

Synesthesia as an Intervention to Modify Children's Access to Enhanced Learning and Memory

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Abstract

Synesthesia is a phenomenal experience where a person reports more than one sensory experience activated for one stimulus. A specific type of interest is grapheme-color synesthesia where a person sees graphemes (letters and numbers) and it elicits a secondary response (color). It is through these experiences that people with grapheme-color synesthesia are given a secondary benefit: enhanced learning and memory. If people in society seek to equip children with the tools they need to succeed and excel in development, and synesthesia is a tool that helps with that, it would be logical to consider synesthesia as an intervention to increase children's access to enhanced learning and memory. However, in order to assess whether it should be considered for inducement, synesthesia must be evaluated in isolation of its instrumental benefits. This thesis outlines the intrinsic values of synesthesia, the instrumental values, and the applications to children before weighing whether inducement is permissible. Synesthesia is argued to be intrinsically neutral by balancing the positive and negative attributes including their respective counterarguments. Afterwards, instrumental advantages and disadvantages are weighed, and counterarguments are provided to keep a balanced review. Finally, the costs and benefits of synesthesia in the realm of learning and memory are scaled to determine whether induced synesthesia is permissible. This thesis concludes, that in order to permit induced synesthesia, the data must be valid and replicable in order to accurately predict and achieve the correct type of synesthesia and reduce creating more harm than good; therefore, induced synesthesia is not permissible.

Keywords: synesthesia, learning, memory, intrinsic, instrumental, value, mathematics

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Synesthesia as an Intervention to Modify Children's Access to Enhanced Learning and Memory

Synesthesia is a feature in which a person experiences cross-module activation of more than one of their senses. For example, a person can see sounds through colors or feel the same sensations as another person they observe. To provide an example of a type of this unusual occurrence, think about your typical morning routine: waking up in the morning, making yourself breakfast, and getting dressed to go to work. This time affords you minimal sensory stimulation as you only process one sensation at a time (e.g. hear the alarm chime, smell coffee lofting into the air, and watch as your breakfast is slowly prepared in the microwave). Now, imagine an alternative reality in which a secondary sensory experience accompanies the sounds you hear. When the high-pitched alarm chimes, blue waves from your alarm clock bounce around the room. The microwave's beeping noise is coupled with a shade of orange. Throughout your day, colors are paired with sounds. This is the experience of a person with chromesthesia and, to them, these pairings are normal.

Conventionally, these experiences are generated with an inducer (the stimulus) that triggers the synesthetic experience resulting in the elicitation of the concurrent (the response) at a given point in time. For example, graphemes are inducers and colors are concurrent for grapheme-color synesthesia. To some people with this condition these experiences provide secondary benefits: strong memory and learning. Unique perceptions of one's environment through various forms of synesthesia prompt questions related to education, morality, and research applications. In order to narrow the scope of this issue, these subcategories will be addressed since induced synesthesia could apply to children.

As a society, we want to give our children all the tools they may need to succeed and/or put them ahead in development. In academic settings, this sentiment is especially prevalent. In the realm of education, some of the benefits of inducing synesthesia may include accurate and faster

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responses and stronger learning association skills (Ghirardelli, Mills, Zilioli, Bailey, & Kretschmar, 2010, Bankieris & Aslin, 2016). However, there are many pressing issues considering the employment of this tactic in education. One of which being, whether this is worth investing energy into when there may be alternatives to explore that have been proven to improve the education system. A question that is worth pondering is whether induced synesthesia could be helpful for everyone, some, or none. For example, could this be beneficial for those that are not visual learners and instead tactile or auditory learners? If implementing inducement ends up being unhelpful to individuals whose learning style is not visual, then it may deter students from education or set back students in their knowledge acquisition and critical thinking capabilities. Essentially, this methodology could be another institution-enforced learning style which is *not* conducive to how children think. Overall, this would only exacerbate the original issue. Finally, there is the educational question of how teachers would be trained to adapt to a new curriculum adjusted to a synesthetic experience, since they are all unique to the individual induced. Obviously, these issues are all hypothetical, so it remains, and will continue to remain uncertain what the answers are to these questions as long as no research is done on the effects of induced synesthesia in educational settings.

On the ethical side, it is important to consider how permissibility of induced synesthesia will affect future decisions related to behavioral corrections. As a society, it is vital to tread carefully on trailblazing in this field of study, for these decisions can be cited for research and implementation of similar corrections across the board. This idea of a slippery slope is especially pertinent when considering issues where we already permit behavioral correction, such as rehabilitation for prisoner treatments (to return offenders back into society as productive law-abiding citizens) and treatments for patients with mental health issues. In some circumstances, we permit behavioral correction in neurological malfunction situations and already accept this as

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morally permissible, so does that mean that alterations for induced synesthesia are also morally correct? Thus, is it morally correct to alter people's behaviors at all? If we have been provided the opportunity to improve our mental capacity, to what extent are we obligated to intervene in child development to become similar to people with synesthesia for their enhanced learning and memory? Lastly, is it morally permissible to use synesthesia to reap the (academic) benefits or should it be studied for its own sake?

In the sciences, these are some of the benefits inducing synesthesia in early development may have: a greater understanding about synesthesia and determining a biological basis for the phenomena. However, there are pressing ethical issues considering employing this tactic in education. Why should we invest in this field over others issues that are important right now, such as cancer research? Could synesthesia be connected to an existing field and contribute to solving those issues? For example, if we permit behavioral correction in an attempt to enhance cognitive abilities (either through biological modifications or sociological treatments), then we may offer a reason to correct other behaviors, such as people suffering from mental disorders. If we give permission to do research in this field, then would this open the door to genetic modification in humans? Lastly, what are potential side effects and could be minimized, if not avoided?

To further understand and fully judge synesthesia as an intervention to modify children's access to enhanced learning (benefits or costs of induced synesthesia to potential subjects), the reader may find an affinity with the following goal: there is value in understanding synesthesia to change our education system. That being said, we must be cautious about the ethical implications connected to biological modifications (i.e., gene editing) through synesthesia's intrinsic and instrumental benefits and disadvantages. If the educational, moral, and scientific implications are sufficiently addressed, I believe that if the opportunity to increase our mental capacity is presented, we ought to pursue it. As long as previous case studies and experiments demonstrate consistent

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and reliable results, then induced synesthesia could be a sound treatment option for educational purposes. In order to come to a consensus for such a judgement, it is important to understand the physiological impact and derivation of the phenomena. This thesis will define induced synesthesia's prevalence in the US, the biology that underlies synesthetic experiences, and lastly, weigh its "intrinsic neutral", "instrumental good," and "instrumental bad" to determine whether synesthesia should be pursued as an inducement tool for memory enhancement.

The Prevalence and Neuroanatomy of Synesthesia

There are at least 60 different variations of synesthesia that have been documented, which include: lexical-gustatory synesthesia (the association between words and taste), mirror-touch synesthesia (when an individual feels the same sensations as another person they observe), chromesthesia (sound to color), and more (Simner & Hubbard, 2013). Five percent of the general population are affected with either one or more types of synesthesia. There also appears to be a genetic basis since studies show it runs in families. Brang and Ramachandran (2011) found that children born from at least one parent with synesthesia are likely to develop it themselves. The relationship to the type of synesthesia developed in the child versus the parent is still speculative (Brang & Ramachandran, 2011). This thesis focuses on grapheme-color synesthesia (colors are associated with achromatic numbers and letters) since it affects 1% of the general population, 64.9% of the synesthetic community are grapheme-color, and a large proportion of that research that has arisen in the last two decades looks at grapheme-color over the other (Campen, 2008).

The intimate link between memory and synesthesia occurs either by virtue of synesthetic experiences (due to enriched information) or structural changes occurring within the brain. As more studies emerge, we realize that synesthesia is not an illusion or imagination, but rather has a neurological basis. In 1997, Baron-Cohen et al. found that synesthesia can be measurable in the brain using positron-emission tomography (PET) and functional magnetic resonance imaging

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(fMRI) (Baron-Cohen & Harrison, 1997). They showed that chromesthesia has increased activation in visual areas of the brain in response to an inducer (sound), while a person without synesthesia does not show this activation. MRI studies show that there are three brain regions that consistently show an association to grapheme-color synesthesia: dorsolateral prefrontal, inferior parietal, and occipito-temporal regions (Rothen, Meier, & Ward, 2012). Rouw et al. (2011) describe the structural and functional imaging studies further.

The human physiology of the eye permits creatures to visualize the world. This process involves neuronal connections firing onto one another to transmit information to the brain for processing. The eyes are comprised of rods and cones and they are responsible for vision at lowlights and highlights (including colors) respectively. When the information is transmitted to the brain for processing, we have learned that images are translated upside down in the human eyes and the brain is wired to correct that. This example showcases the complexity of vision that influences our perception of our environments. Therefore, through science, we can find evidence that links the body and the mind, gaining a deeper insight into this concept of perception. People with synesthesia possess a characteristic to add to the field of knowledge. This community of people is endowed with a different perception of the world unique to each person, lending them enhanced memory and learning. Memories are important because they allow us to perform tasks efficiently and aid in making decisions. For example, memories allow us to take the lessons learned in classes and apply in relevant fields, or learning foreign languages enable us to interact with numerous societies. Memories allow us to build relationships, remember our job duties, and some say memories make up a person's identity. According to David Hume, our memories help draw connections between the events and experiences in our lives, an important aspect in the way we form our identities (Morris & Brown, 2017). Without our memories, our quality of life decreases (e.g. we are inefficient in performing tasks and we spend our time constantly relearning).

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Memories come from strengthened synaptic connections among neurons. These connections are most prominent in people with synesthesia according to the hyperconnectivity hypothesis; synesthesia arises from the lack of neural pruning that happens during maturation. This is significant because, according to research, an adult can be trained to have synesthesia; however, the effects only last up to five weeks. Otherwise, they have to continue to train in order to maintain it. On the other hand, children have more plastic neural connections. An adult normally loses the connections linking different brain regions together; however, people with synesthesia somehow retain them. This is a plausible explanation for the co-activated regions of the brain for sensory stimuli. Consequently, if children are the target audience (because they will have synesthesia long-term thus benefit the most), then I will investigate whether it is morally permissible for adults or parents to intervene (when the child could have otherwise led an entirely different life) simply to access the benefits (strong memory and learning). To answer this inquiry, one must break down whether synesthesia is in and of itself good overall and then discuss the applications.

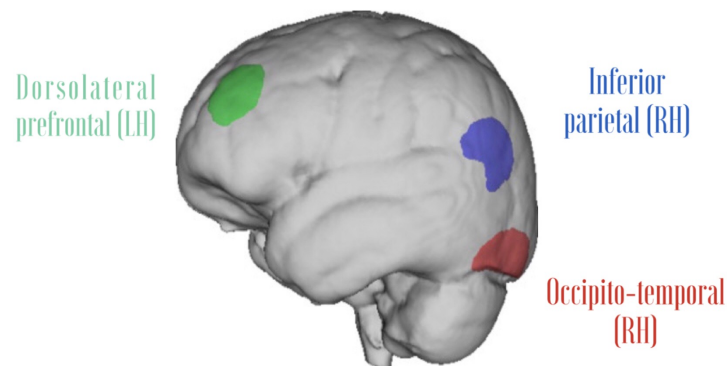


Figure 1. This an MRI for a person with grapheme-color synesthesia (Rothen et al., 2012). The occipito-temporal is the site where visual perception occurs. The inferior parietal is for emotions, sensory info, language and math. The dorsolateral prefrontal is the site where executive functions (working memory, planning, abstract reasoning) occurs.

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Relative Frequency of Different Types of Synesthesia:	
Grapheme to color	66.50
Time Unit to colors	22.80
Musical sound to colors	18.50
General sound to colors	14.50
Phonemes to colors	9.90
Musical notes to colors	9.60
Smells to colors	6.80
Taste to colors	6.60
Sound to taste	6.20
Pain to colors	5.80
Personalities	5.50
Touch to colors	4.00
Sound to touch	4.00
Temperatures to colors	2.40
Vision tastes	2.10
Sounds to smell	1.80
Vision to sounds	1.50
Orgasm to colors	1.00
Emotion to colors	1.00
Vision to smell	1.00
Vision to touch	1.00
Smells to touch	0.60
Touch to tastes	0.60
Smells to sounds	0.50
Sounds to kinetics	0.50
Sound to temperatures	0.50
Tastes to touch	0.50
Kinetics to sounds	0.40
Personalities to smells	0.40
Touch to sounds	0.40
Touch to smells	0.30
Vision to temperature	0.30
Musical notes to tastes	0.10
Personalities to touch	0.10
Smells to tastes	0.10
Smells to temperatures	0.10
Tastes to sounds	0.10
Tastes to temperatures	0.10
Temperatures to sound	0.10
Touch to temperatures	0.10

Note. Comparative frequencies of different kind of synesthesia. Data are based on Sean's Day's tabulation of 738 self-reported cases from a nonrandom sample. In Day's sample, 72% were female and 28% were male. (Data are reproduced with permission from <http://home.comcast.net/~sean.day/html/types.htm>.) (Cytowic & Eagleman, 2009)

Table 1. The frequency of each type of synesthesia reported in 2009.

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Intrinsic Values

Although the promises of synesthesia are appealing, one must first delve into the intrinsic and instrumental values that accompany this phenomenon to provide a balanced review. Doing so allows one to debate whether it is worth inducing synesthesia, specifically in children. Let us define intrinsic value as the subject of interest having value in itself. Some examples of intrinsically good are happiness, love, wisdom, health, friendships, etc. while pain and sadness are considered intrinsically bad. Not because of the results they bring about, but because how they are valued independently. However, this thesis will argue that synesthesia is intrinsically neutral thus it makes it a compelling candidate for inducement because it is neutral because it could be instrumentally good.

Intrinsically Neutral

When we think about health, pleasure, love, etc. we immediately attribute them as intrinsically good without further examples or explanations. However, when we think about synesthesia, we do not immediately attribute it as either good or bad and for that reason, it is intrinsically neutral. Its neutrality lends support for inducement and to begin the argument around inducement in people, one must first separate the two kinds of synesthetic experiences: developmental and acquired forms. Developmental synesthesia arises from birth or early childhood while acquired synesthesia forms in adulthood through pharmacological drugs (i.e., LSD), accidents/concussions, or training/hypnosis. This distinction will identify how important the synesthetic experiences are to the individuals who can experience them.

This thesis will consider a situation where a person with synesthesia lost their synesthetic experiences. From there, one can clarify if synesthesia is a valued form of experience because living a life without it may heavily change one's life, even for the worst, and if adjustment is possible. To add to the complexity, one can ask how influential losing one's synesthetic

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experiences may be, if it is tied to an existing passion. This is important because we can distinguish how synesthetic experiences are tied to identity, preference, and if the adjustment is possible. An example about Sean Day, a musician with multiple synesthesias, will be described to showcase that while inducement may not be clear, if the synesthesia was lost, the transition is possible, but there may be a cost.

Developmental Synesthesia. This form is neutral because the benefits and drawbacks are balanced. We can look at the benefit (normalcy as valuing and missing the synesthesia when it is lost) and balance it with the drawback (there are unknown ramifications if lost where additional important matters are also lost and missed whether or not they miss the synesthesia). We can identify things that are instrumentally valuable by seeing what people value because it can bring more intrinsically good outcomes. One way we can see what people value is by looking at what people would miss if they lost it. Things that are a normal part of someone's life tend to be missed if they are lost, suggesting that they are valued to that person. So, if people with developmental synesthesia find it normal, then this gives some initial reason to conclude developmental synesthesia is intrinsically valuable.

First, we identify things as being instrumentally valuable by seeing what people value because it can bring more intrinsically good outcomes. For example, we value health and that is an intrinsically good feature to attain health. To attain it, we use money, but money alone is meaningless unless we can use it. In this case, we can use the money to purchase medicine and medicine contributes to good health. Another reason why we value health is because good health means that we can live longer. Living longer allows one to form relationships with people and forming relationships or having friendships is an intrinsically good matter. All in all, money leads us to intrinsically good features and it is a natural tendency to pursue intrinsically good items. Given this information, it is normal to value intrinsically good items. For synesthetic experiences,

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their natural state of being is different and they have a reoriented view of normalcy. Normalcy is a standard by which behavior is measured and provides social coherence in organization, but, can also marginalize those that don't fit within the norm. However, artists operate outside of the mainstream culture and we applaud them for this and their creativity, thus we appreciate the artwork more. Although synesthesia is abnormal to non-synesthetic community members, we can still appreciate the instrumental outcome/benefits just like how we can appreciate artists for not fitting the norm. They have a different view of normalcy which means that we have to redefine normal. The benefit to this is that the definition is flexible, so if we value typical mainstream items such as money because it has instrumental application that leads us to other intrinsically good items, then we can value synesthesia because it also has instrumental applications that also leads us to other intrinsically good items. For example, education is an intrinsically good and synesthesia provides enhanced cognitive abilities that can help them learn better. Another example is that having relationships is an intrinsically good matter and synesthesia can enhance empathic abilities which allows us to form those relationships.

Second, to identify what people value, we can look at what people would miss if they lost it. We appreciate the value of something when there is a possibility that it will no longer exist. We reminisce all the good aspects about a person and what they have done when they are on their deathbed. We start to care for the environment when the Earth's resources are on the edge of depletion. We study harder for exams when we are threatened to fail. Universally, we do this unintentionally because we find comfort of their continuous existence, but then that comfort is suddenly stripped away. We often take advantage of matters that deserve our gratitude the most, so when the item of value no longer exists we can fully assess how important it was. If synesthesia is valuable, then all persons with synesthesia would miss it if/when they lost it. This is supported by the claims on Reddit despite the fact that none of the individuals have ever actually lost their

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synesthesia. All of the responses say they had the revelation that their experiences are not universal later on in adolescence or adulthood; the strange coloration of letters and numbers is easily overlooked until they described their perceptions to others, or professors raise the topic around the phenomenon. Another case that support how synesthesia is valuable if it were missed is still supported in a case about Sean Day, a musician, who had and lost his synesthetic abilities. This case will be reviewed more in detail later. All in all, we can evaluate how important something is if it is missed when it is lost.

Third, things that are a normal part of someone's life tend to be missed if they are lost suggesting they are valued to that person. Matters that are normal to someone's life are unintentionally expected to have a constant presence and therefore, we do not really appreciate it when it is there. In spite of that, when it disappears it violates our expectations and from there we have to ask ourselves if we are okay with this change/it being gone. We live in a rapidly changing world; however, many people fear change and even resist it. When normal parts of our lives change, the fear of uncertainty and the failure to adjust become powerful emotions. Synesthesia is normal to a person who has always had it (developmental synesthesia). That is because all they know is that a certain concurrent (response) is produced when an inducer (stimulus) is present. As mentioned before, people do not question whether their perceptions are any different to anyone else's, until they reach adolescence or adulthood. These sensory pairings are intimately linked to a synesthete. A person with chromesthesia finds it normal for sounds and colors to be paired, just as a person without synesthesia who witnesses fireworks also automatically pair these two together. If their synesthesia is lost, then those fears settle in. So, if their synesthesia was tied to other matters that they expect to also have a constant presence, then it may be even more difficult to grapple and accept their loss. For example if one's synesthesia is tied closely to music and allows them to appreciate music more, then losing it could mean the knowledge of no longer fully

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appreciating music the same way anymore. Sean Day, a musician, wrote an autobiography of his synesthesia and includes how he had lost it. This autobiography illuminates an instance where a person experienced the world with both lenses: with and without synesthesia. Day had multiple types: (he sees shapes, movements, and colors when he hears music, induced by the timbre; he sees shapes, movements, and colors when he tastes food; and he see shapes, movements, and colors when he smells odors). Growing up, he did not realize his skill until he turned to music to just see the colors (at age nine or ten). In 1999, on the 17th floor of a building in Taiwan, Day survived an earthquake (a 7.3 on the Richter scale), and the PTSD from the incident lead to subsequent loss of all three of his synesthesias and was “immediately aware of the loss” (Day, 2013) Two months after the incident, Day sought out to restore his synesthesia by listening to music or trying food because he had started to “miss” it (2013). This case demonstrates an actual instance where someone lost—not one, but three of—their synesthesias and found value in them after they were lost. Especially considering that he is a musician and his synesthesia is tied to his appreciation for music. Consequently, when one’s synesthesia is tied to an intimate aspect of one’s life, losing their synesthetic experiences are difficult to endure because it can mean losing other matters that they thought were permanent as well.

Fourth, if people with synesthesia find their experiences normal, then this gives some initial reason to conclude developmental synesthesia is intrinsically valuable. If synesthesia is a valued form of experience, then we can answer this question by asking how a synesthete would feel if they lost their synesthesia. In order to provide specific claims, I turned to Reddit and posted questions in a synesthesia community page for personal accounts because these answers are difficult to attain in primary literature (Chapman, 2019). One response, “I would miss it if it was gone. It would almost be like a milder version of losing a sense like sound or sight. It wouldn’t impair my functioning in the way losing those things could, but I would be sad to lose access to

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the perceptions it gives me.” According to these accounts, there is an intimate and personal tie to their experiences that makes it difficult to part. The responses collected say that if they lost their synesthesia, they would do whatever it takes (within reason) to restore it, because they believe losing it would heavily change their lives, even for the worse. This is especially the case when their type of synesthesia pairs well to existing passions that they already attribute their identity to. Consequently, if people with synesthesia see it as part of their identity and we value identity, then synesthesia is valuable.

Identity is Valuable. In a scenario where one’s synesthetic skills pairs well to an existing passion, losing their synesthesia could negatively impact one’s life because it could mean losing other matters, such as part of their identity. One person mentions, “I like having synesthetic experiences as I feel like it enriches my art! But I feel like it doesn’t make me ‘better’ at art, it’s just personal to me in a way I like.” All in all, most responses pooled agree that if their ability was taken away, they would be “heartbroken” and feel “lost” because these are the only experiences they have ever known. Losing synesthesia is extra difficult when another commodity is also lost – identity. This is important because identity is intrinsically good since it is an entity’s makeup. To support this claim, individuals were asked on Reddit if they believed their synesthesia is part of their identity. There were two types of answers: it is either part of their identity or it complements one aspect of their identity. The first type was found with this answer: “It’s part of who I am; my life would be completely different without it” and some add “But it’s not one of the labels I would assign if asked to define myself” and “maybe not so much as part of my identity as being an Artist or Christian or Transgender is to me” (Chapman, 2019). The intimate connection seems to weave its way into components of one’s identity, yet it does not overpower the ones deemed most valuable. So even if it was lost, at some level it can be harmful or harmless. On another level, we can look at a response that supports that second type of answer that their synesthesia complements

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one aspect of their identity and maybe even enhances their experience of it. One said, “I’d say more that my love of music is part of my identity and my synesthesia (auditory-tactile) is sort of encapsulated in that. But it’s not really something I bring up when telling other people about myself, and I don’t consider it to be a crucial part of my identity on its own” (Chapman, 2019). From this response, while it is a constant presence in their day-to-day routine, there are other existing features synesthetes identify with, such as love for music, which enhances their ability to enjoy their experiences more. Consequently, losing their synesthesia does not entail losing a major part of themselves, the experience is just no longer the same, but still pleasurable. Therefore it seems that if it complements part of their identity, and they value their identity, then they value the synesthesia too. Although it may not be the most valuable thing to them, it seemingly still has some value in their lives because there was a connection that cannot be easily dissolved upon losing the synesthesia.

More Than One Lost. When Day lost his synesthesias, he may seem to have adjusted just fine to his new lifestyle, but he was also unable to connect to a passion that he strongly attributed his identity to. His synesthesias did not return in its full level until seven months after the earthquake and he was “wholly unconcerned” because he was “too stressed out and had too many other concerns on [his] mind to care about [his] synesthesias being gone” (Day, 2013). Once it returned to full level, he “didn’t really become depressed or anguished about [the] loss” (Day, 2013). Although Day’s synesthesias complements his lifestyle, as a musician, he was able to recover after losing his ability and transition just fine into a new lifestyle without the supplementary experiences. Thus, with these types of synesthesias, one can adjust to a world without their synesthetic experiences even if it is tied to an existing passion that contributes to his identity. Even if he missed it a little bit, it was still valuable to him at some in his life and those emotions are more obvious when it finally did return and he said, “It was only once [his]

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synesthesia started coming back that [he] cared and realized how much [he] had missed [his] colored music, flavors, and smells.” On the other hand, Day’s passion for composing and listening to music dwindled immediately after losing his synesthesias. He said, “I tried to produce some by listening to music; but...music was still unenjoyable and provided no comfort.” (Day, 2013) In that event, when one loses their synesthesia, they also lose their passions and those passions are tied to their identity.

The main takeaway is that people born with synesthesia are better off because they do not suffer and if their synesthesia pairs well with something else that they cared about, then they have a greater experience for it. The only downside is when the synesthetic experience is lost and it is difficult to adjust because it could mean losing more to it than just that, such as identity. The evidence so far indicates that synesthesia is valuable because it contributes to their identity and we value identity by its very nature.

Acquired Synesthesia. For these individuals, whether their synesthesia is tied to an existing passion, they can adjust easier compared to having developmental synesthesia. All things considered, these individuals already know what a life without synesthesia is like. In short, it is “easier” to let it go because they have seen the world in both lenses and can transition with more ease if they lose it. However, the type in question is not the acquired form but the developmental form, but we can still take away from the arguments that synesthesia is neutral because having it then losing it is not harmful.

Summary. In summary, members of the synesthesia community agree that their experiences are normal, at least within the populace. This is because the synesthesia community is growing and becoming more accessible to converse commonalities. Therefore, synesthetes feel that having synesthesia is heading towards normalcy, especially in a community that welcomes discussion and shares their own synesthetic experiences. As the phenomenon gains more attention,

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people are more likely to be accurately diagnosed by professionals or be self-diagnosed. As they increase their exposure to other people experiencing similar sensations, this rare condition seems less rare. We can determine what is valuable to a person if it is missed when it is lost. Thus, matters that are normal to one's life tend to be missed when they no longer exist. Therefore, we can judge the value of synesthetic experiences to these community members by creating a situation where they lose it and claim to miss it. When another intrinsically important matter is also at stake, such as identity, then there is even more reason to value the original matter. One of the limitations of collecting these responses is that one cannot guarantee these individuals have synesthesia and answered honestly. Given the substantial reports supporting the normalcy and preference of synesthetic experiences, we must be cognizant that there may also be community members that scrutinize synesthesia because it may not be desirable whatsoever. When analyzing Sean Day's case study, it illustrates that even if the synesthesia is lost, it is not entirely detrimental because it was still possible to adjust; however, it was also at the cost of losing his enjoyment for music. The next topic of interest is sensory obstruction which is an intrinsically bad matter that must be calculated to show synesthesia as neutral.

Sensory Obstruction. Having addressed the value of synesthesia to members of the synesthetic community, we can now focus on one intrinsically bad feature that accompanies synesthetic experiences—sensory obstruction. This section will deliberate sensory obstruction as a hindrance, then offer counter arguments that reveals it is actually intrinsically neutral. In theory, if synesthetic experiences are involuntary, then people with synesthesia would experience sensory obstruction because unrelated colors, textures, tastes, sounds, etc. are involuntarily supplemented. Consequently, it potentially creates a cluttered and overloaded perception of the world. Sensory obstruction is inherently bad and has instrumentally negative consequences that includes possible impairment of proper cognitive function—relevant information gets lost among the co-activated

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concurrents and focusing on tasks becomes more troublesome and frustrating. If we look at the deaf community, we can find suggestive claims against induced synesthesia. For instance, some individuals in the deaf community report that their sensory experiences are too cluttered when they have functioning hearing aids, so the absence of unnecessary audio or noise is peaceful and preferable. Since synesthesia is at the opposite end of the spectrum to being deaf, one can argue if all your experiences are cluttered, then it could be hard to control those sensory experiences and it can be hard to pair it to what you are actually experiencing. Following this logic, synesthesia would be undesirable.

Counterargument About Sensory Obstruction. if synesthesia was induced in infancy, then they naturally assume their experiences are normal to everyone and learn to adapt. These synesthetic experiences occur without their choice, so these sensations are easily assumed to be normal to everyone else too. Even though these sensory activations are involuntary, it does not necessarily obstruct their interactions and activities. It may be the case that synesthesia is only seen as “cluttered” to those who have never experienced synesthesia at all, and maybe not necessarily to those who have only ever known life this way. One synesthete, Lix Bruxton, wrote an article describing her experience and says it is like “pleasant [music] in the background” (Bruxton, 2016) and Day says, “I can just ‘push’ the synesthetic perceptions to my peripheral vision, clearing my main field of vision while the colors flicker on the borders” (Day, 2013). It is always there yet unobtrusive. In the same way that, the brain selects the most salient information among the clutter that is most relevant to the viewer. For example, people can listen to white noise and the brain filters out information using a passive, built-in system, so that one ignores the white noise; however, one can focus and acknowledge the white noise again. Since sensory overload may be more harmful to people who acquire synesthesia, it would be best to have it on the onset of birth or early development. The reasoning is, adults that attain these new skills can face more

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difficulty adjusting because of the potentially distracting responses to stimulus, unlike children, who believe their experiences are natural because they have only ever viewed the world through a synesthetic lens.

Some synesthetes are more or less bothered by their synesthesia than others and they implement techniques to diminish it. For examples, Bruxton said, “in daily life, words sing out to me everywhere I go. Advertising boards, road signs, and posters are all brighter and louder to me. If I zoomed in and allowed myself to see every color, it would be overwhelming.” Although the ever-present colors pose a potential, perpetual distraction, it seems that it can be reduced by looking at it from afar, and, if they do not concentrate on it, then it is like music in the background. Another example was in the case study with SE where claimed she has never mixed colors between images she actually perceived and those within her synesthetic images; thus, allows her to perform well in memory tasks and mathematics (Mills, Metzger, Foster, Valentine-Gresko, & Ricketts, 2009). Likewise, Bruxton stated that while colors are paired with letters and numbers, it does not distract her from enjoying the written word. The synesthetic image and the real image are separate dimensions of objects that can be sorted and isolated. That is, one does not necessarily intrude on the other.

The main challenge to the claim that synesthesia can produce sensory obstruction is that there are no scientific studies measuring the level of obstruction in the synesthetic community. It can only be observed on a case-by-case basis and even then, these findings are subjective to that one person. Hence, the evidence may not represent the population accurately. Due to the lack of substantial evidence, we face a difficult question: how can we make decisions about inducing synesthesia in the absence of this sort of information? Without this evidence, inducement can only be speculative. If synesthesia is desirable, then the results must be valid and replicable. Although there are not many studies that show debilitating effects linked with synesthesia, that does speak

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for the case that obstruction is at a significantly low number. Equally important, one can infer that most people with synesthesia have lived with it since infancy, thus making it less obtrusive in adulthood, for it is just natural for the person. Unfortunately, the origins of synesthesia are still under investigation, so we have yet to understand how many persons have had it early on versus those that have developed it incidentally. Since we can argue the case in either direction, sensory obstruction is intrinsically neutral.

In conclusion, synesthesia is a phenomenal experience of the world that is valued by people who have possessed it during development. This insight is gained when we inquire if it will be missed if it was lost because people tend to miss things that are valuable if they disappear. One argument against inducing synesthesia is that it will lead to sensory obstruction because these experiences are involuntary and color associations are overwhelming, thus impair a person's ability to pay attention to important stimuli. The objection to these claims is that sensory obstruction is subjective, so it can only be analyzed in a case-by-case basis. And if present, there are methods in which sensory obstruction can be reduced so that it is not a hindrance. Given that people with developmental synesthesia automatically adjust, seeming to believe everyone else has done so, people naturally create their own techniques to make synesthesia work for them while they continue to reap their secondary, instrumental benefits. Subsequently, one cannot generalize sensory obstruction as a limitation to all individuals with synesthesia, therefore endorses how synesthesia is neutral. Thus if synesthesia is neutral, then it makes for a compelling candidate for inducement because it is intrinsically neutral, but could be instrumentally good.

Instrumental Values

Even though the features of synesthesia are immeasurable and extensive, it is imperative that we take into account the many facets that make up this inquiry of whether or not it is worthwhile to induce synesthesia. One must first consider the instrumentally good and bad features

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to determine whether becoming a person with synesthesia is worthwhile. Let us define instrumental value where the subject of interest has value because it helps us get or achieve something else. Something has instrumental value when it serves as a means to some end. For example, money is not valuable alone, but rather, the things that money can give you, such as medicine to improve your health (an intrinsic good).

Instrumental Good

When looking at the instrumentally good features, some popular ones are: greater cognitive capabilities (creativity, language learning, and memory), body and sensory awareness (of yourself, your surroundings, and your relationships with yourself and others), emotional regulation (empathy, improved sleep, decreased stress), and more. As part of the discussion on the developmental aspect of synesthesia, it is essential to focus on cognitive capabilities, specifically memory. In general, multiple pieces of evidence support that people with synesthesia have better memory and are considered more intelligent. Long-term memories are essential for everyday functioning, and working memory is important for reasoning, guiding decisions, and behavior. The types of memories this thesis will focus on are long-term memories and working memory, and although short-term memory may be important to some extent, short-term memory is not relevant to this case. Nicolas Rothen, Beat Meier, and Jamie Ward wrote a review that compiles research on synesthesia pertaining to memory (Rothen et al., 2012). They collected current research leading up to 2013 on the neural basis of synesthesia, factors that may enhance memory (imagery, level of processing, etc.), different memory tasks tested, case studies, group studies, and more. The authors suggest that the enhanced memory found in synesthesia is due to the wider changes in the synesthetic brain; specifically, structural and functional changes in their visual system. Those structural changes include strengthened synaptic connections among brain regions that are nonexistent in the non-synesthetic community. The review is relevant because it provides a

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comprehensive view of what types of memory processes had significant differences compared to controls and what the overall results mean. To outline the memory advantage, this thesis will discuss how 1) synesthetic experiences are consistent across time, and this is important for pattern recognition. 2) synesthetic-inducing material supports memory, 3) memory is better when information is congruent to one's synesthesia, and 4) increasing trials also means increased accuracy and speed despite incongruencies.

Consistency. One good feature behind induced synesthesia is heavily tied to its instrumentally good values. For example, individuals that experience synesthesia all have unique, consistent color spectrums within individual spectrums. Consistency is beneficial because that means the synesthetic experiences are not always changing; thus, making their perceptions less chaotic or difficult to process information. As a consequence, this natural ability does not inhibit people with synesthesia from their ability to recognize patterns. However, when they start using this condition to help them detect patterns, it lends an instrumental benefit.

Longitudinal Studies Testing Consistency. To outline consistency as an intrinsically good feature within synesthesia, reported experiences from individuals will be used. In 1923, Leon Ginsberg conducted a study testing tone-color association for his synesthesia (Ginsberg, 1923) and he reported that the colors to text pairings were the same, if not close, five months after the initial recording; therefore, his synesthesia was consistent. The strength and weakness of his study is the failure to use an objective measure to determine what was correct and if that included answers that were "close" to the initially recorded answer. Ginsberg's early study gave insight into how he quantified his research. For example, in the initial test, a "deep brown, almost black" was reported as "blackish brown". Then five months later, "deep brown, with blue tinge; almost maroon" changed to "dark purple". Although Ginsberg's study was limited and susceptible to bias, it paved a path for Baron-Cohen to pursue this research even more.

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Baron-Cohen was the first to provide concrete evidence that synesthetic experiences are consistent across time (Baron-Cohen, Wyke, & Binnie, 1987). He studied a word-color synesthete, named EP, and they presented 100 triggering words and asked her to describe what color(s) she experienced. One year later, they repeated the test, and the subject retained the same color-word associations as her initial response of more than 90% of the time. In contrast to the control group (people without synesthesia) that were asked to create analogous color associations to the words, they performed the same task and tested two weeks later, but they were consistent only 20% of the time. The evidence here supports that synesthesia does not change across time except for the 10% accounted. One limitation to this is that EP has chromatic-lexical synesthesia (she automatically experiences a color when she hears or thinks about the word), so the applications are limited to some extent towards other types of synesthesia. The author fails to include what the 10% accounted. It remains unclear if the test for consistency must be exact, or if it is acceptable if it is close to perfect recall (e.g., if EP reports a word to be orange initially, but a year later says it is a brownish orange). This case study lends support towards consistency, but only to a limited extent. Let us assume the 10% mismatch was due to change from orange to blue. If that is the case, then we have reason not to induce synesthesia because it could be more harmful than beneficial. If consistency allows us to detect patterns in the world and synesthesia is only consistent 90% of the time, then the last 10% may make it difficult, if not impossible, to conceptualize patterns related to their synesthetic experiences.

Pattern Recognition. People with synesthesia already experience the world with consistent color connections which has a positive effect on one's performance in this area of life. According to Dzulkifli & Mustafar, colors increase our attentional level and therefore help us memorize certain information (Dzulkifli & Mustafar, 2013). Their review provides plenty of research to show that color indisputably enhances our attention level. This is because when certain

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stimuli are given more attention, it has a better chance to be transferred to a permanent memory storage, in this case, colors have the potential to attract attention. An early study conducted by Farley and Grant (1976) demonstrated that certain stimuli (i.e. colored multimedia presentations) are given more attention to than monochrome ones, thus, the individuals tested were more likely to recall a colored text than a monochrome one. This experiment on memory performance provided some evidence that supports the claim that colors attract more attention. Following this research, robust evidence from multiple studies explored the relationship between color and memory performance. These studies can be analyzed further in Dzulkifli & Mustafar's review of "The Influence of Colour on Memory Performance: A Review" (Dzulkifli & Mustafar, 2013). Later studies have uncovered that the mechanisms underlying synesthetic and real color are not identical (Janik McErlean & Banissy, 2017). Therefore, it would be comparable but not entirely accurate to say that these involuntary experiences are recreated by people without grapheme-color synesthesia through proper use of highlighting text. Instead, it would be more accurate to say there is another level of processing involved so that text does not appear too cluttered or distracting after highlighting, just as SE mentioned how she can separate the color dimensions or how Bruxton can read signs and books without trouble by using her own tactics. Thus, a synesthete experiencing connections between visual stimuli and color throughout their life in consistent patterns can have an inherent upper hand in their learning ability as a mental organization through color connections produce better memory recall. However, not everything is colored. Instead, only specific stimuli in the realm of the person's type of synesthesia produces a secondary response (color) which is discussed in Mills et al. (2006) experiment later in the thesis. An instrumental good concerning pattern recognition is that a synesthete can make consistent predictions about life from familiar sensations. Even though the synesthetic experience is not the same relative to type from one person with synesthesia to another, it still enables them to detect those patterns. A salient number or word

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has a better chance to be stored in their memory. Therefore, pattern recognition is an instrumental benefit, and it allows researchers to study cases individually. We can look at a few case studies to demonstrate how people have recognized patterns brought by their synesthetic experiences to understand mathematics.

Case Studies. Individuals, including the Cornell University physics professor, Geoffrey Chester, utilized his synesthetic experiences to his benefit – he worked out mathematical formulas until he reached the correct answer because of the vivid colors (Duffy, 2001). He “can remember all the steps of a detailed formula [that he and his students] have been working on weeks before [because] the numbers and colors are so clear in [his] mind.” And until the complex formulas are worked out, we work them out and the vividly colored numbers aid to keep him focused. The following interview with Chester gives an idea of his psyche to solve mathematical equations:

He sees Schrodinger’s Equation in quantum mechanics in varying shades of yellow. He explains that the equations symbol H is yellow ochre, while its basic variable, often called Greek psi, is light yellow. ‘It was a great advantage for me as child, too, in my strict elementary school in Edinburgh, Scotland, where we needed to be ready with a quick answer to our multiplication tables. I could see the numbers in vivid color which helped me to do the calculations quickly.’ He still remembers the beautiful colors generated by multiplying 362×20 (or yellow, blue, and white times white): a gorgeous brown 7, followed by a white 2, pinky-red 4, and bright white 0. Similarly, multiplying bright green 8 by bright green 8 yielded a lovely combination of shiny midrange blue (6) and dark pinky-red (4) (Duffy, 2001).

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$$\frac{\hbar}{i} \frac{\partial \psi(x,t)}{\partial t} = -\frac{\hbar^2}{2m} \frac{\partial^2 \psi(x,t)}{\partial x^2} + V(x,t) \psi(x,t)$$

The diagram includes the following annotations:

- $\hbar/2\pi$ points to the \hbar in the first term.
- i is written below the i in the first term, with an arrow pointing to $\sqrt{-1}$.
- ∂ is written below the ∂ in the first term.
- $\psi(x,t)$ is written below the $\psi(x,t)$ in the first term.
- \hbar^2 is written below the \hbar^2 in the second term.
- $2m$ is written below the $2m$ in the second term, with an arrow pointing to "Mass".
- ∂^2 is written below the ∂^2 in the second term.
- $\psi(x,t)$ is written below the $\psi(x,t)$ in the second term.
- $V(x,t)$ is written below the $V(x,t)$ in the third term, with an arrow pointing to "Potential Energy".
- $\psi(x,t)$ is written below the $\psi(x,t)$ in the third term, with an arrow pointing to "Wave Function".

Figure 2. Schrodinger's wave equation in the perception of George Chester (Duffy, 2001).

Another example is Katinka Regtien, and she uses the number-color associations in mental arithmetic (Duffy, 2001). She claims that upon seeing a simple addition problem, she can first see the color which foretells the number. Her experience is analogous to sensing a word on the tip of one's tongue until it comes to mind. The following quote illustrates how she perceives the problem:

I cannot do arithmetic without visualizing the colors and the forms of the numbers. When I add fifteen and eighty-three, I see mentally first a cream white line (the color often) and a green line (the color of eighty). In that first moment, I already see that the outcome will be in somewhere around the brown line, which is the color of ninety. So I start the arithmetic with cream white, green, and brown lines, corresponding to ten, eighty, and ninety. Then, I zoom in to the place where the smaller numbers are, and the blue five of the fifteen gets more significance than the cream white one (which stands for ten), although the number fifteen is normally more white than blue. The same happens with the number eighty-three. The three is kicked three steps on top of the five and lands on the place of the number eight. And so the outcome is ninety eight. If the sums are more complex, I put them on paper, of course, but still, the same process happens in my mind.” (Duffy, 2001)

Both Chester and Regtien make their synesthesia work to their advantage, and for individuals like Chester, it even propels him further in his academic career. They exemplify how the color associations are consistent; therefore, it allows them to predict future outcomes according to previous attempts to solve the problem and consistently reach the correct answer. By trial and

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error, not only do they understand the image in the “real” dimension, but they also deduce the patterns to understand the image in the “synesthetic” dimension as well.

Counterarguments About Pattern Recognition. One of the downsides to this is that the exact reasoning behind these predictions is still hazy. Although Chester and Regtien are great examples of success stories, we equally find great examples where math and synesthesia are not compatible, but instead, make calculating difficult.

For Margreet van der Wardt, the colors of the numbers are more of a distraction when performing arithmetic, and for Wendy Spijkers, although she understood color theory, the arithmetic problems would conflict with that (Duffy, 2001). She said “When I have to multiply numbers, say, three times three—that is, yellow times yellow—which becomes a pink-red nine, I first have to let that sink in before I can proceed. If I go too fast in doing sums, I lose the colors and the numbers and have to start again.” In sum, this type of synesthesia impedes her when doing simple mathematical calculations.

There are also cases where the numbers do not have a prominent color (a striking color, pale color, hue, or no color at all) and that makes it harder to utilize their synesthesia for their understanding. For Rhyme Wiersma, she has trouble calculating with zero because it is the only digit that does not have a color associated with it (Duffy, 2001). She says, “it is air” because it has no discernible color, so she does not have a “code for remembering it as she does with other numbers.” So, Wiersma mistakes memorizing one hundred instead of one thousand.

All these anecdotes show that there are significant differences in the ways each person uses their ability to perceive numbers in colors. While their synesthesia can be helpful as a mnemonic aid to memorize series of numbers, such as phone numbers, when it comes to performing arithmetic calculations, it can equally be a help or a hindrance. An important consideration is that not all stimuli produce color. Consequently, a person with grapheme-color synesthesia is not

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continuously bombarded by unnecessary concurrents to hinder daily functions— only synesthetic-inducing material are color-associated. However, the lack of color can derail their technique to solve math problems because it may need to be treated exceptionally, and that could be more work than necessary.

Synesthetic-Inducing Material Supports Memory. Numerous studies support that people with synesthesia demonstrate enhanced memory relative to controls, but only for synesthesia-inducing material. Mills et al. (2006) support this with the case study of a person with grapheme-color synesthesia, named MLS. Mills et al. carried out three standardized memory tests [Benton Visual Retention Test-Revised (BVRT-R) (Manna, Alterescu, Borod, & Bender, 2011) (Benton, 1974), Rey-Osterrieth Complex Figure Test (CFT) (Spreen and Strauss, 1998) and the Rey Auditory-Verbal Learning Test (RAVLT) (Spreen and Strauss, 1998)] to see if MLS's memory recall changes if presented with drawings instead of text. If MLS's synesthesia aided her memories, then she would show a significant performance with auditory and verbal memory tests with words because it elicited a synesthetic experience. In contrast, the non-language items (drawings and shapes) should match the control group because they do not evoke her synesthesia. The BVRT-R and CFT test non-language memory by displaying drawings.

MLS scored 1-1.5 standard deviations above the norm or received a perfect score for the auditory and verbal test, thus supporting the authors' hypotheses. The authors asked what her strategy was, and 80% of the reasons for recall were due to color associations. She "used synesthesia for the words but not for the visual figures" (C. Mills et al., 2006). To conclude, objects that elicit her synesthesia (numbers and letters) would produce color associations automatically, thus aid her memory performance, while objects that do not elicit it (drawings and shapes), would be perceived non-synesthetically and so, she would perform similarly to controls. To clarify, MLS's synesthesia is not voluntary. She did not pick to activate her synesthesia for the language

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items and not for the non-language items (drawing and shapes). Instead, this experiment tested to see if a stimulus that does not align with MLS's type of synesthesia can still give her a memory benefit, and it does not. The synesthetic benefit only occurs within the realm of the kind of synesthesia and not beyond that. Therefore, a grapheme-color synesthete won't start seeing colors from shapes because shapes are not graphemes (letters and numbers).

Congruence Supports Memory. Many authors conclude that synesthesia affects the way stimuli are encoded conferring a specific strategy for time-space synesthetes. For example, when a stimulus is congruent (i.e., the colors match pre-existing color associations), it can be easily incorporated into their memory. On the other hand, not all memory tasks give synesthetes a reliable memory-advantage (e.g., digit span and digit matrix) such as when incongruent information is presented and tested. The visual memory advantage is heavily supported, yet limited because the mechanisms providing enhanced memory remains unclear in terms of synesthesia (e.g., meaning visual stimuli such as faces and scenes). Overall, the memory benefit is not necessarily related to synesthetic experiences but rather the structural and functional changes happening in the brain. Those changes include the strengthening and weakening of synaptic connections that are present in people with synesthesia and not those without synesthesia. In an extension of Mills et al.'s (2006) study, a material that does not induce synesthesia still confer a memory benefit to this community. So, we have reason to believe that whether the stimuli are favorable to their synesthetic experiences, overall, they confer an advantage especially when we look at long-term memory tasks that test whether accuracy and speed increase over time in the presence of incongruent information.

Accuracy and Speed. Bankieris and Aslin tested for accuracy and speed of response on people with synesthesia against those without using associative learning tasks over the course of two weeks. The tasks required subjects to learn shape-color pairings for multiple testing blocks.

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Any subject that had an existing color association to the shape (snowflake) was excluded, thus removing prior synesthetic color experiences from the results. The authors aimed to test association learning alone. The subjects were tested two times for their memory: one day after the learning phase and two weeks after the learning phase. The results yielded that people with synesthesia outperformed the controls, which support enhanced long-term memory for shape-color associations. Following this, they shuffled the previous shape-color pairings to new color associations and retested for memory to challenge how synesthesia may interfere with their learning rate for new pairings. They showed no significant difference in their learning rate for new pairings and concluded that synesthesia does not interfere with a person's ability to memorize new associations. Mainly, their findings support that synesthesia offers a heightened ability to learn and retain shape-color associations. The results are relevant because it argues that synesthesia not only enhances one's ability to memorize pairings, but past learning experiences do not interfere with creating new learning associations. Bankieris and Aslin (2016) lend support that people with synesthesia perform better for long-term memory tasks and confirm previous studies investigating synesthesia in learning and memory.

Summary. We can find comfort that synesthesia is consistent across time; therefore, a synesthete's perceptions are not chaotic nor impossible to carry out day-to-day tasks. That includes making the synesthetic experiences work for their advantage if they can recognize those patterns. Unfortunately, it is not always successfully done in terms of solving mathematical problems; therefore, we should tread carefully in the discussion for inducement. While pattern recognition may not be easy for all synesthetes, we can find that only specific types of stimuli confer a memory advantage and accuracy and speed increases when in the face of making new associations. So this gives some reason to believe that even if you can make a wrong prediction, you learn from prior experience and avoid making the same decision again. Lastly, only stimuli pertinent to one's

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synesthesia, such as words, bestow a memory benefit while other stimuli equate the results from individuals without synesthesia. Overall, these studies each support how advantageous synesthesia can be in terms of learning and memory, but to provide a fair view, one must discuss the instrumental disadvantages.

Instrumentally Bad

Even though the research around enhanced cognitive abilities within synesthesia is appealing, we have to equally examine the instrumentally negative effects that can follow if induced synesthesia is worthwhile. This thesis specifically discusses how synesthesia can lead to communication barriers and difficulties in mathematics, then counterarguments will be proposed for each problem; however, they may not eradicate the original issue.

Communication Barrier. A major instrumentally bad feature of synesthesia reported is that there is a communication barrier which could lead to misunderstandings or difficulty translating (basic concepts). Similar to speaking another language, a person with synesthesia uses syntax that is specific to their perceptions. For example, Elle Sees has grapheme-color synesthesia and wrote an article to clarify some common misconceptions around grapheme-color synesthesia and described her perception of the world. She begins by telling the audience how she found out, then incorporates specific color associations she perceives daily, and how synesthesia has impacted her life. It includes how others react when they find out about her skill and the benefits and disadvantages paired with her synesthetic experiences. When a person without this phenomenon hears her description of objects or events, it is comparable to a language barrier. She states, “I recall telling teachers the gender of letters/numbers and getting curious looks. I remember telling family or friends that a certain song sounds like winter or this one sounds like purple” (Sees, 2011). This article offers personal accounts outside of experimental conditions which describe an interesting and unique perspective for people without synesthesia to try to relate to. Sees’

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perspective can inform the audience how much synesthesia has impacted her for better or for worse, and the example showcases how differently she communicates her experiences, which are not always comprehensible to the larger community.

But people, in general, do not ever have the same experiences in the world. Even experiences with another person are still different and communication barriers are not new. For example, two people could be viewing the same movie, but different aspects of the information are given more attention. One person may pay more attention to the music, while another person is more in tune with the storyline. Emotional state also influences perception and because of this drawback, the subject could have either a positive or negative response to the event occurring. Everyone suffers from miscommunication and misunderstandings to some extent; therefore, we should not be quick to dismiss synesthesia for this shortcoming. On the other hand, if it leads to more miscommunication, then that would make induced synesthesia undesirable altogether. As a result, one has to be considerate of the instrumentally negative effects that could develop, which could coax existing issues. So, if more miscommunication does emerge, it would only add to the pile of issues related to communication that we have yet to fully comprehend.

Conflicting Information & Ineffective Processing Styles. If synesthesia was induced in children, it would raise concerns how educators can implement effective styles of learning that would be helpful to children with synesthesia and those without. There are three options to approach this: 1) educators can create appropriate, individualized accommodations, 2) develop national programs for students who have synesthesia that schools can adopt, or 3) create a separate school altogether explicitly for people with synesthesia. Given that there are more than sixty variations of synesthesia, how can society fine-tune the lectures and teaching styles that accommodates to a wide range, if not all, of those variations? Furthermore, the communication barrier extends beyond a synesthete's difficulty in carrying out conversations. It involves children

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who have a hard time processing information when the numbers and text are in the “wrong” color and difficulty minimizing distractions or conflicting information. Sean Day’s autobiography describes how the language barrier could be resolved through a comparison between speaking Japanese and speaking the language of synesthesia.

Counterarguments About the Communication Barrier. In Day’s autobiography, he compares synesthesia to speaking a foreign language (Japanese) in the U.S. Even though Japanese is not commonly spoken, it is not “abnormal” in and of itself (Day, 2013). A person can choose to speak Japanese, but if there are relatively few around who speak or understand it, then it would be beneficial to speak English instead. However, if you run into another person who can speak and understand Japanese, then you are more inclined to speak Japanese with them. Consequently, you may find a larger community of Japanese speakers through friends and families to interact with. Therefore, a synesthete would have to be aware of their listeners before deciding whether it would be appropriate to use the “language” of synesthesia with them. Overall, Day describes how the language barrier can be reduced if people are able to switch to the language that is the most convenient or accommodating. Although his solution seems straightforward, not all thoughts can be equally conveyed from one language to the next. For example, the Japanese word “tokimeku” has been popularized by the Japanese author Marie Kondo to translate as “spark joy”. However, that is not the literal translation—google translator defines it as flutter, throb, or palpitate. This example demonstrates some concepts can be ineffable because there is a secondary experience that is hard to convey. So hearing the word “tokimeku” is the first experience, but that alone does not tell you enough about the meaning; therefore, there is another element at play. Thus, synesthesia is not exactly like switching languages because the switch is not easy since some concepts are lost in translation. To that end, Day’s solution still does not eradicate the communication barrier problem.

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Mathematical Performance. One instrumentally bad matter that has raised concern among parents and educators is that people with synesthesia, specifically types that are related to numbers, perform poorly in mathematics. I will address what underlies these difficulties and how significant poor mathematics skills are in day-to-day use if we were to consider inducing synesthesia in children. Generally, mathematical processes are viewed differently by synesthetes, especially with grapheme-color synesthesia because letters and numbers are associated with colors. For example, a person can view $2 + 3 = 5$ as just pink + green = red (Synesthi & Swaner, 2012). If they know what color theory is, then it can cause confusion that red is a primary color which cannot be created from two secondary colors. However, a solution suggested is that they disregard their colors temporarily, if possible; otherwise struggle in performing basic arithmetic. In an attempt to reduce the problem, there exists an online toolkit called “The MULTISENSE Adaptable Synesthesia Toolkit” for parents and educators, to learn why this matter is important and ways to mitigate the potential problems. One of the techniques for dealing with struggles in mathematics is to be aware of the trouble and enforce how they can remember the color associated with a number when attempting to recall a list of digits. Or encourage the child to spend more time with the multiplication tables or use a verbal style of teaching. Although this toolkit has good intentions, the solutions to the issues are superficial and does not actually eliminate problems with performing mathematics. Therefore, parents and educators do have reasons to be concerned about their child’s education.

Congruent Color Associations Yields Better Performance. One famous case study followed the subject nicknamed SE who had extraordinary memory capabilities and grapheme-color synesthesia. One researcher looked into the accuracy and efficiency that grapheme-color synesthetes have when the colors either mismatch the digits or match the digits (C. B. Mills, Metzger, Foster, Valentine-Gresko, & Ricketts, 2009). For example, when a synesthetes typically

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sees seven as yellow in the “synesthetic” dimension, a matched condition is where math problems are presented where seven is colored yellow in the “real” dimension. On the other hand, a mismatched condition is where math problems are presented where seven is colored purple in the “real” dimension instead. They found that color in addition problems are caused by automatically binding the digit to the color (photism), so when the colors are mismatched, the subject takes longer to solve the problems. The researchers suggested that when the mismatch occurs, color-digit binding not only challenges their visual perception of the digits but also their cognitive perception. SE was making new relationships in her brain that separated out her previous understanding of the colors. The incongruencies take longer for SE to solve the addition problems because it goes against her expectations; however, the accuracy increases with time (Ghirardelli et al., 2010).

Congruent, Incongruent, or Black. Ghirardelli et al. (2010) pursued this case study and investigated color-digit synesthesia on numerical representation on the subject, SE, and control group without synesthesia. Three experiments were conducted to test them in mathematical equations. The first test tested color congruences where addition problems were either matched or mismatched to SE’s color-digit photisms or were black. The second test, the addends were mismatched, but the answer was presented in black. The reverse was shown as well (black addends and colored solution). The third experiment matched SE’s color-digit photisms, but they were multiplication and addition problems instead. The conclusions show that SE responds significantly faster when the colors matched her photisms than when they mismatched. The control groups did not show a difference between matched and mismatched. This study demonstrates the best conditions in which synesthesia permits good results, but it did not compare the control group’s speed or accuracy to properly gauge the relevance to the non-synesthetic community for further application. Moreover, the subject can adjust to the incongruent colors from the digits and increase

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the speed of response while accuracy remains the same among the experimental and the control groups in all situations (Ghirardelli et al., 2010). There was no difference in the control group when shown congruent or incongruent graphemes (Simner & Bain, 2018). In this same study, SE was compared against eight undergraduates that did not have synesthesia (control group) and found that SE was significantly more accurate in the matched conditions (98%) than mismatched (89%) and also against a black condition (91%). The control groups had a 97% accuracy overall with no significant change with all other conditions (Ghirardelli et al., 2010).

Counterarguments About Poor Mathematical Performance. We cannot always blame synesthesia for poor performance. It can be the case that people are simply not good at math and not because they have synesthesia. In fact, some individuals use their synesthesia in order to maximize their performance and we can see this with Geoffrey Chester, where his synesthesia allowed him to not only remember names and numbers in color but apply his synesthesia in mathematics and physics. “I could see the numbers in vivid colors which helped me to do the calculation quickly,” said Chester (Duffy, 2013). Chester likes his synesthesia because it is what he perceives as natural and he believes it makes his quality of life better. Chester benefits from his synesthesia because it aids his competence in mathematics. So, synesthesia and mathematics should be analyzed on a case-by-case basis. As previously addressed in the instrumental good section, Chester sees the Schrodinger’s Equation in varying shades of yellow, so when he’s solving formulas, he uses the colors to keep him focused until he reaches the final answer. Another important drawback about these experiments is that people in general are not typically tested in this way day-to-day, so these tests do not simulate real-life situations. Lectures, textbooks, homework, etc. are not written in rainbow letters and numbers; therefore, one’s synesthesia is not challenged to the same degree as these tests. This may pose as a complication while in elementary school since classrooms are designed to be colorful, thus, one’s synesthesia is repeatedly

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challenged. However, when one moves out of those colorful settings, their synesthesia is no longer challenged. All in all, synesthesia does not directly affect mathematics skills but rather challenges the congruences (matched) and incongruencies (mismatched) that the numbers have to one another. To repeat, this is all subjective, so not all synesthetes experience trouble with mathematics.

Applications from Adults to Children

Although numerous studies of synesthesia have occurred in adults, very little has investigated the cognitive effects in children, which is important if they are the target population to induce. Green & Goswami were the first to study synesthesia in children and found similar results consistent with adults. When digits are paired incongruent to their photism, they experience involuntary difficulties in the numerical tasks (Green & Goswami, 2008). Green & Goswami pioneered research of synesthesia in children to see if the studies found previously in adults can be extended to children to some degree. The researchers examined three features of synesthesia in children: consistency, involuntariness, and linked with a number concept. The ages ranged from 7 to 15 years old. The results of reported synesthetic children (experimental group) were compared to children without reported synesthesia (control group). Their findings show that the experimental group faced difficulties in numerical tasks when the numbers were incongruent to their personal photisms. Green & Goswami (2008) support Ghirardelli et al. (2010); therefore, the applications found in the adults can be assumed so far to be true. However, some of the weaknesses of their methods pose serious dilemmas. The authors fail to report how the children with and without synesthesia were recruited because that information may tell us whether there may have been some bias. We look at additional research from Simner et al. (2018) that aims to repeat these findings and correct those methodological errors.

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Simner et al. investigated how children with synesthesia compare to their peers (control groups made up of non-synesthetic children) in memory-based tasks (Simner & Bain, 2018). This study aimed to advance Green & Goswami's (2008) findings that children demonstrate similar results as adults when testing features about synesthesia by correcting their methodological oversight. Simner et al. (2018) screened more than 600 primary schools to randomly sample a cohort of children with synesthesia and those without. The issue brought by Green & Goswami's (2008) experiment is that the children with synesthesia were brought forward voluntarily by their parents' belief that they had it. This may question the validity of the results because of possible bias. The children (ages 10-11) with synesthesia were tested in a series of cognitive tasks (and compared them to matched controls) and purposely refrained from telling which child had synesthesia or not and what synesthesia is. Their results showed that some tasks show no significant difference than controls (receptive vocabulary test and memory matrix task), but the other tasks showed that they significantly performed above average [processing-speed task, letter-span task (memory/recall task of letters)]. Simner et al. (2018) conclude that synesthesia gives an overall advantage. The findings show that there is no significant difference between children with grapheme-color synesthesia and children without synesthesia in the memory tests in all cases. Their work supported Green & Goswami's results that children with synesthesia significantly performed better in the task at hand than the control group, but in some cases, they performed equally.

Weighing the Results. Although there are a number of instrumental downsides, one can determine whether the instrumental goods outweigh them or not by measuring the consistency of the results. In sum, the findings are inconsistent and unpredictable given the large range of factors involved. For example, different types of memory tasks confer a memory advantage while a select few are not significantly different (e.g. digit matrix and digit span). Smilek et al. (2002) tested a

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subject, named C, for her memory for digits displayed in a matrix (spatial position). C experienced colors with the following inducers: sight, sound, and thinking of the digits and was tested on the onset of displaying the matrix in the black, the congruent, and the incongruent matrices. Then she was tested again 48 hours later. C's performance did not decrease, whereas the controls did. It supports that C was able to retain the memory of the spatial position of the digits even two days after learning it. However, no other studies were able to replicate Smilek et al.'s results (Rothen & Meier, 2009, Rothen et al., 2012).

As for digit span, Baron-Cohen et al. (2007) described the case study of Daniel Tammet and his ability to memorize pi to 22,514 decimal places from memory; however, Rothen and Meier (2009) and Gross et al. (2011) showed no evidence for a memory advantage with digit span in other individuals with synesthesia compared to control. The case with Tammet was exceptional and it is apparent that synesthesia does not confer the digit span memory benefit to all cases. Yet, we should keep in mind that the two memory tasks (digit matrix and digit span) involved memory for contextual associations (digits to spatial position or position in a sequence, respectively), so it does not reflect the real world because it is not often individuals are tested so rigorously. Even though digit matrix and digit span memory tests do not show a significant memory advantage for synesthesia in all cases, the memory benefit is present when the inducer is within the realm of the type of synesthesia. The nature of the task highly influences the results per person.

Summary. In sum, when a new innovation is introduced, people either jump to try it or wait longer after hearing everyone else's experience. For those that jump try it are convinced they should be open to modernity and willing to be progressive. But being a pioneer who gets to be the first to try something does not necessarily mean a positive experience. For example, you could volunteer to test some new piece of technology, such as a phone; however, the phone has multiple issues and instead adds to your load of stress and frustrations. It may even crash suddenly, and you

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lose valuable information that was only stored on the phone. So, for someone that is ready to try a new innovation, they face the risk that they could have an extremely dissatisfying experience. Now, for those that choose to wait after hearing everyone else's experience before trying the innovation, they save themselves from dealing with that excess load of stress and frustration if things went sour. Although it would be practical to wait how a new innovation truly performs in the hands of the consumer, it could be just as beneficial to be the first—you have more knowledge about the product and greater influence with your review. Subsequently, we have to ask how can we know whether we should be a pioneer versus a follower. In the case with synesthesia, we want to address inducement carefully and completely before introducing it to potential consumers that would debate whether they should be a pioneer or a follower. To do this, the intrinsic and instrumental values were outlined to determine whether it is worth the cost of inducing this phenomenal experience of the world at all, or if it instead would be detrimental. By analyzing the intrinsic features, this thesis argued that people can determine the value of something if we consider a case where it is missed when it is lost. Doing so tells us that synesthesia is valuable because it leads to other intrinsically good items (identity); however, it also tells us that the cost is greater once it is lost because it is not only the synesthetic experience that is stripped away—identity is stripped away as well. Sensory obstruction is an important consideration because it may influence a person's ability to effectively use their synesthesia to a person's advantage, including if it is to access enhanced cognitive abilities. In the instrumentally good section, we find that synesthetic experiences (color associations) are consistent and, for the most part, do not change over time. Thus, consistency aids in pattern recognition abilities. In a case where math is involved, physicist Chester and Regtien make their synesthesia advantageous to them by understanding the patterns that allow them to perform well in math, including complex problems as seen with Chester. On the other hand, synesthesia can also be distracting or confusing when the perceived

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and understanding of the colors (color theory) do not make sense together. In the discussion about the instrumentally bad outcomes, miscommunication and poor mathematical performance are concerns that already exist, and synesthesia may worsen it for a person. As a result, it is important to create education settings for youths with synesthesia and implement effective techniques for instructors to use to help students overcome their difficulties processing information. If teachers are truly unable to actively help in these matters, then it seems that synesthesia should be not induced at all. In spite of that, everyday letters and numbers are not colorful. So, when synesthetes are out into the world where lectures and text are not as colorful and vibrant, they no longer have to be challenged (what they perceive in their “synesthetic” dimension are not perceived in the “real” dimension). While the studies with synesthesia are mostly performed in adults, Simner et al. (2018) showcase the same results in children as tested in adults for several memory tasks. Although the evidence presented in this thesis present counterclaims for each benefit and drawback, we have to consider that many of these studies are based individual results, so we have to be careful in generalizing the results to the synesthetic community.

Conclusion

The social implications of inducing synesthesia require vigilance as multiple ramifications may emerge. These repercussions include arbitrary disclosures around sensory obstruction, memory advantages, how often experiences are consistent versus inconsistent, etc. Although synesthesia can offer a plethora of information and advance our cognitive abilities in multiple ways, we must be cognizant that existing research does not show consistent evidence to guarantee the desired outcome for all cases (low sensory obstruction and enhanced memory overall). Furthermore, many experimental findings were supported using case studies based on one person because these specific individuals displayed superior memory. It is necessary to be cautious about the extent to which we can generalize the results to the general population of people with

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synesthesia (Robinson, 2015). Equally important, the findings in these experiments can be generalized to a limited extent because most of the subjects were grapheme-color synesthetes. This is significant if induction requires training to create a specific type or whether it is just a luck of the draw. There are too many combinations of outcomes that cannot be controlled for: type of synesthesia, sensory obstruction, especially when the level of “obstructiveness” is subject, therefore, it cannot be guaranteed for all induced. That means it would be a gamble, and we have to ask whether we are willing to gamble the livelihoods of children. For example, we could induce a grapheme-color synesthete who is unable to control their synesthesia so that their experiences are chaotic or feel overloaded. If we cannot guarantee to have control of perceptions, then a person cannot isolate the actual colors and the synesthetic images from one another. There are many variations and possibilities of this condition and some individual mentioned happen to be lucky in the matter. Although some people were lucky to have a type of synesthesia that they were able to control and work for them, we have to consider the possibility that we could inadvertently induce a type of synesthesia where it is harmful to have in the first place. Subjectively speaking, the most harmful type of synesthesia is mirror-touch synesthesia where they sense the same sensations they observe happening to others as if the sensations are their own — specifically in the case where pain is involved.

Given all this information, if inducement was an option, then we would want to guarantee certain results. We care about guaranteed results because we do not want unexpected and harmful outcomes including side effects. The initial goal of inducing synesthesia is to access the secondary benefits—enhanced cognitive abilities. Grapheme-color synesthetes have a distinct cognitive style of learning that aids in their memory performance and creativity; however, those differences do not dominate the current methodologies of learning and enhanced memory present in non-synesthetic communities. In order to consider synesthesia as an inducement tool, the results must

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be valid and replicable, and induced synesthesia seems to have to produce a large number of unknown variables: the type of synesthesia and the color-associations. Therefore, it would be harmful than beneficial to induce synesthesia, thus it should not be considered a permissible tool to increase children's access to enhanced learning and memory.

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