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Exploring Implications of Synesthesia on Memory

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Introduction:

Synesthesia is a neurological phenomenon experienced by a minority of individuals, with estimates ranging from 1 in 200[1] to 1 in 250,000.[2] Synesthesia may be understood as perceiving one sensory stimulus (such as sound) by more than one sensory modality (such as sight, taste, touch, or smell).[3] This would elicit, for example, a sound being both heard and tasted at the same time. Synesthesia is not to be confused with metaphorical thinking such as using the expression 'time flies' or associating a certain event with a memory every time the event occurs. Descriptions of synesthesia may sound baffling, such as the sound of someone's voice evoking the taste of sour cream for the synesthete, or person who experiences synesthesia. The synesthetic experience is unique for each synesthete, meaning that the sound of the same voice may evoke the taste of sour cream for one synesthete but the taste of rusty nails for another.[4] Regardless of the infinite amount of manifestations synesthesia may take on, it remains consistent for the synesthete in the sense that the same stimulus will evoke the same synesthetic

[1] Sagiv, Noam. Ward, Jamie. "Cross-Modal Interactions: Lessons from Synesthesia" Progress in Brain Research, 2006 Vol. 155, 259-71.
[2] Cytowic, R.E. Synesthesia: Phenomenology and Neuropsychology" (1997) from Baron-Cohen. "Synesthesia: Classic and Contemporary Readings" 17-39. Blackwell Publishers, Oxford.
[3] Sagiv, Noam. Ward, Jamie. "Cross-Modal Interactions: Lessons from Synesthesia" Progress in Brain Research, 2006 Vol. 155, 259-71.
[4] Smilek, D.; M.J. Dixon & P.M. Merikle "Synaesthesia: Discordant male monozygotic twins.", *Neurocase* 2005, 11(5): 363-370

response at any time throughout his or her life.[5] Synesthesia may occur through any combination of the senses, joining more than two senses simultaneously for some synesthetes, and less commonly, uniting all five senses[6].

The world of science has known about synesthesia for at least three centuries, yet only within the past three decades has synesthesia begun to be appropriately explored as a topic of research.[7] Synesthesia is of scientific interest to disciplines as varied as molecular genetics, developmental biology, psychology, and neurobiology. The intrigue of synesthesia stems not only from its curiousness, but its scientific potential to reveal how the brain processes information perceived through the senses. The value in knowing how sensory processing functions in the brain lies in satisfying neuroscientific inquisitiveness as well as leading to probable aid for those suffering from neurological disorders and diseases.

A major area of research regarding synesthesia is that of determining its implications for those who experience it on a constant and consistent basis; synesthetes. Research in this area allows insight regarding similarities and differences, both on the neurological and perceptual levels, between synesthetes and non-synesthetes, as well as among different types of synesthetes. Scientists and synesthetes alike are curious to know what advantages or disadvantages accompany the synesthetic experience. While many correlations between synesthesia and other phenomena have been postulated, only a small number have begun to receive adequate attention through research. One of the main advantages that synesthetes may experience is significantly above-average abilities

[5] Sagiv, Noam. Ward, Jamie. "Cross-Modal Interactions: Lessons from Synesthesia" Progress in Brain Research, 2006 Vol. 155, 259-71.
[6] *Cytowic, R. E. (2002), Synesthesia: A Union of the Senses, 2nd ed, Cambridge, MA: MIT Press*
[7] *Ibid*.

in memory.[8] Further research into this area will answer outstanding questions and clarify current information shortfalls in the realm of synesthesia research on memory. Ultimately, more research involving synesthesia will lead to a greater overall understanding of how the brain perceives sensations, which underlies the very core of experience.

One of the major shortfalls in contemporary studies about the effects of synesthesia on memory are that only individual case studies of single synesthetes compared to a large quantity of non-synesthetes have been conducted. These studies may accurately assess the memory abilities of the synesthetes and non-synesthetes involved, but fail to make a more universal evaluation of the memory abilities of synesthetes compared to non-synesthetes.

Specific Aims:

Several contemporary case studies have determined well above-average recall of numbers and names by synesthetes.[9] [10] I propose undertaking the research of broad-scale analysis of the memory of synesthetes compared to non-synesthetes. In doing so, I will answer the following questions:

Are previously studied synesthetes unique in their memory abilities when compared to synesthetes as a group? Do synesthetes display superior memory to all stimuli (visual, auditory, etc)? Does the type of synesthesia the synesthete experiences influence what area of recall they will excel in, such as grapheme-color synesthetes (synesthetes who see colors when looking at or imagining printed digits, letters, and

[8] Sitton, S.C., Pierce, E.R. "Synesthesia, Creativity, and Puns" Psychol Rep. 2004 Oct: 95 (2): 577-80.
[9] Mills, Carol Bergfeld. Innis, Joanne. Westendorf, Taryn. Owsianiecki, Lauren. McDonald, Angela. "Effect of a Synesthete's Photisms on Name Recall" Cortex, 2006 Vol. 42, 155-163.
[10] Smilek, Daniel. Dixon, Mike J. Cudahy, Cera. Merikle, Philip M. "Synesthetic Color Experiences Influence Memory" Psychological Science, November 2002 Vol. 13, No. 6, 548-552.

words) surpassing non-grapheme-color synesthetes in memory of graphemes but not in auditory stimuli? Through answering the aforementioned questions, this research aims to determine if there is a difference in memory ability between synesthetes and non-synesthetes, as well as explore the affect of synesthesia in its various forms on memory of different types of stimuli.

Background/ Supporting Information:

Mneumonism and Synesthesia

While many writings on synesthesia link it to enhanced memory abilities, it proves a challenging pursuit to find an explanation as to why this might be so. It is an even more exigent undertaking to unearth how the association between synesthesia and memory began. A likely reason for the start of the 'synesthesia and memory rumor' could be the 1968 writings of neuropsychologist Alexander Luria, who wrote about subject "S". "S" was Russian mnemonist Solomon V. Shereshevskii, whose synesthesia is believed to have contributed greatly to his amazing memory abilities.[11] Shereshevskii's descriptions of his own synesthesia depicted it as being 5-way, or having all 5 of his senses perceptually inseparable. An example of this would be hearing the word 'biology' and perceiving simultaneous sensations of the taste of Cheerios, the smell of a swamp, the texture of a frog's back brushed across one's forearm, and a visual of a colored, dynamic landscape. Attributing Shereshevskii's super-human memory to his synesthesia was a convenient explanation for it at the time, and remains so to present day. Before this rationality may be scientifically acceptable, however, it is necessary to investigate mnemonists of similar caliber to determine the presence of synesthesia among

[11] Luria, A.R. (1968/1987). The mind of a mnemonist: A little book about a vast memory. Lynn Solotaroff, translator. Cambridge, MA: Harvard University Press.

them, and whether synesthesia is necessary to experience mnemonism innately. This will allow for verification of a relationship between synesthesia and mnemonist abilities.

Memory and Synesthesia

Case studies have established the greater recall ability of grapheme-color synesthetes on digits and written names, when compared to non-synesthetes[12] [13]. As with mnemonism and synesthesia, more wide-ranging studies must be conducted before it may be safely concluded that synesthesia has such a strong influence on memory. This requires measuring the memory abilities of not one grapheme-color synesthete, but as many as possible. Furthermore, the realm of research of synesthesia and memory is in great need of studying the affects of other forms of synesthesia besides grapheme-color on memory. The current deficit in studying multiple manifestations of synesthesia stems from the prevalence of grapheme-color synesthesia among the synesthete population, the convenience of studying it compared to other forms of synesthesia which are more difficult to statistically measure, and the fact that most of the research thus far on synesthesia has been on grapheme-color synesthesia, making information about grapheme-color synesthesia the most readily available form.[14] It is highly possible that the type of synesthesia a synesthete experiences has an influence on the type of sensory stimuli the synesthete excels at remembering. If the specificity and vividness of synesthetically experienced graphemes are what allow grapheme-color synesthetes to have an advantage in recall of graphemes, it follows suit to postulate that sound-color

[12] Mills, Carol Bergfeld. Innis, Joanne. Westendorf, Taryn. Owsianiecki, Lauren. McDonald, Angela. "Effect of a Synesthete's Photisms on Name Recall" Cortex, 2006 Vol. 42, 155-163.
[13] Smilek, Daniel. Dixon, Mike J. Cudahy, Cera. Merikle, Philip M. "Synesthetic Color Experiences Influence Memory" Psychological Science, November 2002 Vol. 13, No. 6, 548-552.
[14] *Hubbard, E. M. & V. S. Ramachandran (2005), "Neurocognitive Mechanisms of Synesthesia", Neuron 48(3): 509-520.*

synesthetes may demonstrate above-average recall of sound stimuli, tying into the belief that 5-way synesthetes such as Shereshevskii have the greatest advantage of all, because virtually any type of sensory stimulus will evoke the greatest amount of synesthetic responses, resulting in the largest quantity of built-in mnemonic devices from which to recall the stimulus.

Uni-directional vs. Bi-directional Synesthesia

In personal accounts by synesthetes, it has been recorded that synesthetes are sometimes able to recall the synesthetic reaction to a stimulus rather than the stimulus itself, such as remembering that a name evoked a lavender color, yet not being able to recall the name itself.[15] The impression of lavender may serve as a hint when trying to recall the stimulus which evoked it, similar to a mnemonic device, although it is automatic rather than consciously created, perhaps contributing to the ease with which synesthetes are suspected to have in recall ability. It is also possible that in the instance of a synesthetic response being recalled more easily than the stimulus itself, as with the lavender name example, synesthesia acts as a divider for attention of the synesthete between the name and the lavender color, thus causing a distraction. In this particular case, a sound-color synesthete hearing a name that is lavender may prove more difficult in recalling the name than if it were printed out and read by a grapheme-color synesthete because sound-color synesthesia is uni-directional, meaning that while a sound evokes a certain sight, recall of the specific sight will not reveal the sound that caused it. Grapheme-color synesthesia, on the other hand, has been established as bi-directional, meaning that graphemes and their synesthetic colors are interchangeable, one serving as a

[15] *Cytowic, R. E. (2002), Synesthesia: A Union of the Senses, 2nd ed, Cambridge, MA: MIT Press.*

stand in for the other[16]. Studies regarding synesthesia and attention would be complementary to studies of synesthesia and memory so as to take into account the possibility of distraction in stimulus perception as a reason for impaired recall of the stimulus. It would be worthwhile to conduct a test to measure recall for isolated sounds in comparison to long speeches for sound-color synesthetes to help determine the possibility of synesthesia having an impairing affect on attention, and subsequently memory, as this research method proposes.

Hypotheses:

Due to the need to explore the validity of the belief that mnemonism is linked to synesthesia, this research must measure the memory abilities of synesthetes in relation to the number of different types of synesthesia they express. I hypothesize that the more types of synesthesia a synesthete experiences, the easier it will be to recall stimuli. This may or may not be an explanation for mnemonism, although it is a likely influence. This hypothesis is built on studying accounts of mnemonists who describe their experience of stimuli as being infinitely synesthetically detailed[17], studying accounts of synesthetes who claim their synesthesia provides 'clues' for them to remember stimuli[18], and application of a basic knowledge of how memory functions.

I hypothesize that grapheme-color synesthetes will display, as a group, significantly above average visual recall of graphemes in comparison to non-grapheme-color synesthetes and non-synesthetes. Evidence in support of this has been

[16] Jansari, Ashov S. Spiller, Mary Jane. Redfern, Steven. "Number Synesthesia: When Hearing 'Four Plus Five' Looks Like Gold" Cortex, 2006 Vol. 42, 253-258.
[17] Luria, A.R. (1968/1987). The mind of a mnemonist: A little book about a vast memory. Lynn Solotaroff, translator. Cambridge, MA: Harvard University Press.
[18] Mills, Carol Bergfeld. Innis, Joanne. Westendorf, Taryn. Owsianiecki, Lauren. McDonald, Angela. "Effect of a Synesthete's Photisms on Name Recall" Cortex, 2006 Vol. 42, 155-163.

demonstrated by research verifying the bi-directionality of grapheme-color synesthesia, in which a number need only be imagined to produce the synesthetically-corresponding color.[19] This illustrates both the conceptuality of synesthesia and the instance of interchangeability between the synesthetic response to the stimulus and the stimulus itself in the case of grapheme-color synesthesia.

Research Methods:

Project 1: Studying Mneumonism and Synesthesia:

Subproject 1a: Questionnaire

In order to determine the role of synesthesia among mnemonists, it is necessary to find out if modern-day mnemonists experience synesthesia. A simple questionnaire may be administered to mnemonists to survey the presence of synesthesia in its various forms among them. These questions would investigate synesthesia in general, such as asking, 'Does stimulation of any one sensory modality (such as taste) evoke a reaction in any other sensory modalities (such as touch)?' as well as specifically, 'Does looking at printed matter, such as digits or letters, give you an impression of the digits or letters appearing in colors that are different from the colors they are actually printed in?'. It is also worthwhile to briefly delve into what role synesthesia may play for mnemonists through questions such as, "Do the synesthetic impressions left on you after perceiving stimuli make the stimuli more memorable for you than stimuli which do not leave a synesthetic impression?"

[19] Jansari, Ashov S. Spiller, Mary Jane. Redfern, Steven. "Number Synesthesia: When Hearing 'Four Plus Five' Looks Like Gold" Cortex, 2006 Vol. 42, 253-258.

Subproject 1b: Test of Genuineness

For the mnemonists which answer 'yes' to questions involving synesthesia, a Test of Genuineness (TOG) will be given to verify the presence of synesthesia. The Test of Genuineness is standard for 'diagnosing' synesthesia, and relies on consistency of synesthesia reactions over time. It requires synesthetes and non-synesthete controls to describe synesthetic responses (such as color) to over 100 pieces of stimuli (such as words and sounds). Controls are trained to create synesthesia-like associations of color-word pairs. Furthermore, controls are given the opportunity to purposely memorize these pairs for a re-test. Those being tested for genuineness of synesthesia, on the other hand, are surprised with a re-test. Even with advantages in training and preparation for the re-test, the Test of Genuineness results of sound-color synesthesia measure synesthetes as having 71.3% recall and non-synesthetes demonstrating 33% recall. The TOG using the Pantone-based Cambridge Synesthesia Charts requires an auditory CD which plays 99 unique sounds and a selection of 241 color swatches. Test subjects are asked to listen to each sound and indicate which color dominates their visual synesthetic response to the sound.[20] This test may be repeated for other types of synesthesia, such as grapheme-color, in which subjects would choose colors to printed letters, numbers and words. For other types of synesthesia, such as auditory-gustatory, synesthetes will be free to describe their synesthetic reaction to auditory and visual stimuli and will be asked to repeat their descriptions to the same stimuli over time. Controls during these studies will be asked to imagine synesthetic-like reactions to the stimuli and remember their imagined reactions for re-tests. Data from tests measuring synesthete and non-synesthete responses to

[20] Asher, Jullian E. Aitken, Michael R.F. Farooqi, Nasr. Kurmani, Sameer. Baron-Cohen, Simon. "Diagnosing and Phenotyping Visual Synaesthesia: A Preliminary Evaluation of the Revised Test of Genuineness" Cortex, 2006 Vol. 42,137-146.

stimuli will be scored by adding up the number of correctly recalled reactions (those that are the same for the second round of exposure to the same stimuli as compared to the first round) and dividing them by the total number of stimuli. A synesthete is genuinely synesthetic if they score above 70% on the Test of Genuineness.

Subproject 1c: Measurement of Data

Once the genuineness of the mnemonists' synesthesia is established, a measure of the amount of mnemonsists who are also synesthetes is needed to determine if the supposed link between mnemonism and synesthesia is due to coincidence, or if there is a genuine connection between the two. This requires a measurement of mneumonists and synesthetes among the general population in comparison with the frequency of synesthetes among the mneumonist population.

Project 2: Collecting and Categorizing Synesthete Experiment Participants

Subproject 2a: Questionnaire

Case studies which have verified above average memories in synesthetes will have more significance if further studies of the memories of synesthetes as a group are carried out. To begin this procedure, a questionnaire similar to the one given to mnemonists will be given to self-diagnosed synesthetes in order to determine the various types they may possess, such as sound-color, sound-taste, grapheme-smell, etc.

Suproject 2b: Test of Genuineness

The synesthetes will then be given a Test of Genuineness designed to measure the genuineness of their respective types of synesthesia. For many types of synesthesia, this

will rely on synesthetes' descriptions of their experiences in response to stimuli measured for consistency over time, rather than consistency of colors chosen from a catalogue.

Subproject 2c: Assessment of Memory Abilities (General Method)

Once the synesthetes are verified as synesthetes (by scoring over 70% consistency over time for synesthetic responses to stimuli), it is appropriate to measure their memory abilities, grouped as a whole and into various sub-categories according to the types of synesthesia they express. This will be done by measuring the ability of the synesthetes to recall audio and visual information randomly over various periods of time. This will be conducted through presentation of visual and auditory stimuli, such as printed and spoken letters, numbers, names, and words. The test subjects, both synesthete and non, will be asked to recall the stimuli presented to them in correct order immediately after exposure, 48 hours after exposure, and 6 months after exposure. These times of testing recall are a collaboration of several already existing tests for measuring memory of synesthetes. One such test measured the consistency of a grapheme-color synesthete's ability to recall digits equally well immediately after and 48 hours after exposure, as compared to a drastic decrease in recall ability over 48 hours for non-synesthetes[21]. Another test determined that a grapheme-color synesthete's recall of printed names increased drastically 6 months after exposure when compared to recall ability immediately after exposure[22]. For this individual study, synesthesia appears to have a greater affect on long-term than short-term memory. Of course, it is dangerous to base a conclusion off of a case study, giving more of a need to conduct broad-scale studies.

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[21] Smilek, Daniel. Dixon, Mike J. Cudahy, Cera. Merikle, Philip M. "Synesthetic Color Experiences Influence Memory" Psychological Science, November 2002 Vol. 13, No. 6, 548-552.
[22] Mills, Carol Bergfeld. Innis, Joanne. Westendorf, Taryn. Owsianiecki, Lauren. McDonald, Angela. "Effect of a Synesthete's Photisms on Name Recall" Cortex, 2006 Vol. 42, 155-163.

A comparison of memory abilities among synesthetes and non-synesthetes will serve as a foundation for determining the frequency of superior memory ability in both respective groups. If synesthetes demonstrate, on average, significantly higher memory skills than non- synesthetes, as suggested by case studies, further research will be required to determine how this occurs.

Project 3: Visual Memory

Subproject 3a: Visual Stimulation

In this subproject, the affect of grapheme-color synesthesia on memory will be measured by comparing the recall ability of graphemes for grapheme-color synesthetes to recall ability of graphemes by control groups. Graphemes will be presented as a series of random numbers, letters, words, and names (30 each). These will be presented via a PowerPoint slideshow in Times New Roman font, black color on a white background, and 44 point size. Each number, letter, word or name will be shown for five seconds, with a one second interval between each one. This protocol is typical of grapheme-color synesthete memory examinations for case studies, and is certainly applicable to testing multiple synesthetes. For as many color-grapheme synesthetes as participate in this study, just as many non-grapheme-color synesthetes and non-synesthetes will also, ideally, participate. This will allow for a comparison of grapheme-color synesthetes to non-grapheme color synesthetes and non-synesthetes regarding recall of graphemes.

Subproject 3b: Visual Recall

Participants will be asked to recall the aforementioned printed matter 20 seconds after viewing it by writing down as much of it as they are able to remember, as well as the reason they believe they remember it. Examples of this include creating mnemonic

devices, knowing the meaning of the word or a person by that name, or on a more synesthetic level, the colors the printed matter evokes. Depending on the type of synesthesia the non-grapheme-color synesthetes possess, they may or may not have an advantage in remembering the graphemes. For example, reading the word 'clock' to themselves, this may register in their minds as if they had heard the sound of the word 'clock' being spoken. If the synesthete is a sound-color synesthete, this my bring upon the synesthetic response to hearing the word 'clock' being spoken, and the visual (an abstract pile of sawdust, for example) may leave a lasting impression which makes the word easier to recall later, though not as easy as it would be with the experience of grapheme-color synesthesia, due to the bi-directionality of grapheme-color synesthesia. To keep track of this type of occurrence, the 'reason for recall' section of the recall chart will provide a way for documentation of the modes of recall. The test participants will not be presented with the graphemes again, but will be asked to recall the graphemes 48 hours later and 6 months later. These latter tests may be given without the experiment participants knowing that they will be asked to recall the visual stimuli on the determined dates by scheduling the participants to return to the test center on the specified dates without revealing the details of the particular activity they will be doing.

Subproject 3c: Visual Data Analysis

Data will be collected by tallying the number of graphemes correctly recalled by all participants and analyzed by comparing the groups to one another. Averages (mean) of the grapheme-color synesthetes, non-grapheme-color synesthetes, and non-synesthetes scores will be calculated for each trial. For visual purposes, data will be illustrated through bar graphs and further analyzed through application of the t- test. The t-test will

compare the mean, standard of deviation, and data points of the grapheme-color synesthete, non-grapheme-color synesthete, and non-synesthete population scores. Such a comparison assumes that the two populations yield normal distributions and the t-test allows for the determination of whether the two distributions are distinct from one another[23]. This tests the null hypothesis that the means of the two populations are equal. If the grapheme-color synesthetes score significantly higher in recall than the non-grapheme-color synesthetes or the non-synesthetes, resulting in statistically distinct means, it is suggestive that it is the specific type of synesthesia, rather than synesthesia itself, which aids in recall of this specific type of information (printed matter). If non-grapheme-color synesthetes score higher than non-synesthetes but lower than grapheme-color synesthetes, it is suggestive that other forms of synesthesia may be applicable to remembrance of graphemes. Investigation of the modes non-grapheme-color synesthetes use to recall printed information will help determine to what extent this is true, by reading the 'reason for recall' section of the recall chart filled out by each participant. If there is not a significant difference in recall ability between the groups, it suggests that previous case studies are not able to serve as examples of memory abilities of synesthetes in general, but rather as an indication of the memory abilities of the individual synesthetes involved. Likewise, if recall scores become higher with time for synesthetes, rather than decrease as is expected for non-synesthetes, this will coincide with previous studies and lead to a need for further studies involving synesthesia and long term vs. short term memory.

Project 4: Auditory Memory

[23] Press, William H.; Saul A. Teukolsky, William T. Vetterling, Brian P. Flannery (1992). *Numerical Recipes in C: The Art of Scientific Computing*. *Cambridge University Press*, *p. 616*.

Subproject 4a: Auditory Stimulation

The procedure for measuring recall of sounds is conducted by presenting participants with a series of sounds that are both lingual and non-lingual (50 each). The lingual will be spoken words, phrases and verbose sentences read by various human voices. Non-lingual sounds will be easily identifiable, such as the sound of a dog barking, alarm clock ring, water running, flute being played, or a thunder roll. Participants will listen to the sounds via headphones in cubicles designed to minimize outside distraction, with a 3-second pause between sounds.

Subproject 4b: Auditory Recall

Participants will be asked to fill out a recall chart 20 seconds after hearing the first 50 sounds (human voices speaking words, phrases, and long sentences), as well as 20 seconds after the second set of 50 (daily sound effects). Similar to the grapheme recall test, the participants will be asked to write down as many of the stimuli as they are able, along with the reason why they remember it. The participants will then be asked to recall the sounds from the test 48 hours later and 6 months later, without knowing in advance that the purpose of their visit will be to recall the auditory stimuli. In order to ensure that the participants will be available to re-recall 48 hours and 6 months later, they will be scheduled to come into the testing center without knowing the purpose. If they are not able to come in at those times, they may fill out the recall form via mail or e-mail/internet, after being contacted with instructions to do so.

Subproject 4c: Auditory Data Analysis

The data will be collected and grouped into categories of sound-color synesthetes, non-sound synesthetes, and non-synesthetes. The average (mean) number of sounds

recalled will be calculated for each group and compared on a bar graph. The data will be analyzed through a t- test to measure differences between the means of the scores of sound-color synesthetes, non-sound synesthetes, and non-synesthetes. This test will allow for a comparison of sound recall of spoken word and daily sounds for various types of individuals. It will also allow for comparison of sound-color synesthesia to other forms of sound synesthesia in terms of sound recall. Joined with the grapheme recall test, a sound recall test will provide a means to compare the affect of bi-directionality of synesthesia on recall. This is possible through comparison of grapheme-color synesthetes' scores for the grapheme recall test to those of sound-color synesthetes' scores for the sound recall test. A significantly higher average score for the former will help explain a lesser score for the latter, because recall of synesthetically induced images in response to sound does not allow for immediate recall of the sound itself, unlike recall of synesthetic color for graphemes.[24]

Further Discussion of Possible Data:

If sound-color synesthetes perform better as a group on recall tests than non-sound synesthetes, this will shed light on the degree to which the type of synesthesia a synesthete experiences influences memory. If sound synesthetes score higher than non-synesthetes on the sound recall exam, this further supports the hypothesis of synesthesia aiding in memory for modality-specific instances. If non-sound synesthetes score higher than non-synesthetes on the sound recall exam, it is possible that this is due to other types of synesthesia being employed to aid in the formation of pneumonic devices, such as

[24] Jansari, Ashov S. Spiller, Mary Jane. Redfern, Steven. "Number Synesthesia: When Hearing 'Four Plus Five' Looks Like Gold" Cortex, 2006 Vol. 42, 253-258.

mentally spelling out the words heard during the spoken word section of the exam. The above scenario would give grapheme-color synesthetes an advantage in auditory memory by recalling the colors brought on by seeing the word spelled out in their minds. A comparison of non-sound synesthetes' scores for the spoken-word and daily sound sections will aid in the determination of whether or not this is the case. Further exploration will be taken by studying what reason the participant gives as to why they recall a specific sound, as written in the 'reason for recall' section of the recall form.

Comparison of Possible Visual and Auditory Data:

It is probable that the memory of auditory stimuli by sound-color synesthetes will be higher than non-synesthetes and non-sound- synesthetes, but not to as great of a degree as recall of graphemes for grapheme-color synesthetes because sound-color synesthesia is not bi-directional. This means that a synesthete's recall of the colors induced by sound does not automatically allow recall of the sound itself, but it may provide an opportunity to deduce what the sound was. It is possible that sound-color synesthesia may appear to be a hindrance on memory of auditory stimuli if attention to sound for sound-color synesthetes competes, and sometimes loses, with the synesthetically induced colors. For colors to be induced synesthetically, the sound needs to be perceived by the brain as a sound, rather than registering as having a specific conscious meaning. This results in sound- color synesthetes experiencing color in response to hearing without necessarily listening to the words that are spoken. I predict that sound-color synesthetes will have compromised scores on recall of auditory stimuli for this reason, meaning that their scores will not be as high as they would if sound-color synesthesia were bi-directional.