

BEHAVIORAL ASSESSMENT OF SYNESTHETIC PERCEPTION: COLOR  
PERCEPTION AND VISUAL IMAGERY IN SYNESTHESIA

A THESIS IN  
Psychology

Presented to the Faculty of the University  
of Missouri-Kansas City in partial fulfillment  
of the requirements for the degree

MASTER OF ARTS

by  
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Kansas City, Missouri  
2006



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ABSTRACT

This study examined vividness of visual mental imagery and color discrimination ability in synesthesia. It was hypothesized that participants with synesthesia would have higher overall scores on the Vividness of Visual Imagery Questionnaire (VVIQ) and participants with colored synesthetic experiences would have lower Total Error Scores (TES) on the Farnsworth Munsell 100-Hue test (FM 100 test). Results revealed a significant difference between groups on the FM 100 test [ $F(2,28) = 2.67, p = .03$ ], with participants with colored synesthetic perceptions having lower TES scores ( $M = 20.40$ ) than synesthetes without colored concurrents ( $M = 34.00$ ) and participants without synesthesia ( $M = 34.63$ ). An independent samples t-test revealed no significant differences between synesthetes and nonsynesthetes and overall VVIQ scores [ $t(30) = -1.46, p = .16$ ]. These results indicate that synesthetes with colored concurrents may have better color discrimination ability than nonsynesthetes and synesthetes without colored concurrents.

The faculty listed below, appointed by the Dean of the College of Arts and Sciences have examined a thesis titled “Behavioral Assessment of Synesthetic Perception: Color Perception and Visual Imagery in Synesthesia,” presented by Katherine D. Gimmestad, candidate for the Master of Arts degree, and certify that in their opinion it is worthy of acceptance.

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## CONTENTS

ABSTRACT .....	ii
LIST OF ILLUSTRATIONS.....	v
LIST OF TABLES.....	vi
Chapter	
1. INTRODUCTION.....	1
2. REVIEW OF LITERATURE.....	7
3. METHODOLOGY .....	15
4. RESULTS .....	24
5. DISCUSSION.....	27
Appendix	
A. VIVIDNESS OF VISUAL IMAGERY QUESTIONNAIRE (VVIQ).....	30
B. DIAGNOSTIC SYNESTHESIA SCREENING FORM .....	32
C. SCNL DEMOGRAPHICS FORM .....	40
REFERENCE LIST .....	41
VITA.....	45

## ILLUSTRATIONS

Figure		Page
1.	FM100 Hue Total Error Scores .....	26

## TABLES

Table		Page
1.	Participant Demographics.....	15
2.	Vividness of Visual Imagery Questionnaire Total Scores.....	24
3.	Colored Concurrents and VVIQ Color Subscale Scores .....	25

## CHAPTER 1

### INTRODUCTION

#### Statement of the Problem

Much remains to be discovered about synesthesia, the phenomenon in which a sensory experience (inducer) triggers a conscious perception (concurrent) that is in addition to perceptions that most people would experience in response to the stimulus (Grossenbacher & Lovelace, 2001). For example, someone who experiences synesthesia may report seeing the color green (concurrent) in response to hearing or seeing a particular number or letter (inducer). Those experiencing synesthesia (synesthetes) often describe seeing the color in their “mind’s eye” (internal synesthetes) or less commonly, seeing the color projected (external synesthetes). External synesthetes say that although they see the colors externally, they know that these colors are not actually on the inducer (letter or number, for example), as they perceive them. The most common kind of synesthesia is that of colored language synesthesia, although synesthetes have reported myriad forms. Some examples of forms of synesthesia include perceptions of color in response to musical sounds, sensations of shapes in response to taste, sensations of colors in response to sounds. Scientists have studied colored language synesthesia much more than other forms, due to colored language being the most frequently reported kind of synesthesia (Robertson & Sagiv, 2005). Reports of synesthesia may go back as far as the 1700s (Galton, 1883; Larner, 2006), but up until recently, synesthesia was a difficult phenomenon to study. Many people have doubted the genuineness of synesthesia, given that exploration of synesthesia has



historically been largely dependent upon self-report, residing in the perception of the person experiencing it. However, with the development of brain imaging techniques such as functional Magnetic Resonance Imaging (fMRI) and other objective tests developed by researchers (Baron-Cohen & Harrison, 1997), synesthesia has gained credence in addition to renewed interest in the scientific community in recent years.

### Purpose of the Study

This study proposed to elucidate to what degree the findings of multisensory integration are relevant to human behavior. Persons with synesthesia most commonly report colors in their evoked perceptions. By asking participants to discriminate between fine shades of colors, we investigated whether the unusual multisensory condition somehow enhances color perception. In addition, many people with synesthesia describe their synesthetic experiences with great detail, and describe their experiences as quite vivid. We also examined whether these synesthetic experiences increase vividness of visual mental imagery by asking participants to complete a questionnaire that will ask them to report vividness regarding their visual imagery.

### Hypotheses for this Study

1. Synesthetes would report stronger vividness of visual imagery than non-synesthetes, such that synesthetes would have higher overall scores on the Vividness of Visual Imagery Questionnaire than non-synesthetes.
2. Synesthetes with colored synesthetic experiences would demonstrate better color discrimination than non-synesthetes and synesthetes without colors as part of their

synesthetic experiences. Synesthetes with colored concurrents would have lower Total Error Scores on the Farnsworth-Munsell 100 Hue test.

3. Synesthetes with colored synesthetic experiences would report stronger vividness of visual imagery than non-synesthetes and synesthetes without colored concurrents on the color subscale of the Vividness of Visual Imagery Questionnaire.

4. Among synesthetes with colored concurrents, the vividness ratings of the concurrents from the Synesthesia Screen would correlate with the strength of vividness ratings on the color subscale of the Vividness of Visual Imagery Questionnaire.

5. Synesthetes with external concurrents would report stronger vividness of visual imagery than synesthetes without external concurrents, as measured by overall scores on the Vividness of Visual Imagery Questionnaire.

6. Synesthetes with external concurrents would report stronger vividness ratings of their concurrents from the Synesthesia screen than synesthetes without external concurrents.

### Significance of the Study

The scientific significance of this study was to further the knowledge presently known of synesthesia and multisensory processing. In particular, I examined the colored perceptual experiences of synesthetes and their subjective vividness of visual imagery. Although much research has been conducted in effort to describe exactly what perceptual phenomena constitute synesthesia (Day, 2004; Palmeri, Blake, Marois, Flanery & Whetsell, 2002; Schilt et al., 1999), there is a paucity of research as to whether synesthetic experiences may provide some benefit in the domain of veridical perceptual experiences. The neural mechanisms of synesthesia have yet to be illuminated, and although interest in synesthesia research has greatly increased in the past decade, there is little consensus as to whether it

may be an ability that evolved due to advantages resulting from increased associations, or simply a genetic accident.

Research conducted in (often somewhat contrived) laboratory experiments has demonstrated that synesthesia can be detrimental to reaction times on behavioral tasks (Palmeri et al., 2002). Although a number of studies have used behavioral measures to shed light on the novelty of synesthetic experiences, this study is unique in that I measured perception that is not itself synesthetic in nature. To my knowledge, only one study has been conducted examining how synesthesia may play a role in everyday cognitive tasks or behavioral performance. In a sample of 25 grapheme-letter synesthetes and 26 non-synesthetes, Crane (2005) found synesthetes to perform one standard deviation higher than controls on the verbal comprehension index of the Wechsler Adult Intelligence Scale (WAIS). One can postulate that the consistent extra stimulation of colors to the letters and numbers of the synesthetes may have aided them in this verbal subcomponent of the WAIS. In a standard test of color discrimination ability, 150 of 300 participants were categorized as “Experienced” color discriminators, and had 3 to 20 years of experience in the color control laboratories of dyes, rugs, plastics, textiles, and paints (FM Scoring Software, 1976). These individuals had significantly better color discrimination as compared to the remaining participants. I postulate that the effects of practice with color gave these participants an advantage on the color discrimination task.

With the consistent color stimulation provided in synesthetic experiences of those with colored synesthesia, it was interesting to observe whether this unusual multisensory phenomenon of synesthesia actually provides an advantage in relevant behavioral tasks, and how these experiences may influence color discrimination abilities. Similarly, given the

markedly different perceptual experiences reported by synesthetes, with the majority of these experiences perceived as being very vivid and real in the “mind’s eye,” I also wanted to find out more about the perceived vividness of visual imagery for synesthetes as opposed to non-synesthetes.

### Definition of Terms

*Colored language synesthesia.* Synesthesia in which letters or numbers are automatically and consistently paired particular letters with specific colors (Baron-Cohen & Harrison, 1997). The color may fill up the letter/number, manifest itself in the background, or simply present itself in the mind’s eye in response to the stimulus (Grossenbacher & Lovelace, 2001).

*Concurrent.* The concurrent is the resultant sensory experience to an inducer, most often experienced by synesthetes as colors (Grossenbacher & Lovelace, 2001).

*External synesthesia.* For the purposes of this study, external synesthesia refers to synesthesia in which the synesthete visually perceives concurrents associated with the inducer outwardly (Martino & Marks, 2001).

*Grapheme.* A grapheme is a letter or number, associated with colored language synesthesia.

*Inducer.* An inducer is the stimulus or event that triggers the sensory experience in a modality (sense) normally not experienced in non-synesthetes. For example, a colored-hearing synesthete may hear a certain word or musical sound (inducer) and may perceive the sound as possessing a particular color (concurrent). The inducer can be in the same sense modality or in a different sense modality than the concurrent (Grossenbacher & Lovelace, 2001).

*Internal synesthesia.* For the purposes of this study, internal synesthesia refers to synesthesia in which the concurrents associated with inducers are experienced in the “mind’s eye” of the synesthete, and not visualized externally on a medium such as paper or other external representation (Martino & Marks, 2001).

*Modality.* Any of the various forms of sensation, such as vision or hearing.

*Synattribution.* Conscious experience of non-sensory phenomena that are triggered by something not otherwise explained by synesthetic perception, conception, or knowledge (Grossenbacher, 2004b).

*Synesthesia.* Synesthesia is the automatic perception of a stimulus as an experience of a different sense, such as consistently picturing certain letters or numbers in specific colors (Kolb & Wishaw, 2003). This definition will include both “internal” and “external” synesthesia.

*Synesthetic Conception.* Conscious experiences of sensory phenomena triggered by conceptual thought or affective feeling (Grossenbacher, 2004b).

*Synesthetic Perception.* Conscious experiences of sensory phenomena triggered by sensory stimulation (Grossenbacher, 2004b).

## CHAPTER 2

### REVIEW OF LITERATURE

#### Theoretical Reflections

Synesthesia, from the Greek word “syn” which means “together,” and “aesthesia” meaning “perception,” has been reported as early as the 1800s. Interest in synesthesia was great between the mid 1800s and before the behaviorist trend in psychology around the early to mid-1900s (Cytowic, 1998). Despite the interest, scientists had difficulty studying something that so heavily relied upon self-report, and many doubted the genuineness of synesthesia. With the rise of behaviorism, scientists generally regarded synesthesia as an invalid field of study, judging subjective experiences as immeasurable. In the past few decades, however, interest in synesthesia has returned (Duffy, 2001). Presently, researchers employ a large and increasing number of methods to assess the validity of synesthetic experiences. Many of these methods involve functional neuroimaging, but also some, ironically in the light of the decrease in interest during the behaviorist era, are behavioral tests.

Although synesthesia is arguably fascinating in its own right as a rare and unusual multisensory experience, it may offer insight upon multisensory processing in general. The *binding problem*, or the question of how sensory information is integrated to provide a unified experience of perception (Palmeri et al., 2002), is a challenging question. *Binding* applies to the question of how individual senses (modes) and how our senses work together (cross-modal). Further insights into synesthesia, both an intramodal and cross-modal

exception, may provide greater understanding of sensory integration considered “normal” perception.

### Characteristics and Properties of Synesthesia

Aside from a literal translation of the Greek origins of the word, what is synesthesia? Although there are varying definitions of synesthesia at present, and what makes one a synesthete, what is most agreed upon is that synesthesia constitutes as “mixing of the senses” (Kolb & Wishaw, 2003). Although “mixing of the senses” often implies a stimulus (inducer) triggering a response (concurrent) in another sense modality, such as hearing a spoken word provoking the experience of color, which could be called cross-modal, synesthesia also occurs with the inducer and concurrent belonging to the same sense modality (Grossenbacher & Lovelace, 2001). For example, a synesthete may see a number such as “4,” which may trigger the corresponding visual color orange, for that synesthete.

Synesthetic experiences occur involuntarily on the part of the synesthete – that is, that they follow automatically, and synesthetes cannot ignore their perceptions. Synesthesia is usually reported as being unidirectional, as in the example above of the number “4,” the color orange would not trigger the automatic conception of “4.” Although synesthesia can result from injury or from certain drug use, synesthesia in the sense that this researcher intends is present in synesthetes for as long as the synesthetes can remember, typically reporting experiencing it from early childhood onward.

Synesthetic perception is idiosyncratic and varies greatly among synesthetes. Typically, for colored language synesthetes, every letter of the alphabet, and every number from 0-9 will possess a particular color. The colors are highly specific; they are not simply pure shades such as red, yellow, blue, or green – synesthetes describe them in highly

detailed shades – not blue, but azure blue. Synesthetes, although many of them share the commonality of perceiving letters/numbers in color, often disagree on what colors the letters/numbers should be. For one synesthete, the number 7 may be an illuminated forest green; another may report it as being a “lovely shade of dark copper.”

Synesthetes describe their experiences as being consistent over time; numbers and letters do not change dramatically or at all in their perceived synesthetic colors. A number of experiments have tested comparisons between synesthetes and non-synesthetes in color/language associations, asking participants to “name the color” that goes with a given letter/word/number, and then re-administering the test at a later and unannounced time. Non-synesthetes typically are less than 50% in their consistency, with synesthetes maintaining consistency of reported colors at 90% or greater (Palmeri et al., 2002; Schilt et al., 1999).

### Forms of Synesthesia

No one knows for sure how many forms of synesthesia occur, and scientists and artists alike have offered differing numbers of forms of synesthesia. Sean Day (2004) reports that there are at least 39 forms of synesthesia, with colored language synesthesia being the most common form, with a 67.3% occurrence out of 695 synesthetes. Among other forms cited are pain to color, sounds to color. Other kinds also include tastes inducing color, as well as touch to color synesthesia. The synesthetic experience of color to inducers is by far the most common experience reported by synesthetes overall (Day, 2004).

An example of an unusual form of synesthesia would be taste/shape synesthesia, written about extensively by Cytowic in 1993 in his book “The Man Who Tasted Shapes.” Cytowic worked with a subject who would experience the tactile experience of shapes in response to shapes, revealing his synesthesia to Cytowic by commenting, “There aren’t



enough points on the chicken” (Cytowic, p. 3). This particular synesthete had experienced shapes in response to taste for as long as he could remember, and would report various tactile sensations such as “long, smooth, glass columns” in response to something “smooth” tasting, and would use his synesthetic experiences to help in his cooking (Cytowic).

Scientists often divide synesthesia into the two categories of either “associative” or “projected,” with associative (internal) synesthetes far outnumbering projectors (external synesthetes). Associative synesthesia is the synesthetic experience taking place in the “mind’s eye,” also termed “associative synesthesia” (Marks, 1973). For example, a synesthete that pairs a particular color with the letter “t” may visualize the “t” in their minds as having a particular shade of green. External synesthetes experience their perceptions as external – in this case, the synesthete actually sees that particular color of green externally, on the piece of paper on which the “t” is printed. External synesthetes report knowing that the letters are black, and that their colored perceptions are not “real,” but they do involuntarily project the colors and see them externally. Interestingly, projector synesthetes typically report that what they see does not interfere with their understanding of what is real and what is not real. They have no trouble in making that distinction, whereas, for example, people with schizophrenia cannot distinguish between what is real and what is not real when they visualize experiences in their external environments that are not real.

People with one form of synesthesia often have another form as well. Day’s (2004) tracking of forms of synesthesia indicates that over half of synesthetes with one form of synesthesia have other forms. Most experimental attention examines colored language synesthesia, due to it being the most common form. Future studies would benefit by asking

synesthetes questions to ascertain what various forms they may have and examining other forms besides colored language.

### Frequency of Synesthesia

At present, there is no set definition of synesthesia, which makes accurate estimates difficult. Estimates have ranged from as rare as 1:250,000 (Cytowic, 1998) to the more frequently reported 1:2,000 in Baron-Cohen's newspaper survey in 1996 to 1:200 (Ramachandran & Hubbard, 2003). As the definition of synesthesia broadens, scientists will most likely find more cases of synesthesia. Recent studies estimate the prevalence of synesthesia to be at least 1% of the world population (Simner, 2005).

### Etiology of Synesthesia

Developmental synesthesia is the most common form of synesthesia, experienced by the individuals since childhood, and the experiences remain stable over time. Synesthesia can also be acquired, due to injury or disease or a drug-induced state (pharmacological synesthesia) (Grossenbacher & Lovelace, 2001) For the purposes of this study, the researcher is concerned with, and is referring to developmental synesthesia when discussing experimental intentions.

### Synesthesia and Heredity

Among the studies conducted examining potential heredity of synesthesia, there is a commonality among them strongly suggesting that synesthesia may be genetically linked (Bailey & Johnson, 1997; Callejas, Smilek, Dixon, & Merikle, 2004; Cytowic, 1998; Galton, 1883; Ramachandran & Hubbard, 2003). The majority of studies to date are in favor of a dominant, X-linked genetic model in terms of heredity; the female-to-male ratios do not

reflect the expected numbers if the proportions of female and male synesthetes adhered closely to the dominant X-linked model (Callejas et al., 2004). Historically, females have been reported to experience synesthesia at a much greater rate than males, with reported female to male ratios of 7.7:1 in a sample of 26 affected individuals (Bailey & Johnson), and a female to male ratio of 4.3:1 in a sample of 300 synesthetes (Callejas et al.). More recently, however, a much more evenly divided ratio approximating 1:1 of synesthesia has been implicated in research (Simner, 2005). Many researchers have speculated that sampling of synesthetic participants has been gender-biased such that women may be more likely to report synesthetic experiences.

#### The Learned Association Theory

This theory posed by Calkins in 1893 (as cited in Harrison & Baron-Cohen, 1997) suggests that in colored-hearing synesthesia the colors perceived are a result of learned associations. Harrison and Baron-Cohen, in their review of theories of synesthesia, presented some plausible arguments to dispute this theory. The authors called into question the high ratio of female synesthetes to male synesthetes, for which Learned Association Theory cannot account. Also, there is an observed trend in the colored alphabets of synesthetes to describe colors for letters in close proximity to each other within the alphabet, and an examination of colored alphabet books does not reveal a similar trend. Harrison and Baron-Cohen also cite heterogeneity in the synesthetic experiences of synesthetic twins, arguing that twins experience similar learned associations growing up. Lastly, they noted that they had not encountered a synesthete who attributed their perceptions to learned associations.

## Cross-Wiring Theory

Ramachandran and Hubbard (2001a) proposed that some, if not all, forms of synesthesia result from neural cross-wiring in specific brain areas implicated in synesthetic perceptions. This theory argues for abnormal neural connections in the brains of synesthetes, either through excessive proliferation, or through a failure to prune during development from infancy to adulthood. Ramachandran and Hubbard (2001a) discussed area V4 (a higher visual area involved in color processing) and the language processing area, which are located adjacently within the fusiform gyrus. Ramachandran and Hubbard argued that brain regions that are in closer proximity to one another stand a higher chance of having “cross wiring” between them and that cross wiring in the fusiform gyrus is probably the neurological cause for most forms of synesthesia. Ramachandran and Hubbard (2001b) pointed out that the most common forms of synesthesia involved languages and colors, and as the correspondingly implicated brain areas are located adjacent to each other, argued a strong case for cross-wiring theory.

In a study conducted in 2001 on two synesthetes, JC and ER, Ramachandran and Hubbard (2001b) presented target graphemes to the participants in the center of a screen as the researchers moved the target grapheme gradually outwards, away from the center focus and into periphery of vision. Both subjects no longer saw the graphemes as “colored” at a critical distance, with JC and ER being consistent in the distance necessary for the colored grapheme to become non-colored. Ramachandran and Hubbard (2001b) argued that if synesthetic perceptions did indeed arise from memory associations, then the location of the grapheme as stimulus should not affect the synesthetic experience of a color. Interestingly, in this experiment, when researchers presented colored graphemes to JC and ER in their

peripheral visual fields, they accurately named the colors. Given that the area of V4 emphasizes central color vision and has been implicated in colored language synesthesia, it is particularly interesting that the synesthetic perceptions of JC and ER could be essentially removed by placing the stimulus (non-colored grapheme) farther away from the center of the screen, whereas perception of colored graphemes was not affected (Ramachandran & Hubbard, 2001b).

CHAPTER 3  
METHODOLOGY

Participants

I recruited participants with public advertising. I put fliers up in the Kansas City area. In addition, I recruited synesthetes at the American Synesthesia Association at the University of Texas in Houston, from October 28th to October 31st, 2005 by handing out fliers at the registration desk at the conference, as well as by word of mouth at the conference. All participants had self-reported normal or corrected-to-normal vision, hearing, and touch, as assessed by standard measures. After being interviewed, participants were assigned to one of three groups: Synesthetes with colored concurrents, synesthetes without colored concurrents, and non-synesthetes (see Table 1.).

Table 1

*Participant Demographics*

	Total (n)	Female	Male	Age <i>M(SD)</i>	Age Range
Colored concurrents	11	9	2	40.7(14.0)	21-61
Non-colored concurrents	3	2	1	44.7(21.5)	21-63
Non-synesthetes	21	11	10	28.1(10.7)	19-61

## Instruments

### *Vividness of Visual Mental Imagery*

The Vividness of Visual Imagery Questionnaire (VVIQ) (Marks, 1973) (see Appendix A) consists of four scenarios in which participants are asked to imagine and consider before their mind's eye, and then write down a number corresponding to their subjective vividness of the image. There are a total of 16 questions in which a participant is asked to rate the vividness of the visual imagery that comes to their mind's eye, both with the eyes open and then with the eyes closed. An example of a question from the VVIQ would be imagining a person the participant sees on a frequent basis, with the image in question being, "The exact contour of face, head, shoulders, and body." The responses in the VVIQ are made according to a 5-point scale: 1 – No image at all, you only 'know' that you are thinking of the object, 2 – Vague and dim, 3 – Moderately clear and vivid, 4 – Clear and reasonably vivid, 5 – Perfectly clear and as vivid as normal vision. The total scores for the Vividness of Visual Imagery for each individual participant were scored, adding the self-reported scores for the "eyes open" and "eyes closed" scenarios of the 16-item questionnaire. Scores ranged from 16 to 80.

Previous research on the VVIQ has indicated that it is a valid and reliable measure of vividness of mental imagery (LeBoutillier & Marks, 2001; McKelvie, 1995). In a study in which 263 participants were assessed with the VVIQ, split-half reliability was .88, and test-retest reliability was .74 (McKelvie, 1995).

### *Presence or Absence of Synesthesia*

The NIMH-Naropa Synesthesia Screening Interview (Synesthesia Screen) is used for detecting synesthetic experiences and assessing strength of concurrents (Grossenbacher,

2004a). Participants were asked a series of questions by the researcher, with the researcher writing down the participants' responses. Administration of the Synesthesia Screen typically requires one to two hours to complete (see Appendix B).

There are two forms of the Synesthesia Screen: Research and Clinical. This study utilized the lengthier but more thorough research version, and the descriptions that follow pertain to this version. Four sections of primary screening questions were included: Synesthetic Perception, Synesthetic Conception, Synattribution, and Knowledge of Synesthesia. Synesthetic Perception consists of ten questions asking about conscious experiences of sensory phenomena triggered by sensory stimulation. Synesthetic Conception consists of five questions asking about conscious experiences of sensory phenomena triggered by conceptual thought or affective feeling. Synattribution consists of six questions asking about conscious experience of non-sensory phenomena that are triggered by something not otherwise described in the other primary screening sections. Knowledge of Synesthesia is intended to gauge the participants' understanding of and familiarity with the term synesthesia.

The four sections all begin with primary questions, or questions that ask for a "yes" or "no" response to whether the participant has ever had the experience described in the primary question. If the participant answered "yes," then probe questions were asked. The researcher then asked for at least two specific examples from the participant in which the participant may have been describing inducers and concurrents indicative of synesthesia.

If the researcher determined that the examples were indicative of synesthesia, a series of additional parametric questions were then asked. The parametric questions involved how early the participant could remember having had such experiences, when the



most recent time was that they had the experience, and so on. An example of a parametric question is, “What is the youngest age at which you are pretty sure that letters had colors?” Parametric questions also asked about frequency, vividness over time in the participant’s life of the experiences, and potential moderating influences on synesthetic experiences.

In the current study, we focused on the parametric question asking about vividness of the most recent synesthetic experiences, with the vividness rated on a 7-point Likert scale. An example of this question in an interview would be: “During your most recent experiences of letters having colors, how vivid was the most vivid color you experienced? Use a scale from 1 to 7, 1 is no color sensation at all, you only have the idea of it. Seven is as distinct and clear as you have ever experienced in any circumstance.”

The Synesthesia Screen Manual (Grossenbacher, 2004b) delineates the criteria for a positive diagnosis of synesthesia. First, the participant had to respond “Yes” to a primary question asking about a class of inducers. After such a response, the following criteria must have been met: (1) There must be more than one inducer in the inducer set, such as the color forest green in response to both the numbers 3 and 6; (2) At least two different concurrents in response to two distinct inducers; (3) Concurrent attributes did not cohere; (4) The inducer-concurrent mapping was not something commonly experienced, such as feeling blue or shuddering in response to the sound of fingernails on a chalkboard. Meeting the criteria just described is sufficient to provide a positive diagnosis for synesthesia.

If the form of synesthesia involved colored concurrents in response to inducers, the synesthesia was categorized as being with colored concurrents. If the form of synesthesia involved concurrents perceived outwardly, the synesthete was categorized as having external

synesthesia. If the concurrents were perceived inwardly, or in the “mind’s eye,” the synesthete was categorized as having internal synesthesia.

### *Color Discrimination Ability*

The Farnsworth Munsell 100 Hue test (FM100) is commonly used in determining color vision abnormalities and testing color discrimination abilities (Dain, 2004; Kinnear & Sahraie, 2002). By the elimination and replacement in a series of Munsell colors, which originally consisted of 100 Munsell hues, 85 hues were used to comprise the FM100 test (Dain, 2004). The hue differences among these 85 hues are equivalent to each other in terms of being noticeable by people with normal color vision. Each hue color maps onto a particular position in Farnsworth Munsell color space, as depicted in the Farnsworth Uniform Chromaticity Scale Diagram. In this circular diagram, equal distances on this diagram represent equal differences of color to the normal eye. The positions of colors in this diagram begin at the top of the circular diagram, with a red hue being assigned the numeric value of 1, and then proceeding counter-clockwise to yellow, green (at the bottom of the diagram, with the midrange of 42 on the green portion of the test), blue, and purple before returning to the top of the circle, with the value of 85 near the top of the circular diagram preceding the number 1.

The FM100 test consists of four separate rectangular trays, each of which contains a linear array of colored plastic caps. The 22 hues in the first tray (85-21) range from red-yellow to yellow-green, the 21 hues in the second tray (22-42) yellow-green to green-blue, the 21 hues in the third tray (43-63) green-blue to blue-purple, the 21 hues in the fourth tray (64-84) blue-purple to purple-red. The color caps have the same chromaticity and value, with equal incremental hue variation on the top side of the caps, and are numbered on the

bottom side. The numbers on the bottom sides of the color caps correspond to the numbers of the hues in Farnsworth Munsell color space as described above.

At the start of the task, all but the two end caps were lined up outside of the tray in pseudorandom order. Individuals taking the test were asked to place the caps back into the tray in order of hue. In addition, the trays were presented to the participants in pseudorandom order.

To provide a standard broad-spectrum light source, artificial daylight was provided with the Graphic Technology Incorporated Color Matcher D65 lamps installed in a Graphic Technology Mini-Matcher light box 1E.

The FM100 test analysis software provided by GretagMacbeth, Inc. produced Total Error Scores (TES) for each participant. The researcher entered the participants' order of the color caps, and the software generated an error score reflective of the number of total errors. The FM100 test Total Error Scores placed an individual into one of three categories of color discrimination ability: Superior ( $TES \leq 16$ ), Average ( $20 \leq TES \leq 100$ ), and Low ( $TES > 100$ ) (Dain, 2004; Kinnear & Sahraie, 2002). About 16% of the population is assigned to the range of the Superior category, 68% to the Average category, and 16% to the Low category (Dain, 2004).

The FM100 test has been found to be a reliable and valid test for detecting color vision deficiencies (FM Scoring Software, 1976; Seshadri, Christenson, Lakshminarayanan & Bassi, 2005). In a study with 60 participants, 30 with congenital red-green deficiency and 30 with normal color vision, the FM100 test had a coefficient of agreement of 0.83 with the Nagel anomaloscope, and a 100% and 83.33% rates of sensitivity and specificity, respectively (Seshadri et al.). The FM100 test has been reported to have a test-retest

reliability of .83 in a sample of 300 participants, ranging in age from 15 to 45 years. An average reduction of 30% in Total Error Scores was observed between the first and second administration of the test.

### *Presence of Color Blindness*

In addition to asking participants if they had any color vision deficiencies, the Ishihara Test was used to screen for color blindness. Originally published in 1906, the Ishihara Test is considered the “gold standard” for fast identification of red-green color deficiency (Birch, 1997; Dain, 2004) (the most common form of color deficiency, estimated to affect approximately 5% of the population) (Spaulding, 2004). The Ishihara test consists of plates with numbers embedded in circles of isoluminant colored dots of varying sizes. Individuals taking the test are presented the plates one at a time and are asked to name the numbers embedded within the plates. Studies have indicated that the Ishihara test has sensitivities and specificities ranging from .85 to .95 (Birch, 1997; Dain, 2004). Participants with one or more errors on this test would have completed the FM100 test to be consistent with testing procedures and to double-check for color deficiency, but would have been excluded from the FM100 test data analyses. However, no participants had any errors on the Ishihara Test.

### Procedures

Testing was conducted on an individual basis in a quiet room at both sites. In the Sensory and Cognitive Neuroscience Laboratory in the Department of Psychology at the University of Missouri - Kansas City, all testing was done in a sound- and light-attenuating

chamber. In Houston, Texas, all testing was done in a hotel room on the premises of the University of Texas Medical Center.

Upon arrival, the researcher asked the participant to read and sign an informed consent form. The researcher explained the study and answered any general questions at that time. The participants were given a short survey requesting demographic information such as sex, age, and handedness (see Appendix C). Each participant was assigned an identification number on the demographics form that was used to identify the participants on the remaining tests.

Upon completion of the informed consent form and demographic survey, the participants were then administered the Ishihara test by the researcher. Next, participants were seated comfortably in front of the light box. Participants were then presented with the FM100 test and were asked to sort the color reference caps as described previously. Administration of the FM100 test was conducted according to the instructions in the FM100 test Scoring Software. Upon completion of the FM100 test, participants were then administered the VVIQ self-reporting their answers to the questionnaire. The researcher then administered the Synesthesia Screen (see Appendix B) to the participant as previously described. Each testing session lasted between one and two hours. At the end of testing, each participant was thoroughly debriefed, including another summary of the study's purpose, an explanation of the measures, and a brief description of the hypotheses being tested.

### Data Analysis

An Analysis of Variance (ANOVA) was conducted with synesthetes with colored concurrents, synesthetes without colored concurrents, and non-synesthetes as levels of the independent variable and Total Error Scores on the FM100 test as the dependent variable.

A two-way mixed ANOVA was conducted on the VVIQ total scores with the imagery condition of eyes open or eyes closed as the within-subjects factor and participant category of synesthetes with colored concurrents, synesthetes without colored concurrents, and non-synesthetes as the between-subjects factor, with overall VVIQ scores as the dependent variable. In addition, a one-way ANOVA was conducted with participant category of synesthetes with colored concurrents, synesthetes without colored concurrents, and non-synesthetes as the between-subjects factor, with overall VVIQ scores on the color subscale of the VVIQ as the dependent variable. Among synesthetes with colored concurrents, a logistical regression was conducted, with the self-reported concurrent vividness from the Synesthesia Screen as the predictor, and strength of the vividness scores on the color subscale of the VVIQ. Lastly, one-tailed t-tests were conducted to compare external and internal synesthetes on their overall VVIQ and vividness ratings of their concurrents as reported on the Synesthesia Screen.

All statistical tests were conducted using SPSS with the alpha value for significance set at .05. If significant differences were found, post hoc testing was conducted to ascertain the source(s) of the differences. To control for the effects of experiment-wise error rates, Bonferroni tests were used (Tabachnick & Fidell, 2001).

## CHAPTER 4

### RESULTS

Synesthetes scored slightly higher on overall VVIQ scores, but this difference was not significant. An independent samples t-test revealed no significant differences between synesthetes and nonsynesthetes and overall VVIQ scores [ $t(34) = -1.46, p=.16$ ] (see Table 2).

Table 2

*Vividness of Visual Imagery Questionnaire Total Scores*

	Total (n)	VVIQ Score $M(SD)$	Score Ranges
Synesthetes	14	121.4(15.1)	63-141
Non-synesthetes	21	113.7(14.19)	53-142

*Note.* Synesthetes in this table refer to both synesthetes with and without colored concurrents.

Synesthetes with colored synesthetic experiences did not report stronger vividness of visual imagery compared to non-synesthetes and synesthetes without colored concurrents on the color subscale of the Vividness of Visual Imagery Questionnaire. An independent samples t-test revealed no significant differences between synesthetes with colored concurrents and participants without colored concurrents and the color subscale of the VVIQ [ $t(34) = 0.50, p=.62$ ] (see Table 3).

Table 3

*Colored Concurrents and VVIQ Color Subscale Scores*

	Total (n)	Color Subscale <i>M(SD)</i>	Score Ranges
Colored concurrents	11	59.0(7.8)	46-70
No colored concurrents	24	57.6(7.7)	28-74

*Note.* “No colored concurrents” in this table refer to both non-synesthetes and synesthetes without colored concurrents.

Among synesthetes with colored concurrents, the vividness ratings of the concurrents from the Synesthesia Screen ( $M = 6.0$ ,  $SD = 1.5$ ,  $R = 4$ ) failed to correlate significantly with the strength of vividness ratings on the color subscale of the Vividness of Visual Imagery Questionnaire. A Pearson Correlation indicated no significant relationship between the vividness ratings of the concurrents from the Synesthesia Screen and strength of vividness ratings on the color subscale of the VVIQ ( $r = .15$ ,  $p = .67$ ).

Synesthetes with external concurrents ( $n = 4$ ) did not report stronger vividness ratings of their concurrents from the Synesthesia screen than synesthetes without external concurrents ( $n = 10$ ). An independent samples t-test revealed no significant differences between synesthetes with external concurrents ( $M = 6.75$ ,  $SD = 0.50$ ,  $R = 1$ ) and without external concurrents ( $M = 5.78$ ,  $SD = 1.56$ ,  $R = 4$ ) on vividness ratings of their concurrents from the Synesthesia Screen [ $t(13) = -.68$ ,  $p = 0.12$ ].

Synesthetes with external concurrents reported slightly lower vividness of visual imagery as compared to synesthetes without external concurrents. An independent samples



t-test revealed no significant differences between synesthetes with external concurrents ( $M = 117.25$ ,  $SD = 15.96$ ,  $R = 39$ ) and without external concurrents ( $M = 123.50$ ,  $SD = 15.22$ ,  $R = 78$ ) on overall VVIQ scores [ $t(13) = 0.66$ ,  $p = .52$ ].

Synesthetes with colored concurrents scored significantly lower than synesthetes without colored concurrents and non-synesthetes on the FM 100 test in TES scores. A One-Way ANOVA indicated a significant difference between groups on the FM 100 test [ $F(2,28) = 2.67$ ,  $p = .03$ ], with participants with colored concurrents having lower TES scores ( $M = 20.40$ ,  $SD = 11.23$ ) than synesthetes without colored concurrents ( $M = 34.00$ ,  $SD = 8.49$ ) and participants without synesthesia ( $M = 34.63$ ,  $SD = 18.14$ ) (See Figure 1).

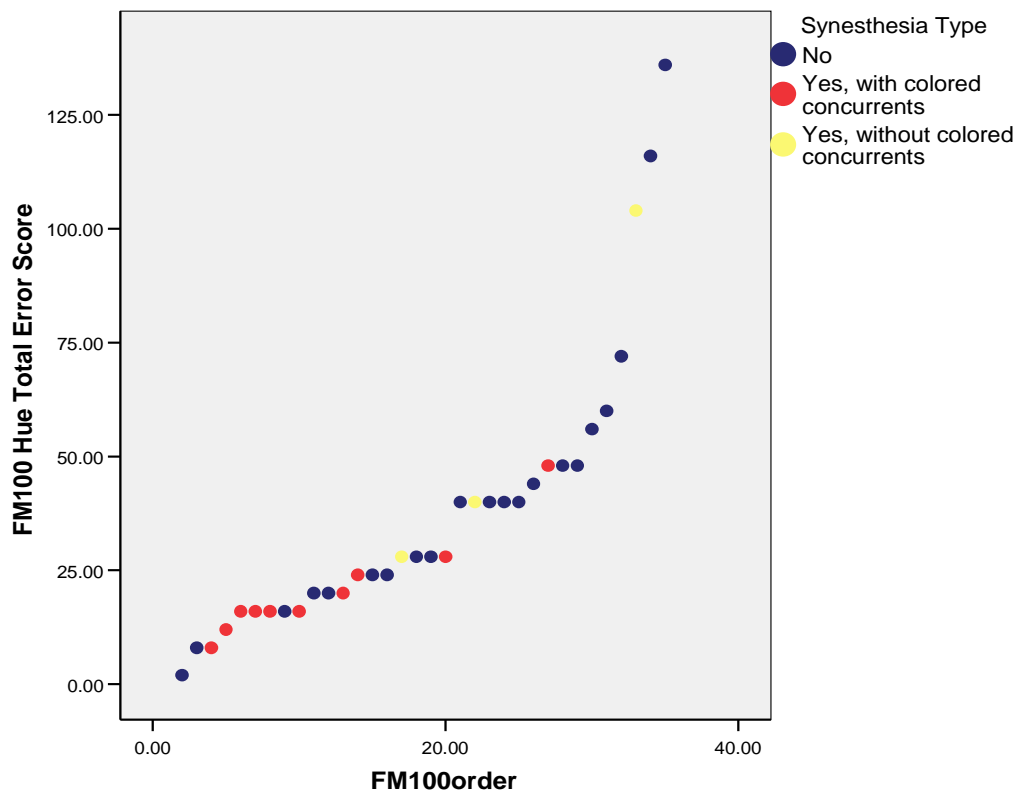


Figure 1. FM100 Hue Total Error Scores

## CHAPTER 5

### DISCUSSION

Overall, no significant results were found regarding vividness of visual imagery and synesthesia. Although synesthetes scored slightly higher than non-synesthetes regarding overall vividness of visual imagery, this difference failed to reach significance. Results of a power analysis indicated that, with a sample size of 88 participants, the trend of synesthetes reporting greater vividness of visual imagery would have reached significance at the .05 level. It is possible that differences in vividness of visual imagery between synesthetes and non-synesthetes are present, but a greater sample size is needed in order to find reliable differences.

No significant results were found when examining synesthetes with colored concurrents compared to synesthetes without colored concurrents with respect to vividness of visual imagery when visualizing colors. Within an already modest sample size, there were few synesthetes without colored concurrents to compare to synesthetes with colored concurrents. A greater sample size would help to further explore whether such visualizing color differences may be found with respect to presence or absence of color concurrents in synesthetic experiences.

In addition, no significant correlation was found between vividness of colored concurrents and vividness ratings of visualizing colors. Given that most synesthetes, when asked to rate their vividness of colored concurrents, reported the highest or second-to

highest ranking on a Likert scale, this may reflect a limited amount of variability in data in addition to a limited sample size.

Synesthetes with external concurrents did not report stronger overall vividness of visual imagery or stronger vividness of their concurrents when compared to synesthetes with internal concurrents. Although the rationale was that external concurrents might be more vivid in nature than internal concurrents, it is possible that external or “projected” synesthesia does not affect vividness of visual imagery differentially. As noted above, this experiment was limited in number of synesthetes, especially when grouped according to location of concurrents.

Synesthetes with colored concurrents made significantly fewer errors on the FM 100 test than synesthetes without colored concurrents and non-synesthetes. As predicted, they demonstrated better color discrimination ability on this standard color discrimination task. Since color discrimination ability declines with age beginning around the age of 20, the synesthetes with colored concurrents in this experiment would have been predicted to perform significantly worse than the synesthetes without colored concurrents and non-synesthetes, given that the color synesthetes were approximately ten years older as a group (Mantjarvi, 2001). However, the synesthetes with colored concurrents still demonstrated better color discrimination ability when compared with the other two groups.

Synesthetes with colored concurrents, experienced automatically and on a regular basis, whether in the mind’s eye or external, may involuntarily have more experience with fine shades of color. There have been many reports of synesthetes being very particular in their descriptions of their colored concurrents – for example, not simply “blue” but “azure blue, with a greenish tint to it” for an inducer. Perhaps this extra experience with color

accompanying the sensory experience of synesthesia with colored concurrents provides for better color discrimination in the veridical domain.

As mentioned previously, “Experienced” color discriminators (those working in occupations where they were expected to work with colors on a daily basis) had significantly better color discrimination as compared to the remaining participants in the FM 100 normative sample (FM Scoring Software, 1976). In addition, Hubbard (2007) recently reported findings indicating more activity in the color-processing areas of the brain in synesthetes when compared with non-synesthetes during neuroimaging.

As previously discussed, much research in recent years has focused upon addressing the questions of what synesthesia may involve in terms of synesthetic experiences, but little research has explored potential effects of synesthesia in the veridical domain. Although this experiment did not find significant differences in reported vividness of visual imagery between synesthetes and non-synesthetes, a striking difference was found in color discrimination ability. The experiment here is, to my knowledge, one of the first attempts to examine how synesthesia may affect non-sensory synesthetic experience. As researchers continue to explore the perceptual and sensory phenomena of synesthesia, they will also benefit from examining how this sensory ability may also influence other non-synesthetic sensory experiences of synesthetes.

APPENDIX A

VIVIDNESS OF VISUAL IMAGERY QUESTIONNAIRE (VVIQ) (Marks, 1973)

Rating	Description
1	'No image at all, you only "know" that you are thinking of the object'
2	'Vague and dim'
3	'Moderately clear and vivid'
4	'Clear and reasonably vivid'
5	'Perfectly clear and as vivid as normal vision'

For items 1-4, think of some relative or friend whom you frequently see (but who is not with you at present) and consider carefully the picture that comes before your mind's eye.

	Eyes Open	Eyes Closed
1. The exact contour of face, head, shoulders, and body.	_____	_____
2. Characteristic poses of head, attitudes of body, etc.	_____	_____
3. The precise carriage, length of step, etc., in walking.	_____	_____
4. The different colors worn in some familiar clothes.	_____	_____

Visualize a rising sun. Consider carefully the picture that comes before your mind's eye.

	Eyes Open	Eyes Closed
5. The sun is rising above the horizon into a hazy sky.	_____	_____
6. The sky clears and surrounds the sun with blueness.	_____	_____
7. Clouds. A storm blows up, with flashes of lightning.	_____	_____
8. A rainbow appears.	_____	_____

Think of the front of a shop, which you often go to. Consider the picture that comes before your mind's eye.

	Eyes Open	Eyes Closed
9. The overall appearance of the shop from the opposite side of the road	_____	_____

10. A window display including colors, shapes and details of individual items for sale. \_\_\_\_\_
11. You are near the entrance. The color, shape and details of individual items for sale. \_\_\_\_\_
12. You enter the shop and go to the counter. The counter assistant serves you. Money changes hands. \_\_\_\_\_

Finally, think of a country scene, which involves trees, mountains and a lake. Consider the picture that comes before your mind's eye.

- |                                                                      | Eyes Open | Eyes Closed |
|----------------------------------------------------------------------|-----------|-------------|
| 13. The contours of the landscape.                                   | _____     | _____       |
| 14. The color and shape of the trees.                                | _____     | _____       |
| 15. The color and shape of the lake.                                 | _____     | _____       |
| 16. A strong wind blows on the trees and on the lake, causing waves. | _____     | _____       |

----- Stop Here -----  
*(This portion for the researcher's use)*

- |                                                          |       |
|----------------------------------------------------------|-------|
| Eyes Open                                                | _____ |
| Eyes Closed                                              | _____ |
| TOTAL (add all items):                                   | _____ |
| Shape only (add items 1, 2, 5, 9, 10, 11, 13, 14, & 15): | _____ |
| Color only (add items 4, 5, 6, 8, 10, 11, 14, & 15):     | _____ |
| Movement only (add items 3, 7, 12, & 16):                | _____ |

APPENDIX B

NIMH-NAROPA SYNESTHESIA SCREEN INTERVIEW (RESEARCH VERSION)  
Naropa University Consciousness Laboratory (© 2004 Peter Grossenbacher)

Screen Session Logged: \_\_\_\_\_ Data Entered: \_\_\_\_\_

Staff Inits: \_\_\_\_\_ Today's Date (m/d/y): \_\_\_\_/\_\_\_\_/\_\_\_\_

Start Time: \_\_\_\_\_ End Time: \_\_\_\_\_ MinutesTotal: \_\_\_\_\_

First: \_\_\_\_\_ Last: \_\_\_\_\_

Participant ID#: \_\_\_\_\_

Participant Age: \_\_\_\_\_ Participant Sex: \_\_\_\_\_

Interview Medium: telephone in-person (circle one)

**Section I: Synesthetic Perception**

Sometimes, something experienced in *one* of the five senses triggers extra sensations in *another* sense. Here is an example to give you an idea of how this could work. Suppose when you touch something hard like concrete, you get the smell of **vanilla**, or when you touch something soft like cotton, you get the taste of **salt**.

To find out if you've had any such experience ever in your life, I'm going to go through a series of Yes-or-No questions. Say "Yes" if it seems clear to you that you have had the experience in question, otherwise say "No." If nothing comes to mind within a few seconds, we will go on to the next question. If you are unsure how to answer any question, please say so.

If at any time something comes up in response to an earlier question, then tell me right away. Also, let me know if you don't understand something.

I will be taking notes, and may pause from time to time as my writing catches up. Do you have any questions, or shall we get started?

Details Noted

<b>S1.</b> Has any sense other than your sense of hearing ever produced an experience of <b>hearing</b> anything?	Yes No
<b>S2.</b> Has any sense other than your sense of sight ever produced an experience of <b>seeing</b> anything?	Yes No
<b>S3.</b> Has any sense other than your sense of smell ever produced an experience of <b>smelling</b> anything?	Yes No
<b>S4.</b> Has any sense other than your sense of touch ever produced an experience of <b>touching</b> anything or feeling a skin sensation?	Yes No
<b>S5.</b> Has any sense other than your sense of bodily position ever produced an experience of feeling a particular <b>body position or movement</b> , such as arms out or waist bending, even if you are <b>not</b> in that posture or movement?	Yes No
<b>S6.</b> Has any sense other than your sense of taste ever produced an experience of <b>tasting</b> anything?	Yes No
<b>S7.</b> Has <b>being startled</b> ever had location, shape, color, texture, movement, weight, sound, smell, taste, or any other sensation?	Yes No
<b>S8.</b> Have shapes, shades of gray, colors, or anything that you <b>see</b> ever had location, shape, color, texture, movement, or any other sensation other than how they're printed?	Yes No
<b>S9.</b> Have <b>numbers</b> that you see or hear ever had location, shape, color, texture, movement, weight, sound, smell, taste, or any other sensation other than how they're printed?	Yes No
<b>S10.</b> Have <b>letters</b> of the alphabet or <b>words</b> that you see or hear ever had location, shape, color, texture, movement, weight, sound, smell, taste, or any other sensation other than how they're printed?	Yes No
<b>S11.</b> Have you ever experienced <b>anything similar</b> to what we have been talking about so far that has not been mentioned yet?	Yes No

TimeCheck: \_\_\_\_\_ MinutesElapsedDuringSynestheticPerception: \_\_\_\_\_



## Section II: Synesthetic Conception

Sometimes, an idea or concept triggers a sensory experience, or sensation. The thought and the sensation go together, so when you have the thought, the sensation happens with it. Sensations may include location, shape, color, texture, movement, weight, sound, smell, taste, etc.

Here is an example to give you an idea of how this could work. Suppose you hear a **high-pitched sound** whenever you think about wealth, or thinking about infinity produces a **skin sensation on your left ankle**.

To find out if you've had any such experience ever in your life, I'm going to go through a series of Yes-or-No questions. Say "Yes" if it seems clear to you that you have had the experience in question, otherwise say "No." If nothing comes to mind within a few seconds, we will go on to the next question. If you are unsure how to answer any question, please say so.

If at any time something comes up in response to an earlier question, then tell me right away. Also, let me know if you don't understand something. OK?

Details Noted

<b>C1.</b> When thinking about <b>numbers</b> in any context, have they ever had location, shape, color, texture, movement, weight, sound, smell, taste, or any other sensation?	Yes No
<b>C2.</b> When you have felt <b>any emotion</b> , has that ever had location, shape, color, texture, movement, weight, sound, smell, taste, or any other sensation?	Yes No
<b>C3.</b> When thinking about any <b>periods of time</b> , such as minutes, hours, days, weeks, months, seasons, years, or periods of history, etc., have they ever had location, shape, color, texture, movement, weight, sound, smell, taste, or any other sensation?	Yes No
<b>C4.</b> When thinking about <b>places or geographic locations</b> , have they ever had shape, color, texture, movement, weight, sound, smell, taste, or any other sensation?	Yes No
<b>C5.</b> Have you ever experienced <b>anything similar</b> to what we have been talking about that has not been mentioned yet?	Yes No

TimeCheck: \_\_\_\_\_ MinutesElapsedDuringSynestheticConception: \_\_\_\_\_

### Section III: Synattribution

Sometimes, an experience includes a sensed quality. The experience and the sensed quality go together, so when you have the experience, the sensed quality happens with it. Sensed qualities may include personality, gender, age, evenness or oddness, atmosphere, et cetera.

Here is an example to give you an idea of how this could work. Suppose you experience the number 5 as mean, or the color red produces a sense of evenness.

To find out if you've had any such experience ever in your life, I'm going to go through a series of Yes-or-No questions. Say "Yes" if it seems clear to you that you have had the experience in question, otherwise say "No." If nothing comes to mind within a few seconds, we will go on to the next question. If you are unsure how to answer any question, please say so.

If at any time something comes up in response to an earlier question, then tell me right away. Also, let me know if you don't understand something. OK?

Details Noted

<b>N1.</b> Have you ever experienced a <b>personality</b> characteristic or attitude as part of something other than a person or other being?	Yes No
<b>N2.</b> Have you ever experienced <b>gender</b> , such as male or female, as part of something other than a person or other being?	Yes No
<b>N3.</b> Have you ever experienced <b>evenness or oddness</b> as part of something other than a number or numeric quantity?	Yes No
<b>N4.</b> Have you ever experienced youth, elderliness, or any <b>age</b> as part of something other than someone or some thing that actually has age?	Yes No
<b>N5.</b> Have you ever experienced <b>mood or emotion</b> as part of something that does not actually have mood or emotion?	Yes No
<b>N6.</b> Have you ever experienced anything similar to what we have been talking about that <b>has not</b> been mentioned yet?	Yes No

TimeCheck: \_\_\_\_\_ MinutesElapsedDuringSynattribution: \_\_\_\_\_

## Section IV: Knowledge

### Verbal Response

**K1.** Have you ever heard of “synesthesia?”

“Yes” “No”

**{If has heard:}** **K2.** Do you know what synesthesia is?

“Yes” “No”

**{If does know:}** **K3.** In your own words, what is synesthesia?

**{If does know:}** **K4.** Have you ever experienced synesthesia?

“Yes” “No” Unsure

**{If Yes or Unsure, that is, possibly has experienced synesthesia:}**

**K5.** What kinds of synesthesia have you experienced?

**{If mentions any form not already discussed: Ask secondary questions.}**

**K6.** It is important that we have not missed anything or gotten something wrong. So is there anything you’d like to go over again?

“Yes” “No”

End Time: \_\_\_\_\_

## Secondary Questions: Examples, Inducers, and Concurrent Attributes

{Example 1:} Please give me an example. {Example 2:} Please give me another example.

{> If has mentioned only a partial subset of a known inducer set, ask until answer is no: }

{Inducers:} Have any [known inducers] other than [mentioned inducers] had [concurrent]?

{> Ask until answer is no: }

{More Concurrent Attributes:} Have [inducers] ever had anything besides [concurrent]?

### Parametric Questions

A. {Locus:} With [inducers] having [concurrent attribute], where have you experienced the [concurrent attribute]?

B. {Age:} How old were you when [inducers] first had [concurrent]?

C. {Cause:} Do you know of any event that may have caused [inducers] to have [concurrent]?

*{if Yes:} D\*. What may have caused [inducers] to have [concurrent]?*

E. {Recent:} How long ago was the most recent time that [inducers] had [concurrent]?

F. {Condition (Med & Spec):} With [inducers] having [concurrent], has that happened **only** in specific circumstances, such as having taken a drug or medication, or while in any particular state of mind?

*{if Yes:} G\*. What are the specific circumstances?*

H. {Count:} How many times in your life have [inducers] had [concurrent]?

*{if count > 2 & < 5:} I\*. How old were you each time [inducers] had [concurrent]?*

*{if count > 4:} J. {Stop:} Have [inducers] ever stopped having [concurrent] [condition]?*

*{if Yes:} K. {stopAge:} How old were you when [inducers] first no longer had [concurrent] [condition]?*

*{if Yes:} L. {stopDur:} For how long had [inducers] stopped having [concurrent] [condition]?*

*{if Yes:} M. {stopWhy:} Do you have any idea why [inducers] stopped having [concurrent]?*

**{if count > 4:}** N. {absFreq:} During your most recent experiences of [inducers] having [concurrent], **how many times** per day or month or other time period was there [concurrent]?

**{if count > 4:}** O. {relFreq:} During your most recent experiences of [inducers] having [concurrent], in those instances of [perceiving] [inducers] {condition}, what percent of the time was there [concurrent]?

**{if count > 4:}** P. {MoreFreq:} Was there ever a time in your life when, for those occasions that you [perceived] [inducers] {condition}, they had [concurrent] **more** than during your most recent experiences of [inducers] having [concurrent]?

**{if Yes:}** Q. {+age:} How old were you when, for those occasions that you [perceived] [inducers] {condition}, they had [concurrent] the **most**?

**{if Yes:}** R. {+freq:} Back then, when you [perceived] [inducers] {condition}, what percent of the time was there [concurrent]?

**{if count > 4 & never stopped:}** S. {less:} Was there ever a time in your life when, for those occasions that you [perceived] [inducers], they had [concurrent] **less** than during your most recent experiences of [inducers] having [concurrent]?

**{if Yes:}** T. {-age:} How old were you when, for those occasions that you [perceived] [inducers], they had [concurrent] {condition} the **least**?

**{if Yes:}** U. {-freq:} Back then, when you [perceived] [inducers], what percent of the time was there [concurrent]?

V. {Vivid:} During your most recent experiences of [inducers] having [concurrent], **how vivid** was the **most vivid** [concurrent] you experienced? Use a scale from 1 to 7, 1 is no [concurrent] sensation at all, you only have the **idea** of it. 7 is [concurrent] as distinct and clear as you have ever experienced in any circumstance.

W. {MoreVivid:} Was there ever a time in your life when [inducers] had [concurrent] **more vivid** than during your most recent experiences of [inducers] having [concurrent]?

**{if Yes:}** X. {+age:} How old were you when [inducers] had the **most** vivid [concurrent]?

**{if Yes:}** Y. {+viv:} Back then, when you [perceived] [inducers], **how vivid** was the **most vivid** [concurrent] you experienced? Use a scale from 1 to 7, 1 is no [concurrent] sensation at all, you only have the **idea** of it. 7 is [concurrent] as distinct and clear as you have ever experienced in any circumstance.

Z. {Purpose:} With [inducers] having [concurrent], has that happened **only** on purpose? Or did you ever not mean for [inducers] to have [concurrent] but they did anyway?

AA. {Prefer:} On a scale of 1 to 7, would you prefer that [inducers] have [concurrent], or not? 1 is strongly preferring that [inducers] **not** have [concurrent], 7 is strongly preferring that [inducers] **do** have [concurrent], 4 is no preference either way.

{>> Ask until answer is no: }

AB. {Other:} Is there anything else important about [inducers] having [concurrent] that has not been mentioned yet?

APPENDIX C

SCNL DEMOGRAPHICS FORM

Subject ID #: \_\_\_\_\_

PI/ Research Assistant Initials: \_\_\_\_\_

**SCNL Demographics Form**

Date (mo/day/yr): \_\_\_\_\_/\_\_\_\_\_/\_\_\_\_\_ Time: \_\_\_\_\_

Age \_\_\_\_\_

Sex: MALE FEMALE

Left-handed, ambidextrous, or right-handed? LEFT AMBI. RIGHT

5 Minute Hearing Test Score \_\_\_\_\_

Vision Test Score \_\_\_\_\_

Study Name \_\_\_\_\_

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## VITA

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