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Synesthesia and Musical Perception

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ABSTRACT

This study aims to explore the effect of learned chromesthesia on one's musical pitch recognition skills. Participants from a high school music class preformed a simple pitch-recognition task. They were then divided into two groups and received instruction on either learning chromesthesia or relative pitch techniques, depending on which group they were in. After this instruction, they completed the pitch-recognition task again to measure their improvement. A short survey was also administered to provide further insight as to whether the techniques they learned were successful in improving their pitch-recognition skills. Results were mixed. Overall, the group that received relative pitch instruction experienced more improvement than the group that received chromesthesia instruction. However, some students in the chromesthesia group were able to experience significant improvement in their pitch recognition skills, although the level of improvement varied greatly among each individual participant. Additionally, the results were likely influenced by various factors such as the participants' prior music experience and the amount of time allotted for the experiment to take place. This study provides a valuable starting point for further research on the practice of learning synesthesia and using it in the field of education- a topic that is still left widely unknown.

Introduction

Synesthesia is a unique condition often described as a "blending of the senses" in which a stimulus is able to invoke an unrelated response from one of the five senses (Bor et. al., 2014). As there are many different combinations of stimuli and responses, synesthesia can be classified into different types. For example, a person with grapheme-color synesthesia has written letters and numbers as their stimulus and colors as their response. Whenever they see written text, they naturally associate colors with the text, having a specific color assigned to each letter/numeral, and oftentimes seeing the text as if it were written in these colors (Constantin, 2017). Similarly, a person with chromesthesia associates colors with sounds. When a person with chromesthesia hears a sound, their brain automatically responds by presenting the visualization of color, either as an internal image in their mind's eye, or as an image projected out into their surroundings.

Even within the realm of people who have chromesthesia, there is still variation in how the condition affects one's experience. Some people with chromesthesia experience color sound associations for all sounds, while some only experience it with music. Additionally, for those who experience associations with music, the color associations can be assigned due to various attributes of the music. For example, the variation within the colored response can be determined by the pitch, mood, volume, or instrument of the music in question (Constantin, 2017).

Literature Review

Cognitive Effects of Synesthesia

Synesthesia has a significant effect on how an individual perceives certain aspects of their environment. A person with chromesthesia specifically is more likely to be musically inclined, and to feel a strong emotional connection with

music, as "the listener associates different pitches and tones to certain colors, which in turn, produces specific feelings" (Makhlin, 2015, p.1). This results in a double emotional response, as the person experiences an emotional response to the music, and another emotional response to the colors produced. In one study, it was found that people who have synesthesia, also known as synesthetes, typically associated brighter, lighter colors with happier music ("happier" meaning major key, high tempo, etc), and darker, more saturated colors with sadder music (Curwen, 2018), showing further proof of the links between music, color, chromesthesia, and emotions.

In addition to altering one's emotional perception, synesthesia also has an effect on one's learning abilities and mental performance. The condition is widely thought to have developed as a way to aid in the learning process. Stimuli that induces synesthetic associations- days of the week, numbers, letters, music notes, etc.- are all items that are taught during early childhood. Additionally, synesthesia is found to develop during early childhood- these critical years where one's learning capabilities are rapidly emerging. Due to the innate cross-modal associations formed by synesthesia, the condition has been found to work similarly to a mnemonic device, providing a way for the child to easily memorize and recall the information they learned (Watson et. al., 2014). Studies have also found that synesthesia is able to improve qualities such as visual imagery and creative thinking, in addition to memory (Meier, 2014).

The positive cognitive effects of synesthesia can be observed specifically in the field of music. Studies have shown that people who possess absolute pitch, which is the ability to innately identify musical pitches, have a 22% chance of having synesthesia, as opposed to the 4% of people who have synesthesia in the general population. (Gregerson et. al., 2013).

Artificial Synesthesia

There has been speculation and multiple attempts as to whether it is possible to experience synesthetic associations as a non-synesthete. One group of researchers created a virtual reality program that allows a person to see what a person with chromesthesia might see while listening to music (Choi & Reich, n.d.). It has also been reported that people have hallucinated colors that move and change in relation to music while under the influence of marijuana or LSD (Mitchell, 1971, p.1). Researchers have also used sensory deprivation to bring forth audio-invoked visual imagery similar to chromesthesia (Nair & Brang, n.d.).

There have been multiple studies of varying success that aim to give non-synesthetes synesthetic associations. Instead of involuntary invocation, a common route is to teach the subjects, having them match a specific color to each note (assuming that they are training chromesthesia), and then solidifying the associations through memorization and repetition (Bor et. a.l, 2014). In a study conducted by the University of Sussex, participants were trained to form color-letter associations. Their results were assessed in two ways: Participants were surveyed as to how many letters caused consistent color visualizations, and how often the colors were visualized. They also took part in a Stroop test, an exercise in which they were presented with letters in various colors- either the color that they were trained to associate the letter with, or an "incorrect color"- and had to say the name of the letter as quickly as possible. Response times were recorded. The concept behind the Stroop test is that participants should be slightly slower in naming the letters written in colors that do not match their predisposed associations, and this detail helped to determine the deepness of the synesthetic experiences they developed. The experiment's results were largely successful, with 93% of participants having experiences considered to be comparable with actual people who naturally have synesthesia. However, the subjects' color associations were reported to have weakened, though they were still present, in the months after the study took place (Bor et.al., 2014).

Because chromesthesia has such a strong effect on one's musical perception and affinity, this raises the question of whether one can experience the same, or at least similar, effects from trained chromesthesia. Although it may be difficult or inconsistent to measure how much someone enjoys music, a reasonable benchmark is to assess their pitch recognition ability.

As stated before, synesthetes are more likely to have absolute pitch (Gregerson et. al., 2013). While it is difficult to attain the complete consistency and automatic recall of someone with "true" absolute pitch, there is

evidence that it is possible to learn absolute pitch as an adult, rather than being born with it or developing it in early childhood (Wong et. al., 2019). In one study, 14% of participants who underwent pitch training for 3 months were able to identify notes with an accuracy rate that qualifies as absolute pitch. Additionally, all of the participants experienced improvement in their pitch recognition abilities by the end of the study (Wong et. al., 2019).

Rather than aiming to induce "true" synesthesia and "true" absolute pitch, the goal of this study is to utilize chromesthesia training to form associations similar to those of true synesthetes, and to observe if it causes improvement in pitch recognition ability. One study proposes the use of a synesthesia inspired learning model for teaching children music, where notes are spatially arranged in a way that shows their melodic relation to each other (reminiscent of a type of synesthesia called sequence-space synesthesia), and color coded so that notes with similar colors are similar in pitch (reminiscent of chromesthesia) (Brainin, 2008). While there is no record of the model's level of success, it theoretically should help with the learning process because it gives a visual representation of something that is only heard, and this cross-modal association is shown to improve memory and understanding (Brainin, 2008).

This study specifically aims to train chromesthesia by having participants (students from a high school in Washington state with prior music experience) form their own color-note associations and instill these through memorization and repetition.

Due to the evidence supporting the prevalence of positive learning-associated traits in people with synesthesia, and more specifically the prevalence of greater pitch-recognition skills in people with chromesthesia, coupled with the evidence that synesthetic associations can be learned in people who do not have the condition, I hypothesize that chromesthesia training will be able to improve the pitch-recognition skills of participants in my study.

Methods

Study Goals

The study aims to determine if learned chromesthesia can improve the pitch recognition ability of high school students who have prior music experience. This study is modeled upon similar studies that researched the process of learned synesthesia. (Bor et. a.l, 2014; Kelly, 1934).

University of Sussex Study

In an attempt to form color-grapheme synesthesia associations, researchers had participants read books with colored letters (Bor et. al., 2014). This study was very beneficial in the formation of my methodology, as it is the most well-known synesthesia training experiment to date, and it provided me with guidelines to structure my experiment with.

E. L. Kelly Study

Participants took part in training sessions to form associations similar to chromesthesia, where they were presented with a colored flashcard while simultaneously hearing a music note. The goal was to memorize the color-note pairs, and eventually be able to experience them without the flashcards (Kelly, E.L., 1934). This is the only study I came across in my research that detailed the process of teaching chromesthesia, rather than another form of synesthesia. The strategy of presenting participants with colored flashcards in conjunction with the exposure of their respective musical pitches was one that successfully inspired the specifics of the methodology for this study.

Setting

The target population of this study is students from a high school in the state of Washington, grades 10-12, who have music experience, as determined by participation in the school's orchestra classes. Students must also not have synesthesia or perfect pitch. This school was chosen because it has a sizable population of 1,837 students. It is

ethnically and socioeconomically diverse, with 34% of students reported as racial minorities and 27% of students receiving a free or discounted lunch. This diversity made it an adequate population to sample from. In terms of the physical location of the study, students participated remotely with instruction and communication from the researcher.

Ethics

This procedure was approved by the local Institutional Review Board to be ethical and permissible. Students were required to sign informed consent forms (or to have their parent/guardian sign a consent form if under 18) and were made completely aware of the procedure before participating. Blank consent forms can be found in the *Appendix* section.

Measures

Musical Training

Participants were given either pitch-recognition training or chromesthesia training, as determined by their placement in the experimental or control group. A control group was implemented in this study to provide a benchmark of just how effective the chromesthesia training was. The usage of relative pitch training techniques was decided upon in this study due to the fact that relative pitch is the most prevalent form of pitch-recognition training (Lundin, 1963), and thus its usage as a benchmark could provide further understanding on the effects of chromesthesia training. For example, if the pitch improvement between the experimental and control groups were equal, it could be concluded that the chromesthesia training was highly effective in improving pitch recognition. If pitch improvement occurred in both groups, but to a lesser extent in the experimental group, it could be concluded that chromesthesia training was moderately effective.

For pitch-recognition training, participants were instructed in basic relative pitch ear-training strategies, specifically mnemonic devices for each note. They were instructed to find a context for each note, whether it be a pitch from a song, the interval from one note to another, or the innate familiarization with the note due to their instrument (for example, middle C is well-known for pianists and A is well-known for string players). After instruction, participants were given practice questions for identifying notes with this technique.

For chromesthesia training, participants were presented with a colored PowerPoint slide for each note (reminiscent of the techniques used in the E.L. Kelly study). At the moment the pitch was played, the respective colored slide was shown. Although color associations are unique to the individual for people who truly have synesthesia, colors for notes were be pre-assigned in this experiment to ensure consistency, and to prevent participants from mistakenly assigning two or more notes colors that are confusingly similar to one another. This decision was made in the University of Sussex study for these same reasons (Bor et. al., 2014). Participants were presented with the color-note combinations in ascending and descending order multiple times, then were given practice questions, where they were asked to identify notes in random order by only seeing the colors. The goal was for the students to memorize as many of the color-note associations as they could.

Both trainings were conducted through a 15-minute video (one video for each technique), and abridged transcripts of the videos can be found in the *Appendix* section for further detail. Although the studies this methodology was modeled on concerning the cultivation of trained synesthesia and musical pitch training has been extensively longer, covering the span of multiple weeks, the training was condensed for two reasons. One, for convenience, as the parameters of this course did not allow for a weeks-long experiment, and because participants would be much less likely to participate if there was a significant time commitment. However, the smaller time window was also chosen because the goal of this study is to not develop chromesthesia or to develop absolute pitch; it is to simply observe the effects of the chromesthesia training. For this reason, there does not need to be an extensive training regime, as the effects of the mere act of training is being observed.

Pitch Recognition Assessment

Participants took a 20-question electronic pitch recognition test from the website musictheory.net, where they must identify notes from one octave of the C major scale (C4 through B4) played in random order. This software was chosen for multiple reasons. First, because of its accessibility: it is free to use, and is a website rather than an app, so all students can access it through their school-issued laptops. It was also chosen because of its adjustable features, in that the user can chose which notes and octaves are being used.

Survey

After the experiment, participants were asked the following questions to determine what specific strategies they employed when trying to recall pitches

a) When taking the second test, did you use/attempt to use the technique covered in the video? Answer on a scale of 1-5, 1 being “completely disagree”, and 5 being “completely agree”.

b) When taking the second test, do you feel that your usage of the technique covered in the video was effective? Answer on a scale of 1-5, 1 being “completely disagree”, and 5 being “completely agree”.

Participants were also be encouraged to write a short statement explaining why they answered the survey questions in the way they did.

The survey component was integral for the chromesthesia group because it is possible that, especially given the time constraints, the chromesthesia associations were not fully developed. In that case, it would be important to specifically analyze the participants who did utilize the associations compared to the participants who did not.

Procedure

Participants were chosen from an orchestra class from the high school and were randomly assigned to the control or experimental group based on alphabetical order of last name. Regardless of group, all participants took part in a 30-minute training/testing session. Both groups started out with taking the pitch recognition assessment, and their scores were recorded. Then, they completed their respective training by watching the instructional video specific to their group. Afterwards, they took the assessment again, and individual levels of improvement were observed through the percentage difference between their scores from before and after training. Then, the survey was administered to observe what strategies the participants truly gleaned from the training.

Limitations

There were two main challenges with the experiment. One was the difficulty of gathering participants. Information was originally sent out to students participating in music classes at the high school, and students were asked if they were interested in volunteering. Unfortunately, the amount of interest gathered was too small, so the experiment had to be conducted in place of the instruction time of one of the orchestra classes so an entire class’ worth of participants could be utilized. Students were also awarded with a formative assignment’s worth of extra credit points as an incentive for participating in the study. Although the sample size (10 students) is not outstandingly large, it is sufficient, as the students in the class were diverse in terms of grade, gender, and the instrument they played. Additionally, the studies that this methodology was modeled upon had similar sample sizes, with 14 participants in the University of Sussex study (Bor et. al., 2014), and 5 participants in the E.L. Kelly study (Kelly, 1934). Another challenge was time constraints. I originally wanted to conduct a full-length chromesthesia training experiment modeled more heavily off the University of Sussex study, but as mentioned above, time constraints would not allow it. I combated this by shifting the focus of the study from the effects of trained chromesthesia to the effects of

chromesthesia training. The difference in the wording is subtle, but it drastically changed the study in that I no longer had to concern myself with helping the participants to develop "true" synesthetic associations. Instead, I rather needed to present participants with a basic foundation of synesthetic association and observe how this simple introduction to synesthesia training affects their pitch recognition. This change also led to the introduction of the survey, so I could effectively observe which students managed to utilize the strategies they learned in such a short period of time, and how effective the training was.

Results

Score Improvement

Data was collected and analyzed to evaluate if the synesthesia training had a positive effect on pitch recognition as compared to the relative pitch instruction received by the control group. This was achieved by measuring the percent by which each individual's score increased between taking the pitch recognition test for the first time as compared to the second time (For example, if one received a score of 25% on the first test and 50% on the second test, it would be classified as an improvement of 25%).

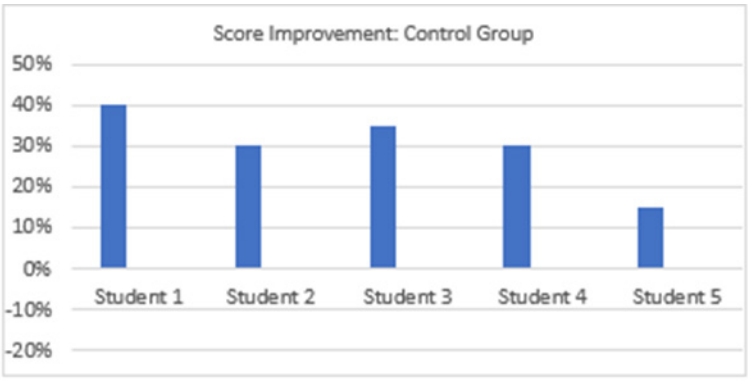

Figure 1. Bar graph of score improvement in control group.

Note: Each student is represented by a number (e.g. "Student 1"), and these pseudonyms will be consistently used to refer to each student for the remainder of this essay.

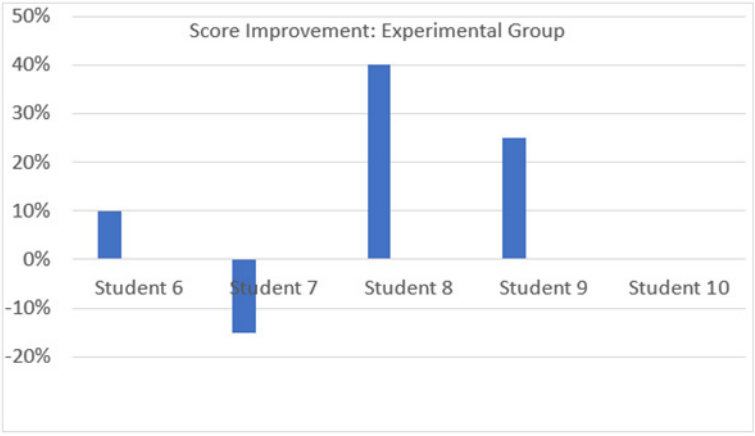

Figure 2. Bar graph of score improvement in experimental group.

This data shows that the control group had an average score increase of 30%, while the experimental group had an average score increase of 12%. Within the control group, all students experienced improvement, but the experimental group had 3 scores improve, 1 student who achieved the same score on both tests, and 1 student that experienced a decrease in score.

Survey

In addition to measuring score improvement, data was also gathered through a two-question survey given to participants to determine if and how they used the techniques they learned when they took the second test. This was completed so that score improvement could be attributed to the techniques this study is researching and not the default exposure to musical pitches that subjects gathered from the instruction videos, regardless of whether they used the specific technique covered in their video. As mentioned earlier, the first question details the extent to which participants used the technique; the second question details the extent to which they believe the technique was effective.

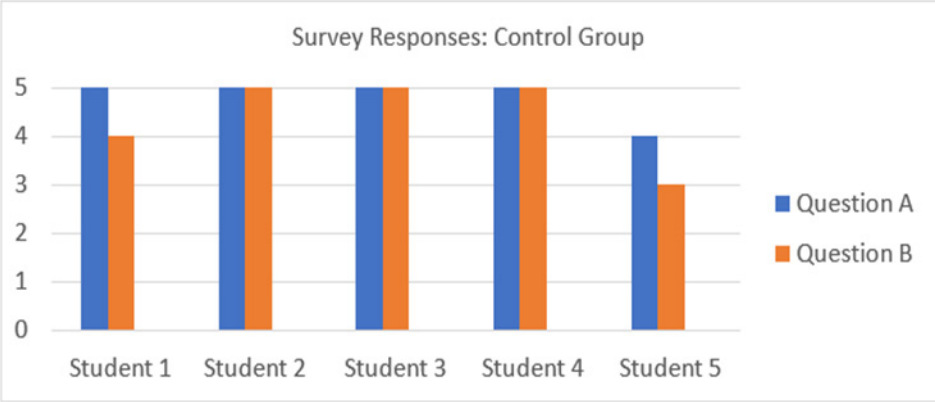

Figure 3. Bar graph of survey responses in the control group.

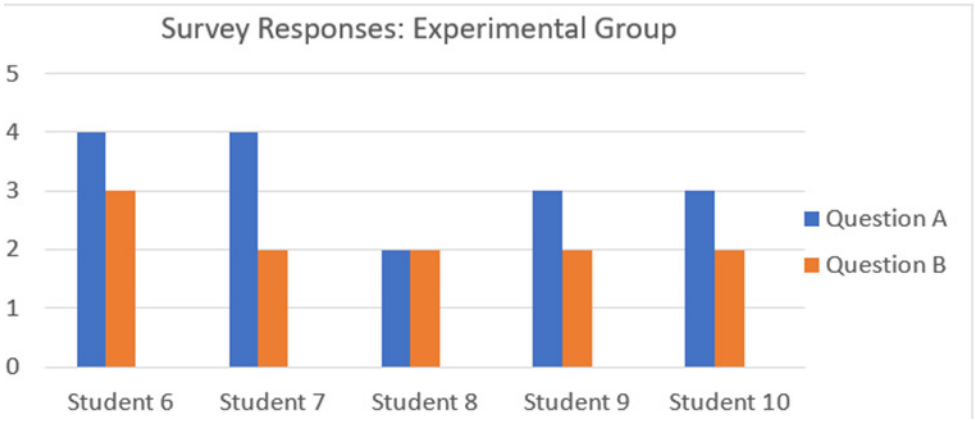

Figure 4. Bar graph of survey responses in the experimental group.

The data shows that the control group had higher answers for both questions (an average of 4.8 for Question A, and an average of 4.4 for Question B), while the experimental group had lower answers for both questions (an average of 3.2 for Question A and 2.2 for Question B). From this, it is evident that the chromesthesia training was less intuitive and effective than the relative pitch training. When presented with these questions, students were also given the option to write personal statements explaining why they gave the answers they did. Within the control group, all students expressed the opinion that the relative pitch technique was intuitive and effective. For example, Student 2 said that they already attempted to use the relative pitch technique before viewing the instruction video, and the video acted as a supplement to help them improve further. Student 3 stated that using a reference note made pitch recognition easier, and the concept came very naturally to them.

In the experimental group, students' responses were less confident, with most commenting on how they were not able to achieve a complete grasp on the color-note associations by the time they took the second test. Students 6 and 9 specifically stated that they were able to memorize 2-3 color-note associations and effectively use them but relied on relative pitch and guesswork for the other notes. 4 out of the 5 students in the experimental group stated that at some point during the second test, they relied on the relative pitch skills they already had from playing an instrument, especially when identifying "easy" intervals (e.g., a note that is a single step away from the previous note played).

Holistically, this data shows that for students with prior music experience, relative pitch training is more effective than chromesthesia training in improving pitch recognition. However, the data still shows that chromesthesia training is capable of improving pitch recognition, as 2 out of the 5 participants in the experimental group experienced a score improvement, and there was an average trend of improvement overall.

When observing this data, it is evident that the lack of improvement in the experimental group can be attributed to two main issues: The lack of "solidity" in color-note associations, and the comparative intuitiveness of using relative pitch techniques. When first designing this experiment, the latter was already presumed to take place, as this study's main goal is not to produce complete synesthetic associations, but rather to observe the baseline effects of synesthesia training on pitch recognition. As mentioned before, participants simply underwent a single 15-minute training session. In contrast, the synesthesia training studies that were used for inspiration of this study were made up of multiple training sessions and lasted for multiple weeks. If this study went to such lengths, it is likely that the results would be different. Additionally, the tendency of the participants to rely on relative pitch is to be expected, as they all have prior music experience, and musicians are required to have a foundational understanding of relative pitch in order to properly play their instrument. If they were to undergo extensive synesthesia training, it is possible that they could use their relative pitch skills to supplement their synesthetic associations. On the other hand, it is possible that the issue of automatic reliance on relative pitch techniques would not take place if this study used the participation of non-musicians.

Conclusion

This data shows that chromesthesia training is somewhat effective in improving pitch recognition. In this particular study, the chromesthesia training did not result in as much improvement as the relative pitch training did. This could be due to the short length of the chromesthesia training, as previously mentioned, which opens up further research possibilities for this topic. While participants in the experimental group only experienced a basic to moderate grasp of the color-note associations, it is possible that with the implementation of long-term training, they would be able to solidify the color-note associations, and gain a more natural, intuitive pitch-recognition strategy, along with the other benefits that natural chromesthesia provides, such as creativity and musicality (Meier, 2014).

Additionally, it would be worthwhile to look into the effects of chromesthesia training on people who have no prior music experience. While this study intentionally sought the participation of people who have prior music experience for the sake of consistency and simplicity, an overlooked downside of this decision was the fact that people with prior music experience would be nearly guaranteed to have prior experience with alternative pitch-recognition techniques, which inevitably affected their experience in implementing the new chromesthesia training techniques. If

chromesthesia training was used as a person's very first introduction to pitch recognition and music theory, it may provide significantly different results.

The information gained from implementing further research in chromesthesia training, and the topic of synesthesia in general, is valuable as it is not a widely researched topic. This information has the potential to be applied in various fields such as education and neuroscience. For example, chromesthesia training could be used by music educators as an aid in teaching the concept of pitch. Because music is an abstract concept, having a graphic representation of notes could help students who identify as visual learners better understand the concept. Additionally, chromesthesia training is just the tip of the iceberg. In theory, synesthesia training could be used for many different types of synesthesia, lending researchers a whole new world of cognitive benefits to look into.

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