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# Sculpting Sound and Painting Music: A Study, Documentary, and Art Exhibition

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# Locating Commonalities in the Perceptions of Colored-Hearing Synesthetes

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## Abstract

Synesthesia, often referred to as a blending of the senses, is known for its involuntary and automatic perceptual responses. Generally, synesthetic perception is known to be quite varied, both in the types of synesthesia and in the perceptions amongst individuals within each of these types. Despite this, a few commonalities have been located in populations of color-grapheme synesthetes, those who perceive letters and numbers with colors. We aimed to similarly locate potential commonalities in the perceptions of a population of colored-hearing synesthetes, those who have visual responses with auditory stimulation.

## Introduction

Synesthesia is a perceptual condition in which individuals, synesthetes, experience an automatic and involuntary blending of the senses. As with anesthesia, meaning an absence of sensation, synesthesia is derived from Greek and means a combination of the senses (Fernay, 2012).

There are many forms of synesthesia, and while not all have been scientifically investigated, 66 varieties have been reported (Simner, 2010). Synesthetes may have visual perceptions of sounds, tastes, sensations, smells, and even their concepts of time, letters, and numbers. While the most commonly investigated types of synesthesia usually involve visual modalities, synesthesia can emerge in any combination of the senses, such as a physical sensation resulting from a certain sound (Barnet, 2008). Scientific knowledge of synesthesia first emerged in the late 1800's, but references to this perceptual phenomenon have been noted in literature as early as the Bible (Jewanski & Simner, 2011). Some argue that most literary accounts are merely a result of creative metaphor. Current theories do suggest, however, that as long as human beings have been around, it is likely that synesthesia has been around (Duffy & Simner, 2010).

One of the more popular explanations of the occurrence of synesthesia reasons that all people are born with its capacity. As neonates, all humans could

have “cross talk” between their senses. As most people grow older, however, *most of* these cross modality connections are lost during the neural pruning that occurs during infancy (Eagleman, 2009). There is currently no conclusive explanation as to why about 4 percent of the population remains synesthetic. Increased excitation and decreased inhibition have been suggested, but neither confirmed (Neufeld et. al., 2012).

For the 4 percent that do have synesthesia, their perceptions are typically very individual. While one synesthete may hear a trumpet as blue, another may hear the same note as bright red. It is not yet known as to why this variation occurs amongst synesthetes (Fernay, 2012).

At the same time, there are some documented consistencies across synesthetes in their cross-modal perceptual experience. Prior perceptual commonalities have been identified in studies of color grapheme synesthetes: those who see consistently colored letters and numbers. In this study, synesthetes perceived ‘A’s as red and ‘O’s as white at greater-than-chance levels (Simner et al., 2005). To our knowledge, consistencies in synesthetic perception have not yet been investigated amongst colored-hearing synesthete populations. It is this topic that is the focus of the current project.

We aimed to locate various underlying consistencies amongst the perceptions of colored hearing synesthetes: those who have visual perceptions in response to auditory stimuli. These synesthetes can have multiple components to their perceptions, such as shape, color, texture, size, and location within the perceptual field. While it is possible for synesthetes to have all of these components to a perception, it is also possible for them to only have some (Eagleman, 2009). For example, a synesthete may only perceive color and not any other component, such as texture. It is also possible for a synesthete to perceive multiple colors or textures. A synesthete may view a trumpet note as two colors at once, as synesthetes can have multiple perceptions simultaneously for the same sound (Eagleman, 2009).

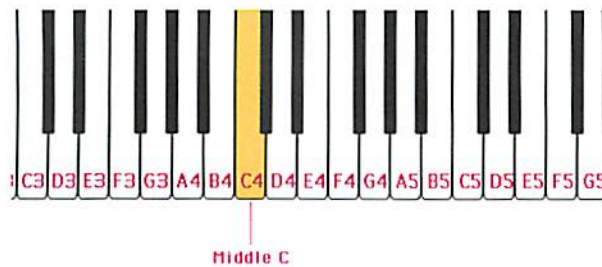
While it seemed that the perceptions of synesthetes varied greatly depending on the individual, we wished to explore possible similarities. Categories of possible similarities we investigated included those in Color, Texture, Shape, Size, and Spatial



Position. This data would then be compared to that collected from a control group given the same set of auditory stimuli.

## Methods

Audio clips were played by a computer and consisted of 6 pure tones and 5 instruments. The tones matched the frequencies of C3, G3, C4, G4, C5 and G5 (see piano diagram below). The instruments used, all in C3, were piano, strings, flute, trumpet, and cymbals. The tones ranged from 130 hertz to 784 hertz, at each of the above increments. The clips were all 3-4 seconds long and were played at the same level of loudness.



This selection of tones and instruments was chosen to represent a variety of auditory sounds and was hoped to evoke a variety of perceptual responses. The variety in the pure tones (e.g. 130 hertz versus 261 hertz) was hoped to evoke trends of perceptions relevant to pitch. The variety in instruments was hoped to evoke trends of perceptions relevant to tone and/or timbre.

## Participants

Self-identified colored hearing synesthetes and control participants were recruited through local advertising and by providing information to synesthetes who had previously participated in a documentary about the condition. Other participants, often siblings or acquaintances of other participants, became involved in the study through word of mouth.

Participants recruited were synesthetes aged 14 and up, with a mean age of 18.1 years. Control subjects were aged matched to the synesthete population, and

participants aged 14-20 were accepted. The control population had a mean age of 18.5 years.

The synesthete population was comprised of 12 female and 3 male participants. The control group consisted of 8 male and 7 female participants. For both populations, age and the presence/absence of colored hearing synesthesia were the only excluding factors for participation.

All participants were compensated \$10 per hour, prorated at \$2 every fifteen minutes. Subjects gave informed consent according to the guidelines of the Institutional Review Board of the University of Connecticut.

### **Materials**

The audio clips were first played using an online server, *surveysurvey.com*, and were later played using a standard MacBook sound program when the server unexpectedly ceased operation.

**COLOR TASK:** Participants used a color chart (see fig. 1) in order to most accurately convey their perceptions for color. A letter-number identification system was implemented for easier and more specific color identification.



Figure 1

**SPACIAL POSITION TASK:** A standard coordinate grid (see fig. 2) was used for participants to identify the spatial position of their perceptions. Participants marked the center of their perception, which was recorded using standard (x,y) coordinates.

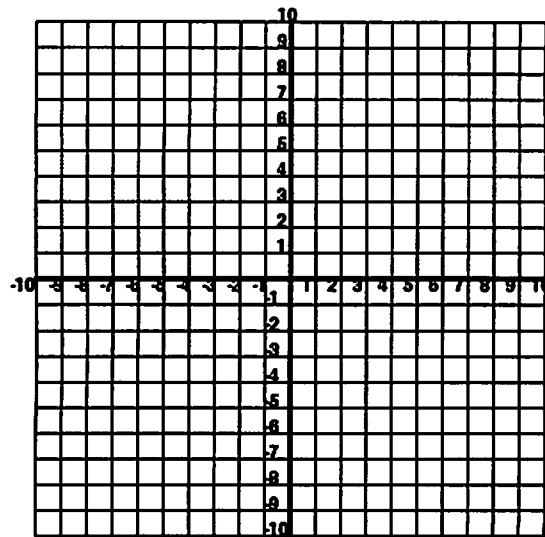


Figure 2

**SHAPE, TEXTURE, AND SIZE TASK:** Participants responded to the remaining sections (shape, texture, and size) using a set of predetermined choices (see figs. 3-5 Appendix A).

The first five participants responded online at *surveysurvey.com* in a survey style answer selection. When this online server unexpectedly ceased operation, later participants recorded their responses on a paper chart in the same format

**Figures 3-5**

**Shape**

- Triangle
- Quadrilateral
- Abstract Round
- Abstract Linear
- Abstract Spikey
- No Shape, just solid color
- Other (elaborate) \_\_\_\_\_
- None
- Skip

**Texture**

- Rough
- Smooth
- Sharp
- Soft
- Other (elaborate) \_\_\_\_\_
- None
- Skip

**Size**

- Miniscule – barely there
- Small – occupies less than ¼ of perceptual field
- Medium – occupies ¼ - ½ of perceptual field
- Large – occupies ½ - ¾ of perceptual field
- Very Large – occupies ¾ to just under whole field
- Whole – occupies entire perceptual field
- Other (elaborate) \_\_\_\_\_
- None
- Skip

***Procedure***

Participants were recruited locally in southeastern Connecticut and were tested in East Lyme, Connecticut. Participants from both the control group and the synesthete population were tested using the same procedures. A population of colored hearing synesthetes and a population of like-aged non-synesthetes were given a set of auditory stimuli to respond to.

There were 5 sections of testing. Each section tested one perceptual dimension. These dimensions were Color, Shape, Texture, Size, and Spatial Position. Participants finished each section separately before moving onto the next. Each of the Shape, Texture, and Size sections had a set of predetermined answers with an “other” option. Participants were instructed to only use this option if their perception fell under none of the listed choices. Participants would then be asked to define the perception they listed as “other” to avoid ambiguity. Participants could also put down more than one perception if they occurred simultaneously.

The 11 audio clips, comprised of the tones and instruments, were played 5 times per each section to note the participants’ consistency. They were played in random order. For example, listeners heard the trumpet noise five different times for the color task.

An online survey system was used to play the clips and gather participant responses. When this server was discontinued and taken offline without warning, participants then responded using a chart with pen and paper. The clips were still played on a computer, offline, and were still played in random order, 5 times per section. Data that was not yet exported from the online server was redone, and two participants, SYN1 and SYN2 were retested and compensated for their additional time.

Testing took an average of 57.2 minutes per participant.

## **Analysis**

The synesthete population would be first compared to the control population to observe consistency amongst responses for each visual dimension.

### ***Response Consistency***

There were three categories of consistency analyzed: Individual-clip consistency, individual-dimension consistency, and group consistency. Consistency was tested 1) because our synesthete population was self-identified and 2) to locate potential commonalities amongst synesthete populations.

**Individual-clip consistency:** Individual-clip consistency was observed as a test of genuineness, as this was a population of self identified synesthetes. It was a measure of a participant's modal response for each sound clip of a visual dimension. (e.g. a participant viewed Trumpet as the same color 5/5 times.) Any synesthete data with less than 3/5 consistency in their responses per audio clip was placed in a category labeled "inconsistent" for that audio clip. The same was done for control participant responses. Individual-clip consistency was measured to gather modal responses for participants' perceptions. Results declaring a participant's perceptions were only charted if they had individual-clip consistency.

**Individual-dimension consistency:** Individual-dimension consistency was the measure of how often a participant had individual-clip consistency for a whole visual dimension. (e.g. a participant had individual-clip consistency for 10/11 audio clips played for the color dimension.) This measure of consistency was used to determine if a synesthete's responses should be omitted from a visual dimension.

If synesthete responses had individual-dimension consistency for less than 8/11 audio clips, data would be omitted from that visual dimension. Because synesthetes can often have strong perceptions for some, but not all of the visual dimensions tested in the study, synesthetes reported as 'inconsistent' in one visual dimension would not be removed from the study entirely. Control participant responses reported as inconsistent remained included in the study, as this is characteristic of non-synesthete responses (Eagleman, 2009).

**Group consistency:** Group consistency measured how consistent participants were as a population for each clip of each dimension. (e.g. 90 percent of synesthetes viewed the same sound as a certain color.) This measure of consistency was used to locate commonalities in the perceptions of the synesthete population.

### **Qualitative Grouping**

Potential commonalities in participant perception were grouped according to the following criteria.

**Color Responses:** Color responses were grouped by their 'temperatures.' Warm colors were classified as those in the A, B, C, D, & H columns of the color chart.



These were hues of red, red-violet, orange, yellow, and brown. Cool colors were classified as those in the E, F, G, I (first four shades of grey in I column), & J columns. These were shades of green, blue, blue-violet, teal, and grey. White and Black (fifth color in I column) were classified as neutral colors. (See fig. 1 above for color chart).

**Shape Responses:** Shape responses were kept in individual categories of Triangle, Quadrilateral, Abstract Round, Abstract Linear, Abstract Spikey, and Solid Color.

**Texture Responses:** Texture responses were grouped according by their coarseness. Rough and Sharp were classified as coarse textures. Soft and Smooth were classified as non-coarse textures. Participants who opted to use the “other” option for their texture response designated “Ripple” as a texture. This was defined by all (2) participants as very smooth bumps. “Ripple” was added to the non-coarse texture list.

**Size Responses:** Size responses were grouped according to the amount of the perceptual field the perception occupied. By the definitions given to the synesthetes (see figure 4, above), Miniscule, Small, and Medium perceptions occupied  $\frac{1}{2}$  or less of the perceptual field. Large, Very Large, and Whole perceptions occupied more than  $\frac{1}{2}$  of the perceptual field.

**Spatial Position Responses:** Spatial Position responses were grouped according to their nearness to the center of the perceptual field. The following diagram grouped perceptions into 3 sections. Area 1 contained perceptions perceived within 3.3 units of the origin. Area 2 contained perceptions between 3.3 and 6.6 units from the origin. Area 3 contained perceptions between 6.6 and 10 units from the center.

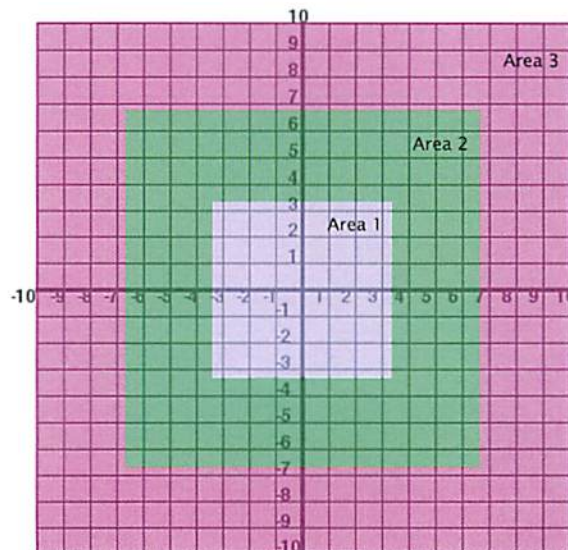
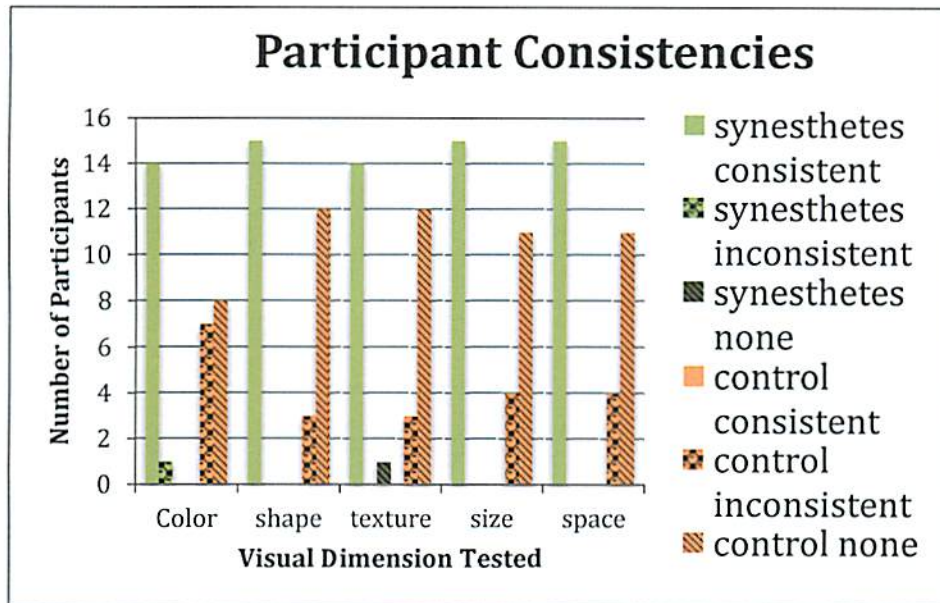


Figure 6

## Results

The following responses were gathered to measure participant consistency.

### *Individual-Dimension Consistency Results*



**COLOR TASK:** Fourteen synesthete participants were consistent in their responses and one was inconsistent. The criteria for individual-dimension consistency led to the omission of synesthete SYN10's responses as this participant had inconsistent responses for 9 of the 11 audio clips played. There were no control participants with consistent color perceptions. Eight control participants perceived no visual color, and seven had inconsistent perceptions.

**SHAPE TASK:** All fifteen participants of the synesthete population had consistent perceptions. Twelve control participants had no visual perceptions and three had inconsistent perceptions. There were no control participants with consistent visualizations for Shape.

**TEXTURE TASK:** Fourteen synesthete participants had consistent perceptions of texture. One synesthete, SYN3, did not perceive texture. Twelve control participants had no visual perceptions for texture and three had

inconsistent responses. There were no control participants with consistent visualizations for Texture.

**SIZE TASK:** All fifteen participants of the synesthete population had consistent perceptions. Eleven control participants had no visual perceptions and four had inconsistent perceptions. There were no control participants with consistent visualizations for Size.

**SPATIAL POSITION TASK:** All fifteen participants of the synesthete population had consistent perceptions. Eleven control participants had no visual perceptions and four had inconsistent perceptions. There were no control participants with consistent visualizations for the Spatial Position task.

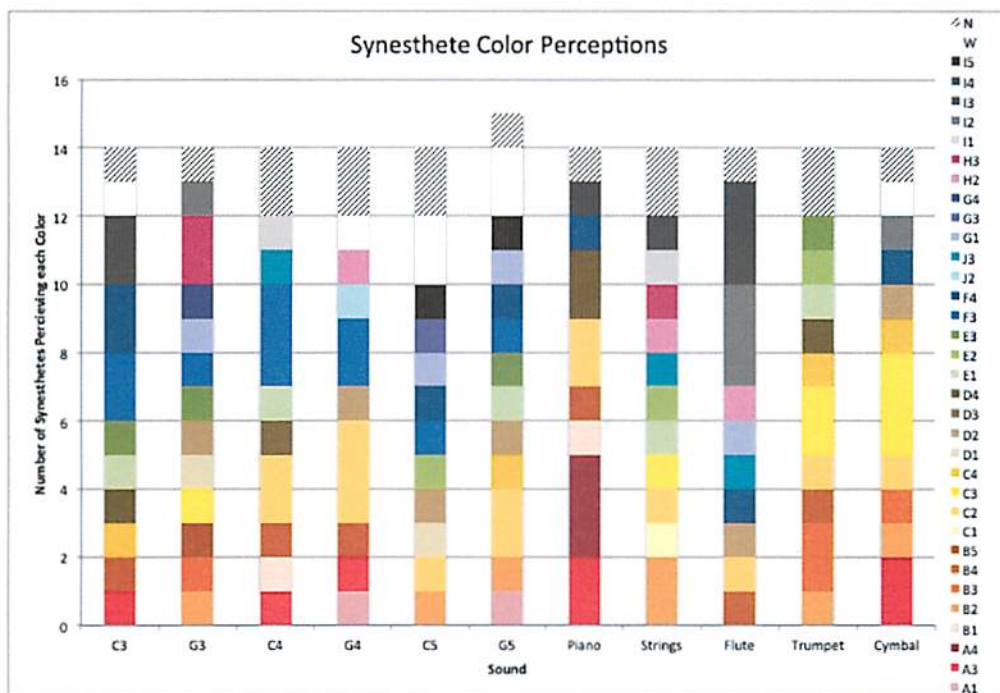
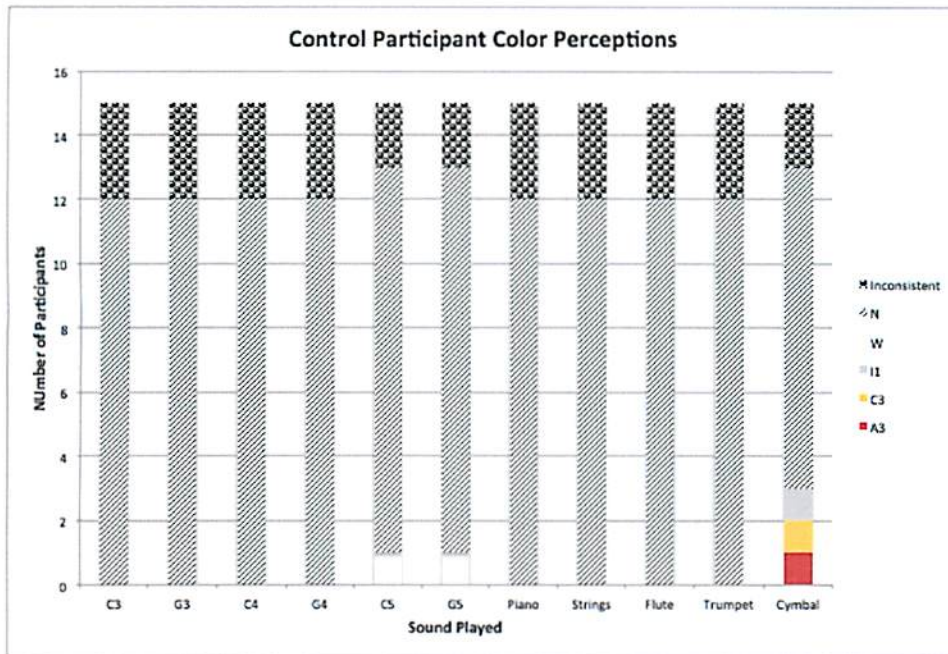
For all visual dimensions, synesthetes reported perceptions more often than control participants. The synesthete responses demonstrated 100% consistency in all categories except color and texture, in which they demonstrated 93% consistency. When control participants did have perceptions, they demonstrated 0% consistency in all visual dimensions.

### ***Individual-Clip Consistency and Group Consistency Results***

The following results display both individual-clip and group consistencies. (i.e. how many participants had common perceptions.) All charts indicating synesthete responses are responses that showed individual-clip consistency. Control participants that did not have this consistency are marked as such. Synesthetes that did not have ICC were omitted from the data of that visual dimension.

**COLOR TASK:** The following graphs show the modal responses gathered from the synesthete and control populations for their perceptions of the shape of the 11 audio clips.





**Group Consistencies**

**Synesthetes:** Synesthetes showed consistencies amongst their perceptions of Piano, Trumpet, and Cymbal. These instruments were consistently perceived as warmer colors (e.g. Red, yellow, orange hues). The pure tones and remaining



instruments were not perceived consistently warm or cool among participants in the synesthete population.

Of synesthetes that perceived color:

79% of synesthetes perceived warm colors for Piano.

75% of synesthetes perceived warm colors for Trumpet.

77% of synesthetes perceived warm colors for Cymbal.

**Control:** Individual-clip consistent responses for color were only perceived by two control participants, and in only the Cymbal category. There were no consistent responses outside of this occurrence.

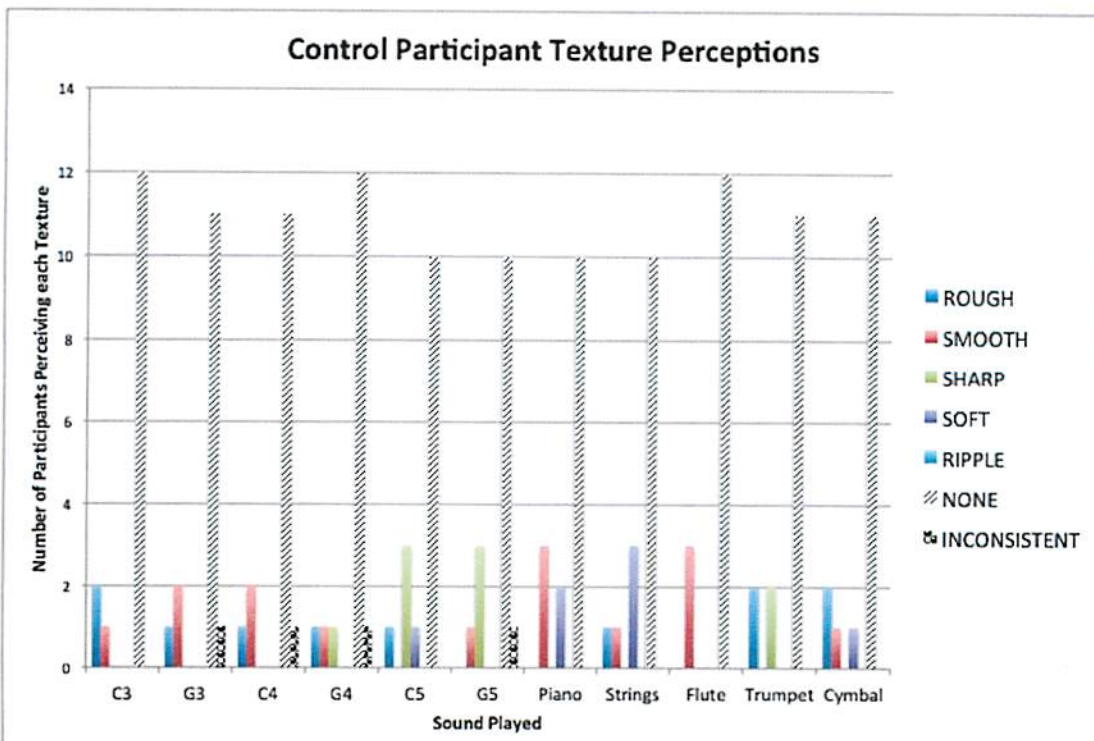
Of the control participant responses perceiving color:

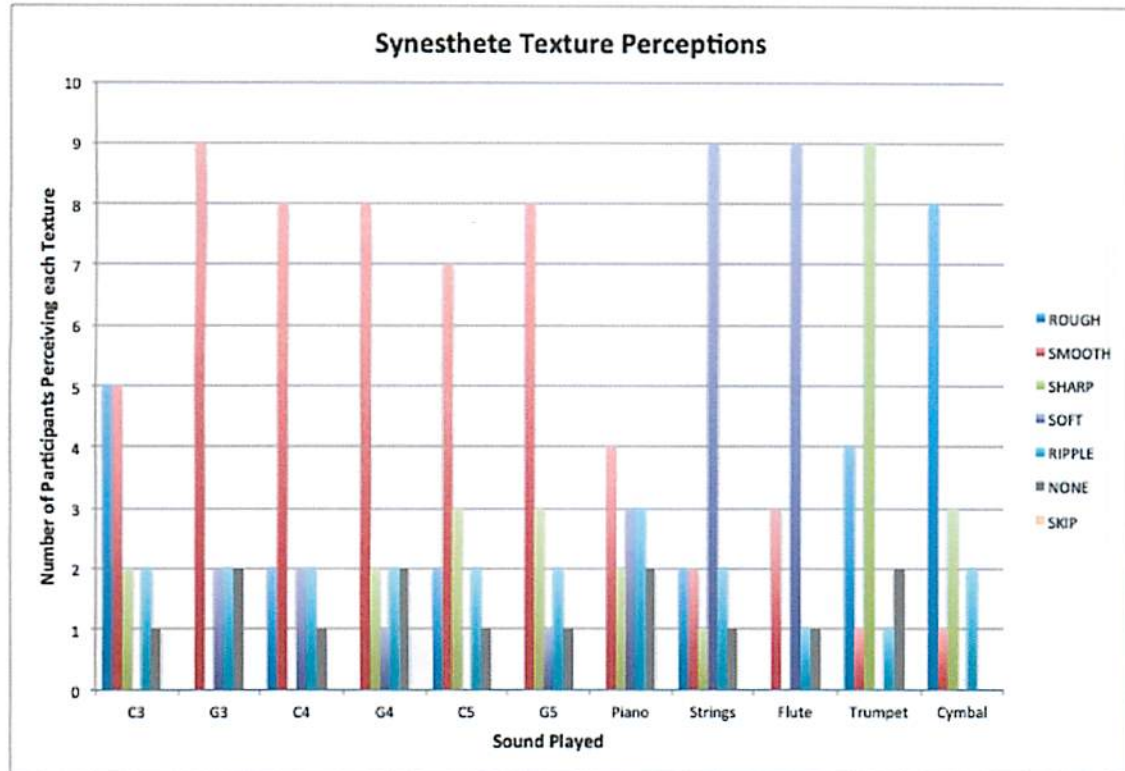
14% of control perceived warm colors for Cymbal.

86% of control participants either did not perceive any color or perceived inconsistent colors.

## TEXTURE TASK

The following graphs show the modal responses gathered from the synesthete and control populations for their perceptions of the textures of the 11 audio clips.





### Group Consistency

**Synesthetes:** Synesthetes showed group consistency for pure tones G3, C4, G4, C5, and G5, and for the instruments Strings, Flute, Trumpet, and Cymbal. Synesthetes were more likely to perceive the pure tones, Strings, and Flute to be of non-coarse textures. Trumpet and Cymbal were perceived as coarse textures.

Of synesthetes who perceived texture:

100% of synesthetes perceived tone G3 to be of non-coarse texture.

87% of synesthetes perceived tone C4 to be of non-coarse texture.

86% of synesthetes perceived tone G4 to be of non-coarse texture.

64% of synesthetes perceived tone C5 to be of non-coarse texture.

79% of synesthetes perceived tone G5 to be of non-coarse texture.

87% of synesthetes perceived Strings to be of non-coarse texture.

100% of synesthetes perceived Flute to be of non-coarse texture.

87% of synesthetes perceived Trumpet to be of coarse texture.

80% of synesthetes perceived Cymbal to be of coarse texture.

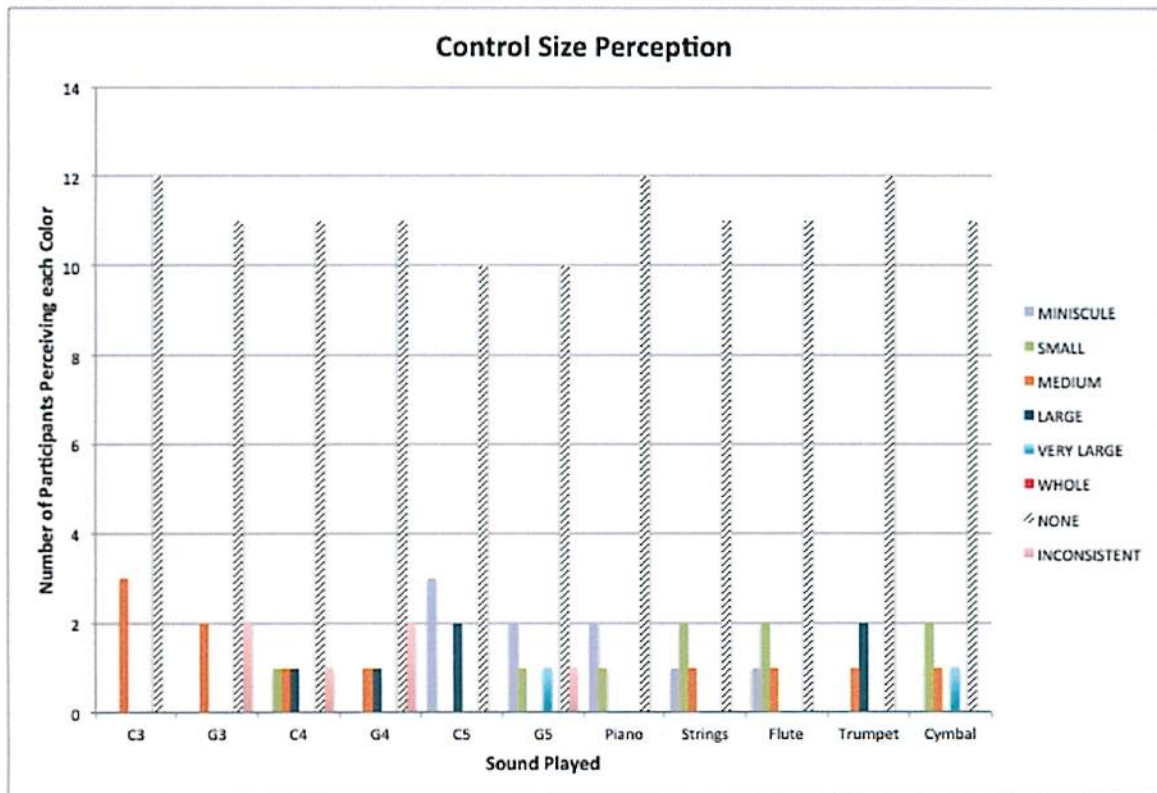
**Controls:** The control group was not likely to perceive any textures. Of the control participants that did perceive a consistent texture, the maximum group consistency perceived was 21%.

21% of control participants perceived flute as a coarse texture.

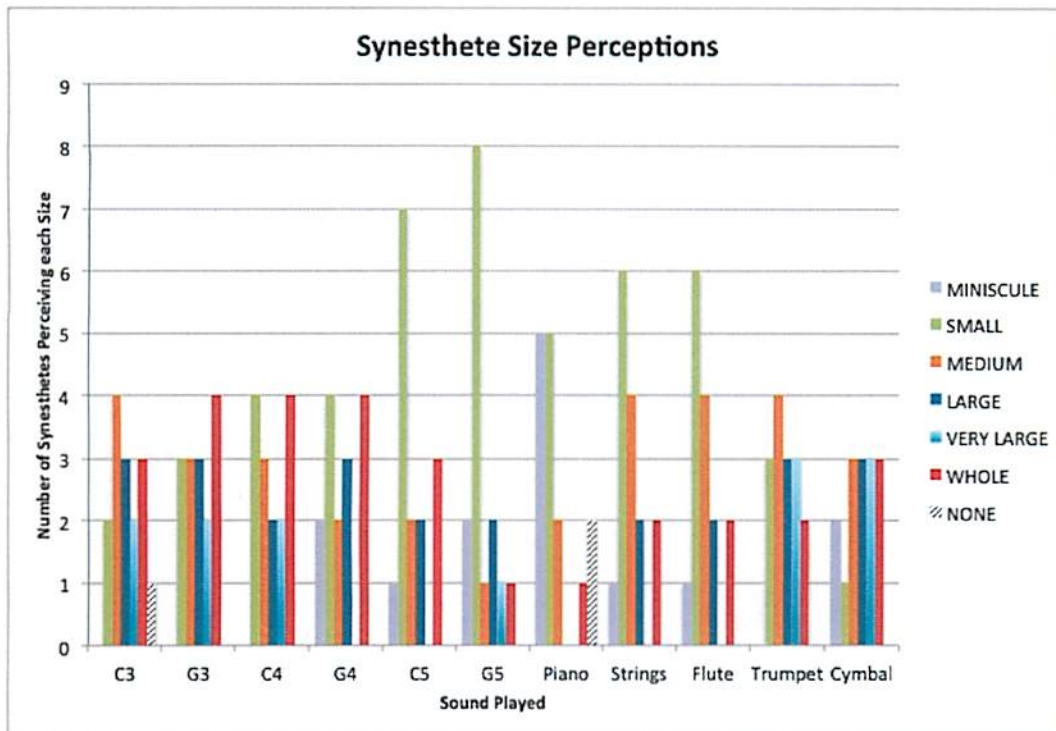
All other consistencies found in the control group fell below 20%.

### SIZE TASK

The following charts show the modal responses gathered from the synesthete and control populations for their perceptions of the sizes of the 11 audio clips.







**Group Consistencies**

**Synesthetes:** Synesthetes demonstrated group consistencies in their Perceptions of tones C5 and G5, and instruments Piano, Strings, and Flute. Synesthetes were more likely to view all of these sounds as smaller, occupying less than ½ of the perceptual field.

Of synesthetes who perceived size:

67% of synesthetes perceived tone G5 to occupy less than ½ the perceptual field.

73% of synesthetes perceived tone C5 to occupy less than ½ the perceptual field.

92% of synesthetes perceived Piano to occupy less than ½ the perceptual field.

73% of synesthetes perceived Strings to occupy less than ½ the perceptual field.

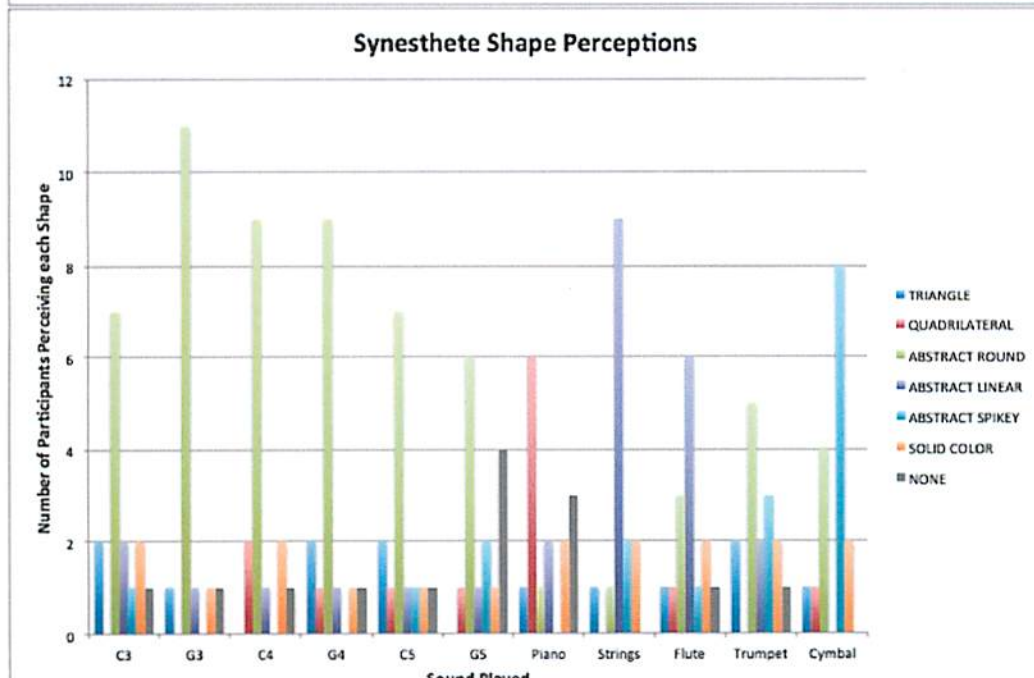
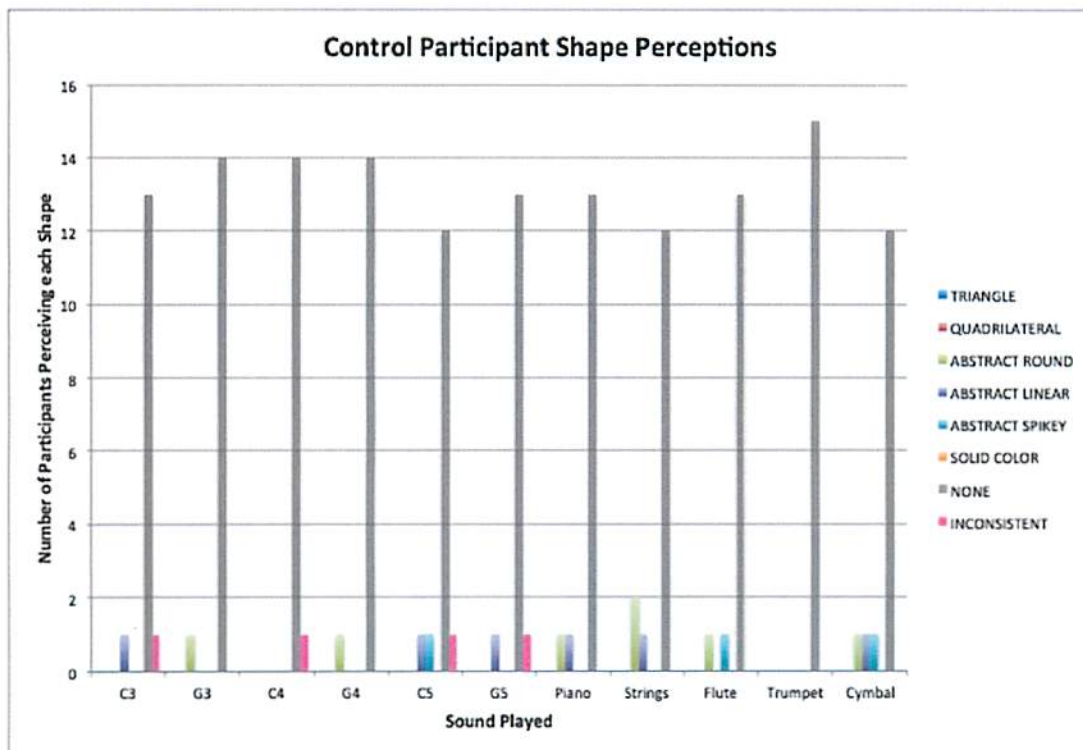
73% of synesthetes perceived Flute to occupy less than ½ the perceptual field.



**Controls:** When control participants did perceive size, with individual-clip consistency there was no more than a 20% group-consistency for any sound.

## SHAPE TASK

The following graphs and table show the modal responses gathered from the synesthete and control populations for their perceptions of the shapes of the 11 audio clips.



### ***Group Consistencies***

***Synesthetes:*** Synesthetes demonstrated group consistencies in shape perception for all of the pure tones. Synesthete Group consistency was also found in the instruments Piano, Strings and Cymbal. All of the pure tones demonstrated group consistency for being perceived as round. Piano was consistently perceived as a quadrilateral, Strings were perceived as linear shapes, and Cymbal was perceived as a spikey shape.

Of synesthetes who perceived shape:

50% of synesthetes perceived tone C3 as abstract round.

79% of synesthetes perceived tone G3 as abstract round.

64% of synesthetes perceived tone C4 as abstract round.

64% of synesthetes perceived tone G4 as abstract round.

54% of synesthetes perceived tone C5 as abstract round.

54% of synesthetes perceived tone G5 as abstract round.

50% of synesthetes perceived Piano as a quadrilateral.

60% of synesthetes perceived Strings as a linear shape.

***Controls:*** Control participants who has individual-clip consistency in their perceptions did not obtain group consistency more than 13% of the time.

Of control participants who perceived shape:

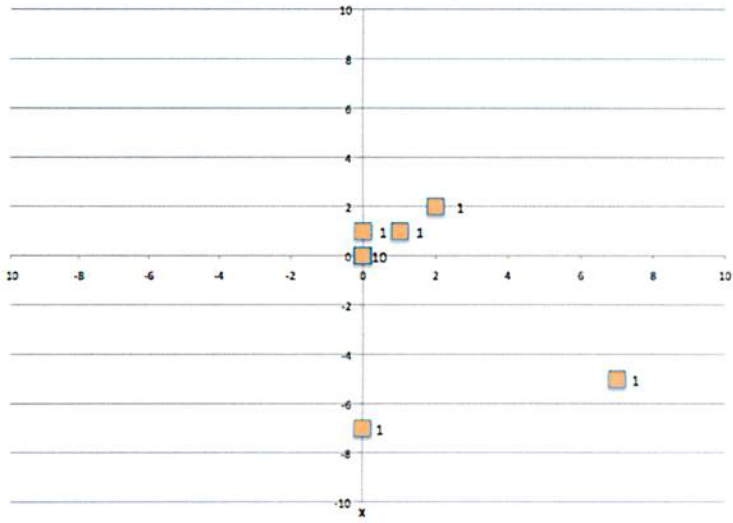
13% of participants perceived Strings as round.

There were no percentages of group consistency higher than this for control participants.

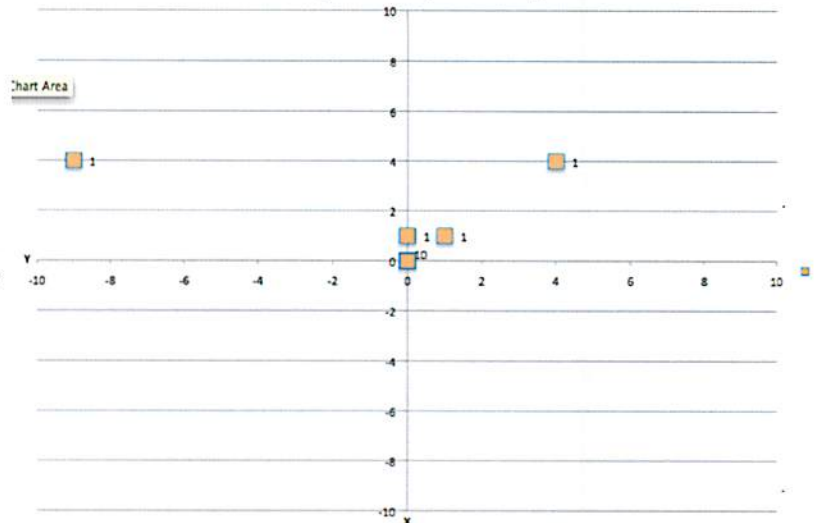
### **SPATIAL POSITION TASK**

The following graphs and table show the modal responses gathered from the synesthete and control populations for their perceptions of the spatial positions of the 11 audio clips.

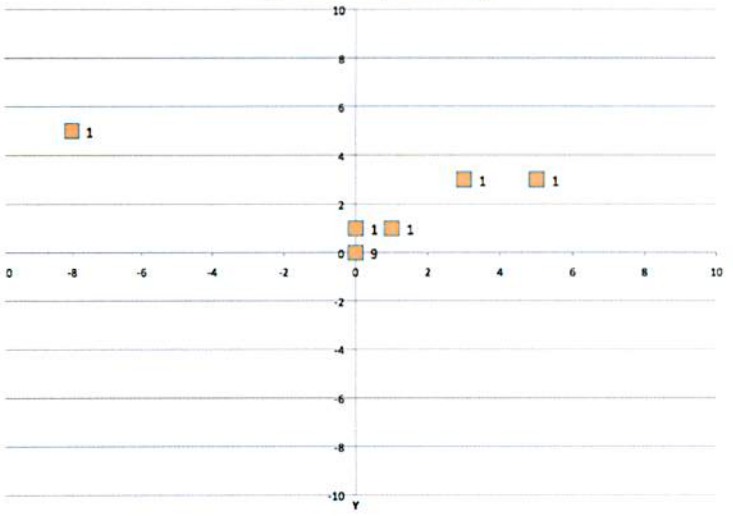
Synesthete Spatial Perceptions of C3



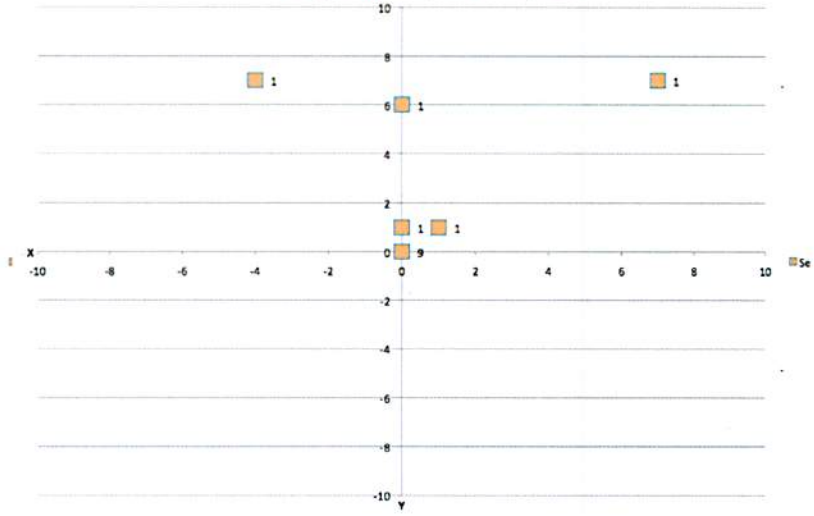
G3 Synesthete Space Perceptions



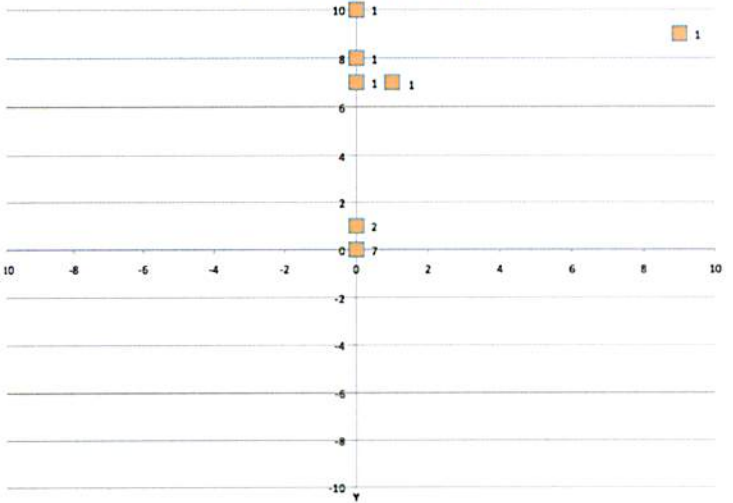
C4 Synesthete Space Perceptions



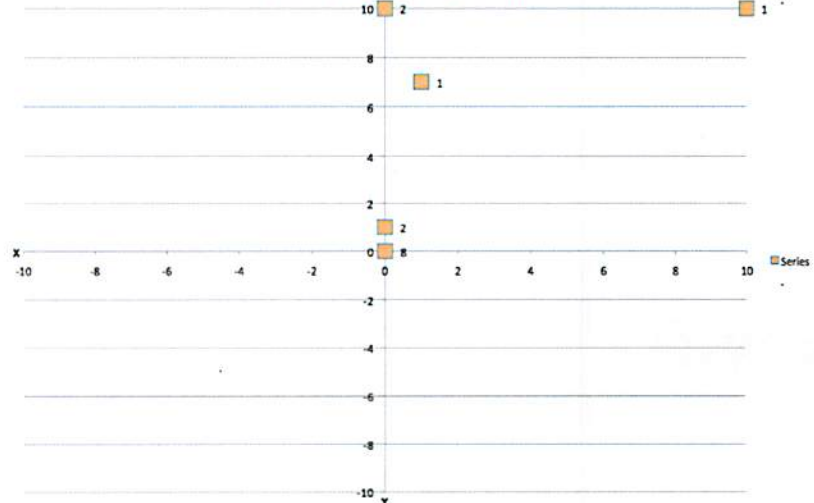
G4 Synesthete Space Perceptions



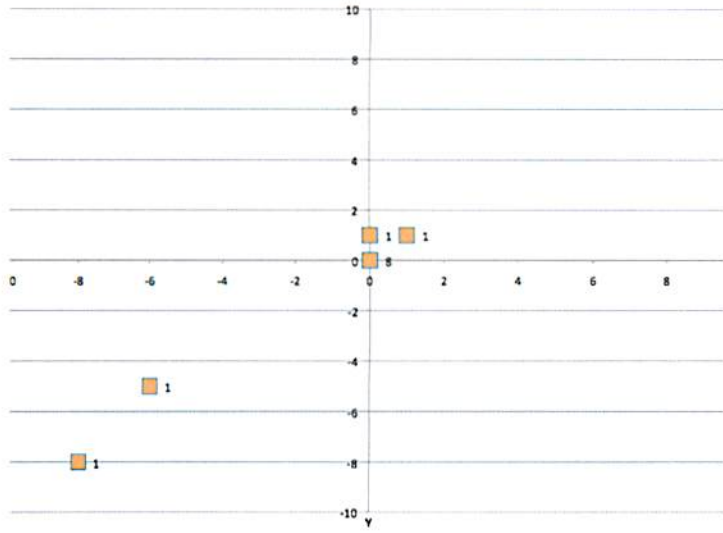
C5 Synesthete Space Perceptions



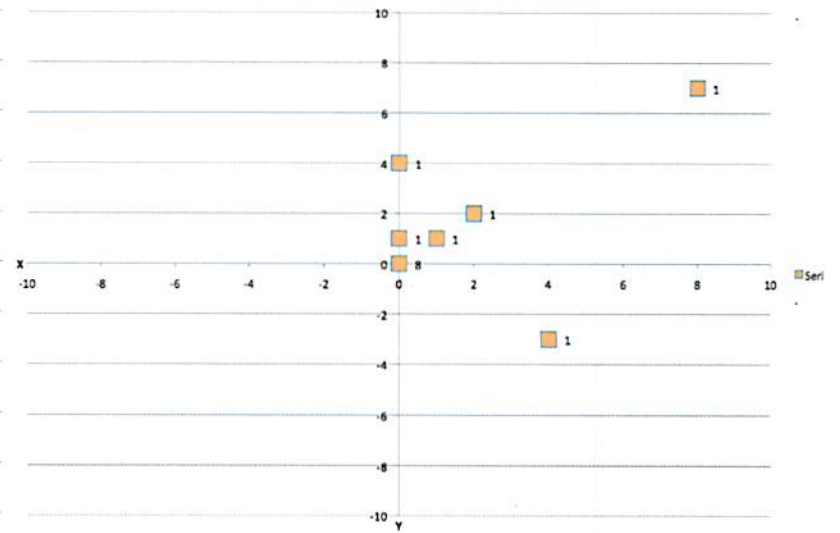
G5 Synesthete Space Perceptions



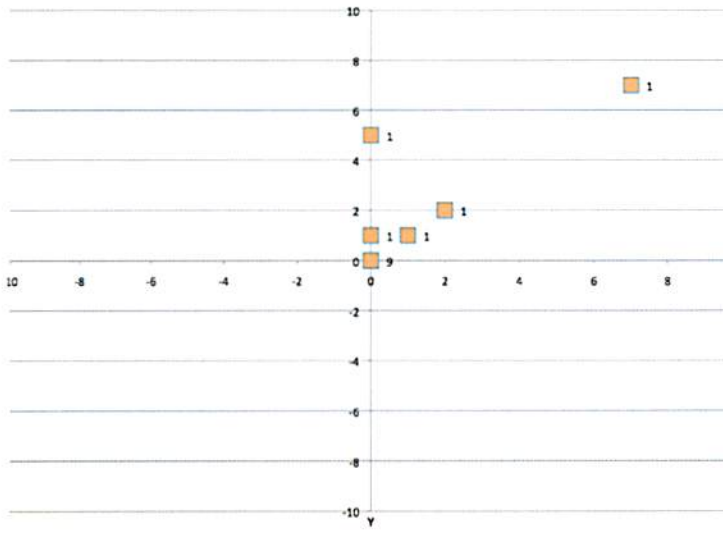
Piano Synesthete Space Perceptions



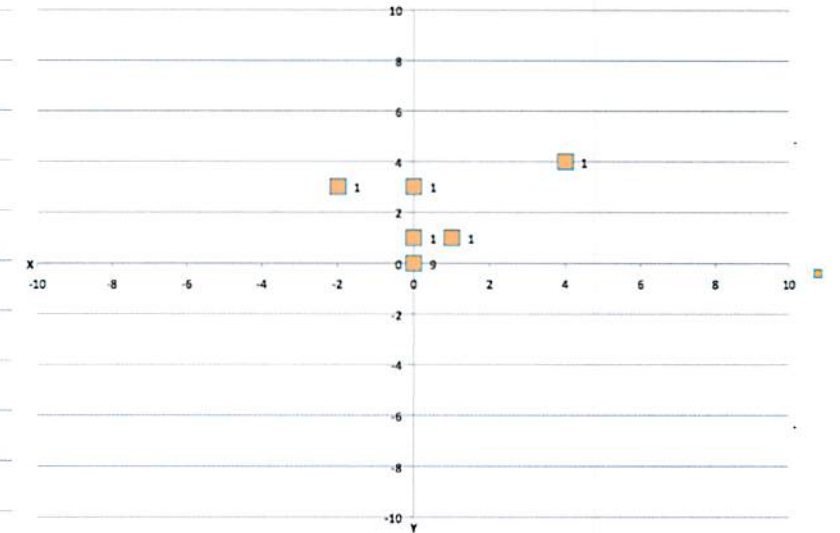
Strings Synesthete Space Perceptions



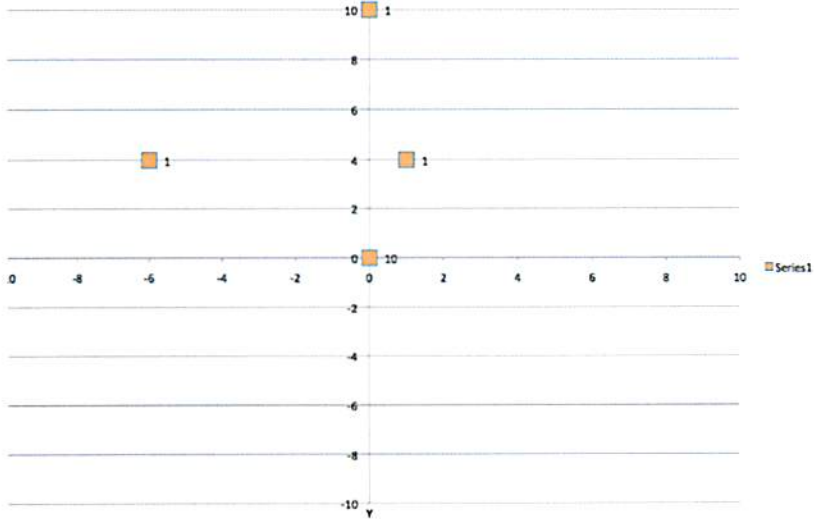
Flute Synesthete Space Perceptions



Trumpet Synesthete Space Perceptions



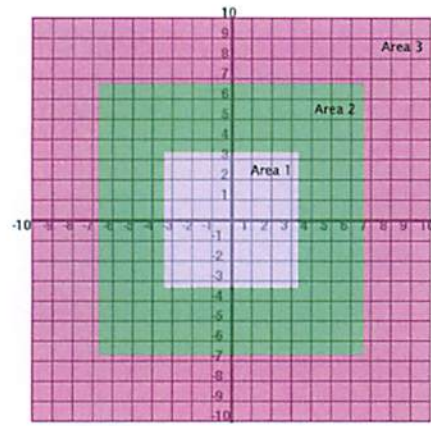
Cymbals Synesthete Space Perceptions





### **Group Consistency**

**Synesthetes:** The synesthete population exhibited group consistency for all 11 audio clips tested. Additionally, for all of the sound clips, a group consistency of spatial positions occurring in Area 1 was found.



Of synesthetes who perceived spatial position:

- 87% of synesthetes perceived tone C3 in Area 1.
- 86% of synesthetes perceived tone G3 in Area 1.
- 80% of synesthetes perceived tone C4 in Area 1.
- 79% of synesthetes perceived tone G4 in Area 1.
- 64% of synesthetes perceived tone C5 in Area 1.
- 79% of synesthetes perceived tone G5 in Area 1.
- 83% of synesthetes perceived Piano in Area 1.
- 79% of synesthetes perceived Strings in Area 1.
- 80% of synesthetes perceived Flute in Area 1.
- 93% of synesthetes perceived Trumpet in Area 1.
- 77% of synesthetes perceived Cymbal in Area 1.

**Controls:** Control participants did not have individual-clip consistency for any clip played, thus there was no display of group consistency.

## **Discussion**

This study examined potential commonalities in the perceptions of colored-hearing synesthetes. Participants were first tested for genuineness, with all synesthetes being confirmed as possessing consistent perceptions for individual sound clips.

While color is often investigated across numerous types of synesthesia, this study also investigated the visual dimensions of shape, size, texture, and spatial position, amongst a population of colored-hearing synesthetes. It was hypothesized and confirmed that there would be commonalities amongst the synesthetes' perceptions.

Synesthetes more often perceived the noises of piano, trumpet, and cymbal to be of warm colors. In terms of textures perceived, synesthetes consistently perceived pure tones as non-coarse. The same was true for perceptions of strings and flute. The trumpet and cymbal were conversely perceived as coarse textured. The pure tones of G5 and C5, along with piano, strings, and flute tended to occupy less than  $\frac{1}{2}$  of the perceptual field. In addition to non-coarse sounds, synesthetes were also more likely to perceive pure tones as rounded sounds. Synesthete consistencies in shape also showed piano as a quadrilateral and strings as linear sounds. Synesthetes also demonstrated remarkable group consistencies in their perceptions of spatial position, with Area 1 (the centermost area) being consistently perceived as the most common location of perceptions for every sound clip played.

It is noteworthy to observe the musical timbres of instruments along side the synesthetes' perceptions. Musical timbres of the warm colored sounds are often described as warm for piano and trumpet, and bright and hot for cymbal. As with color, it is also noteworthy to observe that sounds with perceived non-coarse textures were played by instruments often described to have soft timbres, such as that of the flute. Likewise, instruments perceived as coarse textured are often thought of as having rough or piercing timbres, such as that of the cymbals.

Another notable observation corresponds to the physics of sound and the perception size of the pure tones. Higher pitched tones (i.e. C5 and G5) were

perceived as smaller noises. If we are to observe higher pitched noises, the openings of higher pitched instruments are often smaller, and the wavelengths of these sounds are shorter.

These comparisons, however, remain simply as such. While there were indeed group consistencies for visual dimensions, synesthetes that were not part of the group consistency percentages still possessed individual-dimension consistency. Their perceptions were therefore entirely valid despite being outside of group consistency.

While there were consistencies in synesthetic perception, many questions do remain for both those exhibiting group consistency and those who are not. There is currently no evidence that reasons why some synesthetes perceive a sound as a warm yellow, while others perceive it as a warm orange. It is not known where this difference comes from. Now that commonalities in perception have been located in the perceptions of this colored-hearing synesthete population, the reasoning behind their involuntary perceptions can be investigated in the future.

### Synesthete (SYN) and Control (CTRL) Size Perceptions

SOUND	MINISCULE		SMALL		MEDIUM		LARGE		VERY LARGE		WHOLE		NONE		INCONSISTENT	
	SYN	CTRL	SYN	CTRL	SYN	CTRL	SYN	CTRL	SYN	CTRL	SYN	CTRL	SYN	CTRL	SYN	CTRL
<b>C3</b>	0	0	2	0	3	3	3	0	1	0	1	0	1	10	0	0
<b>G3</b>	0	0	2	0	3	2	2	0	1	0	3	0	0	9	0	2
<b>C4</b>	0	0	3	1	3	1	2	1	0	0	3	0	0	9	0	1
<b>G4</b>	1	0	3	0	2	1	3	1	0	0	3	0	0	9	0	2
<b>C5</b>	2	3	6	0	2	0	2	2	0	0	3	0	0	8	0	0
<b>G5</b>	2	2	5	1	1	0	2	0	1	1	1	0	0	8	0	1
<i>Piano</i>	3	2	7	1	2	0	0	0	0	0	1	0	1	10	0	0
<b>Strings</b>	1	1	4	2	4	1	2	0	0	0	2	0	0	9	0	0
<b>Flute</b>	1	1	5	2	4	1	1	0	0	0	2	0	0	9	0	0
<b>Trumpet</b>	0	0	2	0	4	1	3	2	2	0	2	0	0	10	0	0
<b>Cymbal</b>	2	0	1	2	2	1	2	0	5	1	2	0	0	9	0	0



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