogie* during his last years.

In the first decades of this century, technical limits were a major obstacle to the experiments of Mondrian, Kandinsky...
and Scriabin. During the 1950s technological innovations in electronic and digital images and sound offered new possibilities for the performance of synesthetic experiments. Thus, another era of synesthetic experiments began [37]. Recent experiments seem to mainly involve the physical or electronic translation of music and sound into images and animation [38]. Less attention has been paid to the psychological (i.e. perceptual and emotional) impact of synesthetic performances. In comparison to the psychologically oriented experiments of Scriabin, Kandinsky and Mondrian, current artistic experiments seem more oriented to the physics of synesthesia (e.g. electronics and computer programming).

**Psychological Experiments**

Psychological studies into synesthesia have their roots in medical research. The physician Georg Sachs published the first study of color hearing (audition colorée) in 1812 [39]. At that time synesthesia was considered a medical pathology. Clinical case studies were often used as the basis for research. Sachs described photisms (the visual perception of colored spots in front of the eyes, similar to afterimages) that he and his sister perceived when hearing numbers, days of the week, letters and musical tones [40]. Halfway through the nineteenth century the first scientific hypotheses on the physiological nature of audition colorée were formulated. It was assumed that synesthesia was a normal function of the brain but that it was more developed in some individuals than in others. Gradually, the pathological interpretation of synesthesia as an individual abnormality was abandoned in favor of physiological and psychological interpretation as a normal cognitive function. Psychologists opposed the physiological interpretation and considered synesthesia as the product of a mental association of sense data. The debate that resulted from these two viewpoints laid the foundation for a century of psychological research.

Should synesthetic perceptions be explained by sensory-physiological mechanisms or by mental operations of sense data? This question gave rise to Gustav Theodor Fechner’s first aesthetic-physiological experiments with groups of subjects in the 1860s [41]. Fechner surveyed 73 people about letter-color associations. This type of social scientific experiment was adopted by a number of experimental psychologists and marked an important turn in synesthetic research, which had previously been limited to individual case studies. Perceived correspondences between colors and consonants, vowels and numbers, were studied extensively. The psychologist Lawrence Marks published in 1978 a meta-analysis of 35 studies of a total of 400 people [42] that did not recognize any systematic rules of color-letter or color-number correspondences. However, Marks noted that observations can be made on the dimension of brightness, with bright consonants (e.g. “i” or “e”) corresponding to light colors, and dark consonants (e.g. “o” or “u”) to dark colors.

The increasing significance attributed to synesthesia was expressed at the International Congress of Physiological Psychology, held in Paris in 1890. The subject of synesthesia was scheduled as the opening session in the program and was devoted to a debate between the naturalists and the mentalists. On the basis of a small survey, a special committee proposed a taxonomy of synesthetic experiences and a definition of the concept of audition colorée [43]. The first laboratory experiments with synesthetic subjects emerged in the late 1920s. The debates between the naturalists and the mentalists developed into two disparate theses that are still influential today: the unity of the senses thesis and the modularity thesis.

**Unity of the Senses**

The thesis of the unity of the senses was developed in the 1920s by Gestalt-oriented researchers such as Erich von Hornbostel and Heinz Werner [44]. Hornbostel elaborated on the Aristotelian idea of a common sense. For instance, the sensations brightness, warmth and roughness supposedly originated from more than one sense modality and was logically perceived by the common sense. Hornbostel assumed brightness to be the central dimension that appeared in each sense modality (light-dark, hard-soft, sharp-blunt, light-heavy, cold-warm) [45]. In Hornbostel’s view the unity of the senses was the basis of the unity of the arts. Hornbostel designed laboratory experiments in which he asked subjects to match different stimuli. First he subjected them to an odor and asked them to match it to one of a number of gray cards. Then he asked them to match the odor to a corresponding pitch. Finally, the subjects matched the pitch with a gray card. Gray cards chosen by different subjects were almost identical. Hornbostel interpreted the results as proof that the unity of the senses thesis was valid [46], but in fact he only tested the cross-modal transfer of the brightness dimension.

Werner investigated a developmental variant of the unity thesis: he assumed that although adults differentiate the perceptions of different senses, babies perceive the environment undifferentiated [47]. The emphasis of psychological research shifted from studies of static correspondence rules to the dynamics of the process of synesthetic perception. According to Benjamin Kouner, experiments with color-tone correspondences in 1949 failed to show consistent results [48]. In 1931 Karl Zietz was one of the first psychologists who designed experiments to investigate the process of synesthetic experiences [49]. In an obscured room in a psychological laboratory, subjects were shown strong visual stimuli that produced clear afterimages. While the subjects perceived afterimages, they were given auditory stimuli. It was investigated how the auditory stimuli affected the visual afterimages. The main result was that extremely low and high tones influenced the visual perception of afterimages. A high tone increased the intensity and clearness of a perceived color. Moreover, high tones made colors look harder and colder, and the velocity of the afterimages to appear to accelerate. Zietz concluded that sensations of color and sound are part of an indivisible Gestalt perception in which the auditory and visual perceptions mutually influence each other.

**Conditioning Synesthesia**

Opposite the unitary thesis stood the modularity thesis, which was rooted in European associationistic psychology and the American behaviorism of the beginning of this century. The modularity thesis claimed that synesthetic perception was the product of the conditioning of mental associations of sensory elements. T.H. Howells, for instance, designed laboratory experiments in the 1940s in which subjects were asked to distinguish two complementary colors. During the experiments, a low organ tone played before the presentation of a carmine red stimulus, and a high organ tone before a blue-green one [50]. Eight subjects were presented with 5,000 stimuli. Howells sometimes played the
“wrong” tone before a color and studied the responses of the subjects. Playing a wrong tone disturbed the perception of color. “Correct” tones made the color more clearly distinguishable. Howells concluded that synesthetic perception is a product of conditioning. According to Kouner, most other experiments investigating the conditioning of synesthesia produced inconsistent results [51].

In social psychology, attempts to measure consistencies in synesthetic experiences led to the development of the Semantic Differential Scale [52]. T.F. Karwoski and his associates carried out a series of surveys of subjects in the 1930s and 1940s, asking them to mark their mood on an emotion circle while listening to pieces of classical music chosen by the experimenters [53]. These experiments were repeated with color circles. According to the authors, the correspondences between the scores on different scales were consistent. The results of normal subjects resembled those of synesthetes, suggesting that synesthesia and metaphor were only slightly different [54].

The assumption that synesthesia and metaphor were on the same gradual scale gave rise to linguistic and literary studies of poetic metaphor [55]. Marks assumed the presence of universally meaningful correspondences between sensory modules. Marks tested Hornbostel’s brightness thesis in a series of experiments investigating cross-modal transfer [56]. Subjects were asked to distinguish brief stimuli. The results showed that subjects performed the task faster and more accurately when the experiential stimulus was accompanied by a corresponding stimulus of a different sense modality. Marks concluded that the effects could be attributed to cross-modal transfer.

THE NEUROPSYCHOLOGICAL TURN

The dip in the number of publications concerning synesthesia (see Fig. 1) after WW II may be explained by the fact that synesthesia was no longer considered an isolated phenomenon but as a type of metaphor. The revival of synesthesia studies in the 1980s can be attributed to the rise of neuropsychological interest in synesthesia.

The confusion of synesthesia with metaphor elicited the realization that research should be redirected toward purely synesthetic phenomena [57]. After a psychological committee had clearly defined the concept of synesthesia (i.e., audition colorée) in 1890, it became more progressively diffused during the twentieth century. The diffusion of the concept had not led to conceptual clarifications or to consistent results [58]. In order to produce more valid and reliable results on synesthesia, neuropsychologists began the development of well-defined criteria [59] and clinical tests to distinguish synesthetes from non-synesthetes [60].

In comparison to former psychological studies, recent neuropsychological studies have been focused on fewer subjects [61]. After nearly a century of psychological studies with groups of subjects, neurologists reintroduced the individual medical case study, preceded only by A.R. Luria’s study of the synesthetic mnemonist “S” [62]. Simon Baron-Cohen and his associates developed a reliability test of synesthetes in order to test the consistency of synesthetic responses over a long-term period [63]. Recent studies have started to locate synesthetic processes in the brain by means of Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI) scans [64]. So far, with this neuropsychological research, a very small group of synesthetes (1:2,000, according to Baron-Cohen et al.) have been discovered [65]. The brain scan studies have not yet succeeded in locating abnormal brain activity that would explain synesthetic perceptions. The debate between the modularists and unitarists continues. The modularists consider synesthesia to be the product of neural miss-wiring between, for instance, the visual and auditory areas [66]. The unitarists consider synesthesia to be a natural emotional process of integral sensory perception, and locate the phenomenon in the limbic system, coined the “emotional brain” [67].

CONCLUSION

Current attempts by artists and psychologists to discover formal correspondence schemes in synesthesia have a long history of experiments in art and science. The phenomenon of synesthesia is difficult to control or manipulate; it cannot be understood in simple correspondence schemes, as numerous experiments with tone-color correspondences alone have shown.

Artistic experiments, especially by artists of the early modern movement, have uncovered interesting dynamic and emotional aspects of synesthetic perceptions and have contributed to the phenomenology of synesthesia. Psychologists have restricted themselves to accurately formalizing a few of the isolated aspects of synesthesia and have also contributed methods for assessing synesthesia.

Current psychological studies into synesthesia have caught up with modern trends in brain research and are mainly involved in a search for organic bases. Current artistic experimentation seems primarily to involve digital devices and a search for algorithms to translate music into images (e.g., visual music, animation). The present boom in artistic synesthesia research can be compared to that which occurred in the late nineteenth century. After those first experiments with color organ technology, an era followed of fruitful artistic explorations and scientific testing of the psychological (perceptual and emotional) impact of sound-image devices and performances.

References


9. Gage [8].


17. See Peacock [12].

18. See Peacock [12].


26. See Kandinsky [23].


31. See Cytowic [2].

32. See Peacock [12].


37. See Hornbostel [5]; Werner [5]; Peacock [10]; Steadman [11]; von Maur [20]; Galeyev [27].

38. See the bibliography on visualizing music and sound in Harris [7], and on the “Synesthesia Information Page,” on the Web at <http://130.212.8.138/msp/Instructors/rey/synesth.html>.


40. See Mahling [39].

41. T. Fechner, Vorschule der Ästhetik (Leipzig: Breitkopf and Hartel, 1871).

42. See Marks [2].

43. See Mahling [39].

44. Hornbostel [5].

45. Marks [2]; Hornbostel [30].

46. Marks [2]; E.M. von Hornbostel [30].

47. Hornbostel [5].


49. Zietz [30].


51. Kouwer [48].


54. Snider and Osgood [52].


57. Cytowic [2].

58. Cytowic [2]; Kouwer [48].

59. Cytowic [2].

60. Harrison and Baron-Cohen [1]; Baron-Cohen et al. [4].

61. Cytowic [2].


63. Baron-Cohen et al. [4].

64. Paulus et al. [3].

65. Motlik [3].

66. Baron-Cohen et al. [4].

67. Cytowic [2].

68. Mahling [39].

69. Marks [2].

Glossary

afterimage—a perceptual experience that occurs after the original source of stimulation has been removed. Afterimages are most readily detected in the visual modality.

associationism—a philosophical/psychological doctrine that asserts that higher-order mental or behavioral processes result from the combination (association) of simpler mental elements, e.g. sense impressions.

audition colorée (color hearing)—a special case of synesthesia that produces experiences of color with auditory stimuli.

behaviorism—the approach to psychology that argues that the only appropriate subject matter for scientific psychological investigation is observable, measurable behavior.

gestalt psychology—a school of psychology that asserts that psychological phenomena can only be understood if they are viewed as organized structured wholes (or Gestalten).

limbic system—a complex set of evolutionary old structures of the forebrain lying in an arc below the corpus callosum.

mentalism—the doctrine that maintains that an adequate characterization of human behavior is not possible without invoking mental phenomena as explanatory devices.

naturalism—the doctrine that stresses the biological influences on behavior and thought.

PET scan—a technique of Positron Emission Tomography that produces pictorial representations of brain activity, i.e. regional cerebral blood flow.

sense modality—a sensory system, usually qualified to specify the sense intended, e.g. the visual modality.

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