Investigation into Aphantasia: Neurological, Functional, and Behavioral Correlates

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Introduction: Seeing With Your Mind's Eye?

For many people, imagining calm waves rolling onto a white, sandy beach on a clear and sunny day is an easy way to relax or meditate. They may take solace in picturing the faces of their loved ones when they feel homesick, or pass the time daydreaming elaborate fantasy scenes of dogs on motorcycles. While some may take this ability for granted, there are many people in the world who cannot picture themselves relaxing on a beach, or the faces of their closest friends, or a fantastic and impossible daydream; they see only darkness when they close their eyes. These people have aphantasia, a term coined by Zeman, Dewar, and Della Sala (2015) to describe “a condition of reduced or absent voluntary imagery.”

Historical Overview: 1880 to 2018

This phenomenon has been present throughout historical research on mental imagery. Francis Galton is widely credited with having first documented the inability to produce and experience visual mental imagery. As an early eugenicist, many of his claims are problematic, although the first-hand statements published by Galton (1880) provide valuable accounts on variations in mental imagery. Galton published qualitative reports of the vividness of participants' mental imagery, regarding the illumination, definition, and coloring of a mental image of their breakfast table. Participants described their subjective perception of the vividness and detail of their mental images, with reports ranging from perfectly clear and vivid to extremely reduced or nonexistent. Some participants reported seeing mental pictures that were as bright, colorful, and clear as the real table. Others could easily recall and describe the table and specific details of the scene, but had little or no ability to imagine it visually. One participant reported that his image was, “dim and indistinct, yet I can give an account of this morning's breakfast table... but my imagination is seldom pictorial except between sleeping and waking,” (Galton, 1880, p. 4).

Since being given a name in 2015, aphantasia has become more well-known and has been popularized online and in the media. This phenomenon has also caught the attention of visual imagery researchers. As information on aphantasia becomes more widely available, more people are discovering that they also are unable to conjure mental images, while other people can genuinely visualize objects, places, faces, and memories within their mind's eye. This discovery has led many people to study and share their experiences with aphantasia by creating groups on social media platforms and publishing articles on their personal experiences. There is even a book titled, *Aphantasia: Experiences, Perceptions, and Insights*, which features first-hand accounts from aphants on their perspectives of living with aphantasia (Kendle, 2017).

The Eye's Mind research project, led by Adam Zeman, was established shortly after Zeman et al. (2015) coined the term aphantasia. Since first defining the term, the Eye's Mind has gathered survey data from roughly 11,000 participants with a variety of mental imaging abilities and conducted many studies on aphantasia (e.g., Zeman, MacKisack, & Onians, 2018). The Eye's Mind project is not only focused on aphantasia, but is concerned with a variety of aspects of visualization. One of its primary goals is to determine the neurological correlates of mental imagery and visualization through a meta-analysis of functional imaging research. The Eye's Mind project also examines individual variations in mental imaging ability, focusing specifically on the extreme ends of the spectrum: both aphantasia and hyperphantasia (a heightened ability of voluntary visual imagery), as well as related conditions such as severely deficient autobiographical memory (SDAM) and synesthesia.

In this paper I will conduct a thorough examination and organization of available research on aphantasia. The articles and books I consulted while researching this condition led me to organize the information in a way similar to the Eye's Mind study, as outlined in Zeman et al.'s report (2018). I will examine two theories of the known types of aphantasia, as well as the neurological correlates associated with a range of mental imagery ability, and the functional and

behavioral correlates of aphantasia and low imaging ability. I will then consider published accounts of the effects of hallucinogenic drugs on the visualization abilities of people with aphantasia and review popular strategies for coping with and treating aphantasia. I will end by discussing related disorders and other extreme mental imaging phenomena, providing my own opinion on existing research, and suggesting possible future research about aphantasia.

Types of Aphantasia

There are two main types of aphantasia: congenital and acquired. Congenital aphantasia, as the name suggests, is the lack of mental imagery from birth that persists throughout one's lifetime. Acquired aphantasia, on the other hand, is categorized by a sudden loss of voluntary mental images in those who previously possessed the ability to produce them.

Congenital Aphantasia

Congenital aphantasia was first studied in Zeman et al.'s (2015) groundbreaking study. They initially tested 21 participants with congenital aphantasia, who reported a consistent lack of voluntary visual imagery throughout life. Participants took the Vividness of Visual Imagery Questionnaire (VVIQ), which measures the clarity and vividness of mental images of faces, objects, and locations, as well as another questionnaire about the aphant's personal experiences with aphantasia. All participants received a VVIQ score indicating a "substantial (9/21) or complete (12/21) deficit in voluntary visual imagery," (Zeman et al., 2015, pg. 3). Many participants reported involuntary images occurring as "flashes" (10/21) while awake or experienced while dreaming (17/21). All participants described their lack of voluntary imagery as a persistent, lifelong state.

Acquired Aphantasia

The participants of the study discussed above reached out to Zeman et al. (2015) after learning about a prior study conducted by Zeman, et al. (2010), in which participant MX was compared to a control group on a variety of visual imagery, psychometric, and neuroimaging

tests. MX reported a total loss of voluntary and spontaneous visual imagery following a coronary angioplasty. Unlike the participants of Zeman et al.'s (2015) study on congenital aphantasia, MX had previously possessed the ability to voluntarily imagine visual mental images. Aside from losing his ability to visualize, MX developed no other cognitive impairments following his surgery. Despite self-reporting that he experienced no mental imagery, MX performed normally on multiple tests of visual imagery and visual memory.

Potential Causes: Neurological vs. Psychological Basis of Aphantasia

In their study on congenital aphantasia, Zeman et al. (2015) suggested that this type of aphantasia may have neuropsychological correlates, much like other conditions such as synesthesia and congenital prosopagnosia. In response to Zeman et al., de Vito and Bartolomeo (2015) argued that aphantasia may have a psychological component, and could be a symptom of depressive states, anxiety, or dissociative disorders. While it is possible that some manifestations of aphantasia could be caused or exacerbated by certain psychological disorders, research has shown that both congenital and acquired aphantasia have neurological correlates, and the brain areas activated by aphants during visual imagery tests are different from those activated in individuals with higher levels of imaging ability.

Neurological Correlates

Fulford et al. (2018) conducted an fMRI study on participants with both low and high levels of visual imaging abilities to determine which brain areas are activated in aphants during tests which typically involve mental imagery. They found that participants with higher levels of visual imagery ability had activation in areas of the brain that were distinctly different, and much less widespread, than the areas activated in participants with aphantasia. Tables 1 and 2 summarize the findings of Fulford et al. and organize the information on the brain areas involved with mental imagery for individuals with aphantasia or low imaging abilities and the non-aphant control participants, and an overview of which areas have increased and decreased activation for

both groups during tests of mental imagery. As noted by Fulford et al., there is still some disagreement on how to label and separate different brain areas within the field of neuroscience research.

Case Studies

MX

Before creating the term “aphantasia,” Zeman et al. (2010) were studying neurological differences in people who claimed to lack the ability to produce mental images. The study on MX, an acquired aphant who performed similarly to controls on standard tests of visual imagery ability, cemented the existence and validity of this condition, and led to the founding of the Eye’s Mind study. Functional MRI and Blood Oxygenation Level-Dependent (BOLD) imaging tests showed that while the same brain areas were activated in both MX and the control participants when physically perceiving an image of a face, MX’s activation levels differed from controls when visualizing the image of a face. Most notably, the brain areas with increased activation while MX was “visualizing” are known primarily for executive functioning skills like decision making, working memory, and language production.

AI

In a study that compared 11 control participants with a congenital aphant, Jacobs, Schwarzkopf, and Silvanto (2018) found that AI, the participant with congenital aphantasia, performed as well as controls on tests of working memory and imagery. She even outperformed controls when tested on working memory capacity. However, AI’s performance was impaired on more difficult tasks of working memory that involved spatial reasoning, during which the controls most likely relied heavily on their mental imaging abilities. Jacobs et al. hypothesized that AI’s normal performance could be due to her use of alternative, non-visual strategies. This would explain why her performance worsened as the tests became more difficult. These two

case studies support the research that finds differences in brain areas activated in aphants and controls during imagery tasks.

Functional/Behavioral Correlates

Functionally, there do not appear to be significant differences between aphants and those with higher visual imaging abilities. This is likely a significant factor accounting for the lack of research done on the condition between the late 19th century and 2015; aphants are not noticeably impaired by their aphantasia, so there has never been an immediate demand for research on causes, treatments, or cures. Even today, many aphants are unaware that their conscious experience is different from that of others, and only realize they have aphantasia after learning about it online or hearing about it through friends and family.

Memory

As discussed above, the case study by Jacobs et al. (2018) found that AI, a woman with congenital aphantasia, had no impairments in working memory ability or capacity. MX also performed normally on tests of general memory, visual memory, auditory memory, and autobiographical memory (Zeman et al., 2010). Although the case studies of MX and AI showed aphants with memories at or above the average level, this is not the case for everyone with aphantasia. Two-thirds of the participants in Zeman et al.'s (2015) initial study on congenital aphantasia reported difficulties with autobiographical memory, and connections have been found between low visualization abilities and the disorder known as Severely Deficient Autobiographical Memory (SDAM).

Binocular Rivalry

In a binocular rivalry task different images are presented to participants' right and left eyes simultaneously. This causes participants to subconsciously suppress their perception of one of the images, creating the illusion of the suppressed image disappearing. When participants view one of the images before the test, they are more likely to suppress the non-primed image,

seeing only the image they were previously shown. Similar results occur when participants imagine an image before the test (Keogh & Pearson, 2018). Keogh and Pearson tested participants with aphantasia using a binocular rivalry paradigm, in which they were asked to imagine one of the images prior to the test. The likelihood of choosing the primed image did not differ significantly from chance, indicating that imagining the image had no priming effect on participants with aphantasia. This provides further evidence that aphants do not produce visual images.

Drug Effects

One might assume that, because aphants do not produce visual mental images, they would not experience hallucinations associated with taking hallucinogenic drugs such as ayahuasca. Ayahuasca is a psychoactive drink used in traditional spiritual and medicinal rituals in the Amazon Basin. It is made of a combination of ingredients including *Banisteriopsis caapi* and *Psychotria viridis* plants, and contains dimethyltryptamine (DMT), a psychoactive chemical, and monoamine oxidase inhibitors (MAOI), which activates the psychoactive effects of DMT. A case study by dos Santos, Enyart, Bouso, Pares, and Hallak (2018) examined the effects of ayahuasca on visual imagery in aphants by interviewing a 39-year-old male participant, SE, who presented with acquired aphantasia which he attributed to a traumatic childhood event, to examine the effects of ayahuasca on visual imagery in aphants. SE claimed that his experience with ayahuasca led to a sudden and long-lasting increase in his ability to voluntarily conjure mental images. Throughout the course of his ayahuasca “trip,” SE hallucinated images of his father, and reconciled his feelings of anger towards his family. Even after the effects of the drug wore off, SE reported that he was able to visualize mental images, something he was previously incapable of doing. In response to dos Santos et al., Luke (2018) reported on another case study in which a 39-year-old man with congenital aphantasia, HE, repeatedly used DMT and

experienced many of the mental phenomena associated with the drug, without ever experiencing any sort of visual imagery, neither while using the drug nor any time after using it.

Hallucinogenic drugs like ayahuasca appear to enhance visual imagery in acquired aphants but not in congenital aphants. These case studies suggest an important distinction between the two types of aphantasia.

Alternate Strategies/Techniques

Overall, aphants have shown their ability to perform at, or even above, normal levels on tests of intelligence, working memory capacity, visual working memory, and spatial imagery. This is likely due to the use of alternate strategies adopted and cultivated throughout the aphant's life without imagery. In an account of his personal experiences with aphantasia, Watkins (2018) attributes his reliance on verbal language to his aphantasia. As described by Zeman et al. (2010), neuroimaging research has shown that brain areas involved in executive functioning are activated in aphants during visual imagery tasks. When performing a version of the Brooks Matrix Task, in which participants were required to encode a string of sentences as either a spatial image or a verbal sequence, MX implemented a verbal strategy to improve his performance on the spatial matrix task. Evidence that he used a verbal strategy instead of a visual strategy is shown by the variation in his performance between conditions. His performance on this task was disrupted by a secondary verbal task (concurrent articulation), but unimpaired by a secondary spatial task (tapping on the table).

Aphants are capable of pursuing and succeeding in many different occupations, from creative fields like art, writing, and graphic design, to fields of math and science. However, some contributors of *Aphantasia: Experiences, Perceptions, and Insights* (Kendle, 2017), reported that they struggled with tasks at work that would typically involve visual imagery, such as remembering faces, writing fiction, and drawing original characters. Many shared that they

use photography and other forms of documentations as a sort of external visual memory to help them in their jobs and personal lives.

Coping Strategies/Treatments

Whether one's aphantasia is something that needs to be treated or even cured, or just an alternate form of conscious experience - and even an important part of one's identity - is ultimately up to the individual. Some aphants, after realizing that they lack a cognitive capability that is a crucial component of others' lives, resent the condition and wish to improve or activate their visual imaging abilities. Many of these individuals have expressed interest in treating, or even curing their aphantasia by strengthening their imaging abilities through practices such as image streaming. Metivier (2018) describes the process of image streaming, in which one closes their eyes and attempts to describe certain shapes or colors they see in the darkness behind their eyelids. Aphants, who cannot conjure any images, can facilitate this process by rubbing their closed eyes to stimulate a retinal response, or by looking at a bright light before closing their eyes, and then describing the perceived light response or after-images, respectively, that appear when their eyes are closed. This can also be done by verbally describing a memory one can remember clearly but cannot "see." Metivier claims that regular practice of verbally describing these physical responses, after-images, and non-visual memories can help aphants develop their imaging abilities and become more aware of other mental images like faces, landscapes, and flashes of visual memories.

Alec Figueroa (2018), a youtuber also known as "AphantasiaMeow," has been using a form of image streaming with his clients with self-reported aphantasia or low imaging abilities. In his videos, Figueroa describes the exercises he uses with his clients to develop their mental imaging abilities. He asks clients to verbally describe, in great detail, the physical space they are in and the senses they are experiencing while looking at the space. The clients then close their eyes and try to describe "what they would be seeing" in their mind's eye. Figueroa hypothesizes

that aphantasia is caused by a miscommunication between the verbal and visual areas of the brain, and that by using detailed verbal descriptions of visual scenes, aphants can form connections between these brain areas.

I was unable to find any peer-reviewed research conducted on image-streaming, so it is unclear just how effective these techniques actually are for people with aphantasia. Rather than actually having aphantasia, the people who find these techniques helpful may be too stressed or unfocused on their mental imagery to realize when they are visualizing. Regardless, Figueroa's (2018) clients and some commenters on his videos find these visualization exercises to be very helpful in developing their mind's eye.

Related Disorders

Severely Deficient Autobiographical Memory

As discussed in the Memory section above, two-thirds of participants in Zeman et al.'s (2015) original study on congenital aphantasia reported difficulties with autobiographical memory. A more extreme version of this is known as Severely Deficient Autobiographical Memory (SDAM). SDAM is the inability to "re-live" past episodic memories from a personal point of view with the absence of any past brain injuries or neuropathology (Palombo, Alain, Söderlund, Khuu, & Levine, 2015). People with SDAM are fully capable of learning and remembering semantic information, including facts about personal events. However, they cannot remember the experience subjectively. Event Related Potential (ERP) and fMRI scans have shown that activation of the precuneus decreases in participants with SDAM when recalling past personal events (Palombo et al.). As shown in Table 2, the precuneus also has lower activation levels in aphants when visualizing. The decreased activation in brain areas associated with visuospatial processing and visual memory suggests that people with SDAM are unable to visualize episodic memories. There is yet to be any large-scale research about the general visualization abilities of people with SDAM, however, Watkins (2018) reports that his

experiences with aphantasia and SDAM are closely linked. Although he can recall semantic details about his personal experiences, they are never accompanied by any form of mental visualization. Susie McKinnon, another individual with SDAM, reported that she can produce a single object in her mind's eye, but she cannot put together complete scenes (Hayasaki & Haser, 2016).

Prosopagnosia

Prosopagnosia, also known colloquially as face blindness, is a disorder which results in the inability to recognize faces, even one's own face and the faces of loved ones. Like aphantasia, prosopagnosia can be both congenital - manifesting without any brain damage - and acquired as a result of brain damage in the fusiform gyrus ("Fusiform gyrus," 2019). In general, congenital prosopagnosics tend to score lower on the VVIQ, particularly when imagining "face-specific content, e.g., face shapes and facial emotions," although many also struggle with visualizing objects and locations (Grüter, Grüter, Bell, & Carbon, 2009). As shown in Table 2, there is increased activation in the fusiform gyrus of non-aphants when visualizing, which suggests that this area is involved in the mental imaging process of individuals with average or above average imaging abilities. Although some prosopagnosiacs report higher levels of imagery vividness, research suggests that there is some level of comorbidity between prosopagnosia and aphantasia, with aphantasia potentially being a symptom of congenital prosopagnosia.

Synesthesia

Synesthesia is a phenomenon in which one sense is cross wired with another, which causes individuals to involuntarily experience the second sense when exposed to the first. For example, many synesthetes experience seeing colors when listening to music, with specific colors corresponding to specific notes or pitches. People with synesthesia report a wide variation between the connected senses. Some of the most common manifestations of synesthesia are

chromesthesia - associating sounds with colors - and grapheme-color synesthesia, when individual graphemes such as letters or numbers are associated with a certain color (“Types of Synesthesia - Blend All Your Senses,” n.d.). Synesthesia is frequently co-reported with high mental imagery levels (Spiller, Jonas, Simner, & Jansari, 2015). While not directly related to aphantasia, researching this condition could aid in the understanding of mental sensory experience.

Going Forward: Future Research

In recent years, aphantasia has become an active field of research relating to visual imagery, memory, and neuropsychology. However, there are still many questions that must be answered before this condition is fully understood. Although aphantasia refers solely to the lack of visual imagery, other mental sensory experiences have been reported as being affected. Many aphants lack the ability to produce any mental sensory experiences, while others can recreate songs or voices in their “mind’s ear,” or imagine tactile sensations (Kendle, 2017). Are there multiple forms of aphantasia, like synesthesia? If so, how do these varieties manifest neurologically and behaviorally/functionally? Future research could examine the differences, if any, between manifestations of aphantasia, from “full aphantasia” (complete inability to experience any form of sensory imagining), to only “visual aphantasia,” or perhaps, “auditory aphantasia.”

Beginning with participants in Galton’s (1880) study, many aphants describe their mental experience in a similar way. They explain that they have the capacity to know, but not visualize. If asked to describe an object or count the number of windows in their house - tasks that would typically involve visualization - aphants rely on what they “described as ‘knowledge,’ ‘memory,’ and ‘subvisual’ models,” (Zeman, et al., 2015). I suggest future researchers explore this common subjective report more closely in the future. Neuroimaging evidence already suggests that aphants use brain areas related to executive functioning and decision making when

performing tasks that require mental imagery, but how does this manifest as a conscious experience? Are there benefits to using non-imaging techniques in certain tasks?

There are many promising avenues of research that may lead to a deeper understanding of aphantasia and mental imagery in general. By researching the nuances of mental imagery, we may one day better understand this unique quality of conscious experience.

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Table 1. *Location, function(s), and effects of damage to brain areas associated with visualization in aphants and non-aphants.**

Brain Regions	Location	Functions	Effect of damage
Fusiform Gyrus	Basal surface of temporal and occipital lobes	Contributes to higher level processing of visual information (i.e., faces, words, colors, objects) Part of the ventral stream, or the “what pathway” Fusiform face area (FFA) - specialized for facial perception and recognition	Visual agnosia, prosopagnosia, alexia
Posterior Cingulate Cortex	Caudal area of cingulate cortex, behind the anterior cingulate cortex	Decision making, emotion, autobiographical memory	Coma states, attention impairment, increased volume associated with working memory deficits
Precuneus	Superior parietal lobule, in front of occipital lobe Sections: Sensorimotor anterior region, cognitive central region, visual posterior region - connects with primary visual cortex and cuneus	Visuo-spatial processing, executive functions, working memory, “motor planning,” episodic memory	Decreased activation in epilepsy, Alzheimer’s, schizophrenia
Middle Frontal Gyrus	Middle part of the frontal lobe	Focusing attention, bilingual/multilingual language switching	Impaired working memory and attention control
Superior and Middle Temporal Gyri	Lateral side of the temporal lobe	Involved in language processing, auditory processing, social cognition, recognition of social cues and body language	Increased area volume associated with autism
Anterior Cingulate Cortex	Surrounds the frontal area of the corpus callosum, Made up of Brodmann areas 24, 32, and 33	Involved in attention, decision making, emotion, and error detection	Schizophrenia, impaired volition/will, impaired motor functions/movement
Inferior Frontal Gyrus	Lowest frontal gyrus on the frontal lobe, part of the prefrontal cortex	Language production in Broca’s area, response inhibition/impulse control	Stuttering, Broca’s aphasia, inhibition control impairment
Insula	Part of the cerebral cortex, in the lateral sulcus, separates the frontal, parietal, and temporal lobes	Function is understudied due to concealed location, hypothesized to be involved in self-awareness of body and emotions	Difficulty with sensory perception, emotional imbalances
Cuneus	Medial surface of occipital lobe	Basic visual processing, working memory	Abnormalities in smooth pursuit eye movements
Auditory Cortex	Temporal lobe	Receives and processes auditory sensory information	Cortical deafness/lack of awareness of sounds
Inferior and Middle Occipital Gyri	Occipital lobe, primary visual cortex	Visual processing	Epilepsy, blindness

* See Appendix for references

Table 2. *Brain areas with increased and decreased activation in aphants and non-aphants during visual imagery tasks.***

Brain Regions	Aphants		Controls	
	Increased	Decreased	Increased	Decreased
Fusiform Gyrus		✓	✓	
Posterior Cingulate		✓	✓	
Precuneus		✓	✓	
Middle Frontal Gyrus		✓	✓	
Superior/Middle Temporal Gyri		✓	✓	
Anterior Cingulate Cortex	✓			✓
Inferior Frontal Gyrus	✓			✓
Insula	✓			✓
Cuneus	✓			✓
Auditory Cortex	✓			✓
Inferior/Middle Occipital Gyri	✓			✓

** See Appendix for references

Appendix

Table 1 References

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Table 2 References

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