REVIEW

Aphantasia - neuronal mechanisms of visual imagery vividness (VIV) and its effect on mental (dys)function

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Abstract

Visual imagery, the conscious experience of visual information in the absence of a direct external stimulus, plays for most individuals a prominent role in their everyday life experience, as it is a major component in memory, daydreaming, and creativity. Visual imagery can vary a lot in vividness, from a complete absence (aphantasia) to photorealistic imagery (hyperphantasia). This review will discuss the neuronal mechanisms behind visual imagery vividness (VIV) and how varying degrees of VIV affect mental functioning. Research has shown that VIV involves a complicated network of brain areas including the posterior cingulate cortex, the medial temporal lobes, and the occipitotemporal junction. It is hypothesised that voluntary imagery is based on combinations of information retrieved from stored memory and is similar to the top-down connectivity of perception. Both vivid visual imagery and its complete absence have disadvantages and are linked to various mental disorders.

Contents

Visual imagery plays, for most individuals, a prominent role in their everyday life experience, as it is a major component in memory, daydreaming and creativity (Zeman, Dewar, & Della Sala, 2015). Visual imagery refers to the conscious experience of visual information in the absence of a direct external stimulus. These mental experiences can either be a re-experience of a specific memory, or a completely new experience that is generated from multiple memories. The latter allows for the escape from the limitations of reality into a limitless range of virtual worlds, such as daydreaming.

As visual imagery seems to be a defining feature of human cognition (Dunbar, 2004), it might be hard to imagine that the vividness of these visual mental images can differ considerably between individuals (figure 1; Galton, 1880). Surprisingly, around 0.7% of the population was found to experience no visual imagery at all (Zeman et al., 2020). Although science was long aware of the variation in vividness and its significance, only more recently was the phenomenon of the total absence of visual imagery given a name: aphantasia (Zeman et al., 2015).

Aphantasia can comprise all five senses. However, research has focussed primarily on visual aphantasia as this is the most prominent sense in humans and therefore differences within visual imagery are most perceptible. Nonetheless, visually aphantasic individuals often report decreased imagery in other sensory domains, although not all have a complete lack of multi-sensory imagery. (Dance, Ward, & Simner, 2021; Dawes, Keogh, Andrillon, & Pearson, 2020). The focus of this review will be on visual aphantasia and the underlying neuronal mechanism of differences in VIV.

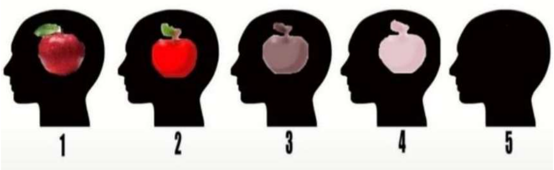

Figure 1: Representation of the differences in visual imagery when a subjects has to imagine an apple. *In 1: a photorealistic mental image of an apple with great details, in 2: the apple is still clearly recognisable but less detailed, in 3: the apple is still recognisable but without any colour, in 4: the mental image of an apple is very vague and in 5: there is no mental image.*

Methods for determining VIV

There are several imagery tests used as an initial assessment of VIV when researching the underlying neuronal mechanism. They all focus on different aspects of imagery by having the subjects either imagine something specific, do a mental rotation task or imagine performing a sporting activity (Pearson, J., 2019). These test are however criticized by some. Self-reporting tests like the Vividness of Visual Imagery Questionnaire (VVIQ) are always subject to human bias as the participants might (subconsciously) choose answers that give preferred results. In addition, mental rotation tasks, like the Shepard-Metzler test, can also be performed using spatial, or kinaesthetic imagery, rather than exclusively visual object imagery (Keogh & Pearson, 2018; Shepard & Metzler, 1971). Nonetheless, it is still incorrectly referenced as a test for general imagery.

A more objective and reliable method for researching general VIV is with binocular rivalry. Binocular rivalry is an illusion, or process, where one image is presented to the left eye and a different image to the right, which results in one of the images becoming dominant while the other becomes suppressed outside of awareness (figure 2). Showing the participant a very weak visual image of one of the rivalry patterns prior to the test results in a higher probability of the image becoming dominant (Pearson, J., Clifford, & Tong, 2008). The same was found to be true for when the participants are asked to imagine one of the images prior to the test (Pearson, Joel, 2014). This indicates that visual imagery resembles a weak version of sensory perception.

Unlike the general “phantasic” population, experimentally naive aphantasics do not show this rivalry priming when asked to imagine on of the images prior to the test (Keogh & Pearson, 2018). Therefore, this test demonstrates in a more objective way that aphantasic individuals are actually unable to visually imagine and it is not a communicational misconception or a lack of

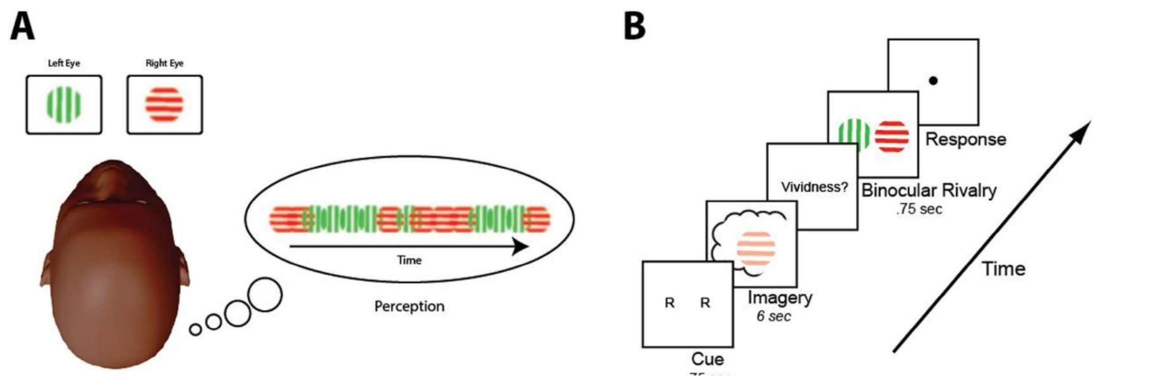

Figure 2: **Binocular rivalry experiment** *A. Illustrates an extended binocular rivalry presentation. Two separate images are presented, one to each eye. Instead of seeing a mix of the two, perception alternates between the two images. Fluctuations occur for prolonged viewing. B. illustrates the experimental setup. Participants were cued to imagine one of two images for 6 sec, after which they rated the vividness of the image. Then they were presented with a very brief binocular rivalry display (750 msec) and had to report which image they saw.*

metacognitive awareness of the visual imagery.

So now that it is established that differences in VIV are scientifically determinable, it is important to determine what kind of effect these differences can have.

Effect of VIV on different types of memory performance

At least since the 1800s, scientists have questioned why imagery differs so much from person to person and how these differences effect cognitive processes (Galton, 1880). Data suggests that most individuals are largely reliant on mental imagery in episodic memory and visual working memory and use it as a tool to perform various memory tasks (Keogh & Pearson, 2011; Keogh & Pearson, 2014; Pearson, J., 2019). Remarkably, VIV was found to have no effect on visual working memory performance (Keogh, Wicken, & Pearson, 2021). No differences were found in capacity limits for visual, general number and spatial working memory for aphantasics compared to phantasics. Nonetheless, other research showed that individuals with aphantasia can perform easy and medium, but not hard, visual working memory tasks (Jacobs, Schwarzkopf, & Silvanto, 2018). These findings indicate that aphantasic individuals use different strategies for the working memory tests that will work up until a certain degree of difficulty.

Moreover, aphantasic individuals showed no significant performance differences on visual components of clinical working memory tests compared to verbal components. However as previously expected, the reported strategies for performing the tasks were different, being less visual in nature for aphantasics, such as labelling the image and holding this information in mind, rather than creating a detailed sensory mental representation (Keogh et al., 2021).

Furthermore, autobiographical memory is connected to VIV. Higher VIV has been linked to increased autobiographical memory (Zeman et al., 2020) and face recognition (Milton et al., 2021). Moreover, aphantasic individuals described a significantly lower ability to remember specific life events in general because of their inability to imagine visual details, and also reported almost no ability to imagine future hypothetical scenes (Dawes et al., 2020).

Object-based memory is also linked to VIV (Bainbridge, Pounder, Eardley, & Baker, 2021). Aphantasic participants showed a deficit in recalling object information during a memory-based drawing test. They also recall fewer objects compared to phantasic control participants, while these objects also contain less visual detail and less colour in their drawings. The participants stated that they relied more on symbolic strategies, like making a list of all the objects or description of the photos. Remarkably, aphantasics did not exhibit any impairment in spatial memory, as few errors were made in the placement of the objects (Bainbridge et al., 2021; Dawes et al., 2020).

Susceptibility to illusions like anomalous perception was also found to be connected to imagery (Salge, Pollmann, & Reeder, 2021). VIV was positively correlated to seeing faces in pure visual noise, although removing suggestive instructions did weaken this correlation. Individuals with more vivid imagery may rely more heavily on reverse processes for perception in daily life, which makes them naturally more prone to prediction error.

Thus, while VIV was found to have no effect on visual working memory performance, autobiographical and object-based memory were found to be impaired in aphantasic individuals. The distinct methods that aphantasic individuals report to use during the memory tests might indicate the activation of different brain regions for aphantasic individuals.

Neuronal characteristics correlated with different degrees of VIV

Visual imagery involves activity across a large neural network as it is quite a complicated process. Functional magnetic resonance imaging (fMRI) research shows a clear distinction in the neuronal activation between phantasic and aphantasic individuals. In a study where brain activation was measured while participants imagined famous faces and buildings, the participants with low imagery vividness activated a more widespread set of brain regions while visualising compared to the individuals with high imagery vividness (figure 3; Fulford et al., 2018). This complies with our earlier statement ("Effect of VIV on different types of memory performance", page 3) that aphantasic individuals use different strategies in visual imagery tests. Moreover, activity in the posterior cingulate cortex, in the medial temporal lobes and in the occipitotemporal junction correlated positively with VIV in multiple fMRI studies (Amedi, Malach, & Pascual-Leone, 2005; Daselaar, S. M., Porat, Huijbers, & Pennartz, 2010; Fulford et al., 2018; Olivetti Belardinelli et al., 2009; Zvyagintsev et al., 2013).

Occipitotemporal variances: connecting visual imagery and perception

There is a large overlap in neuronal mechanisms for visual imagery and visual perception (Dijkstra, Bosch, & van Gerven, 2019). The visual (occipitotemporal) cortex is primarily responsible for processing perception. Neuroimaging studies showed however that imagery and perception are associated with similar category-specific responses in the high-level visual cortex. This indicates similarities in underlying mechanism (Ishai, Ungerleider, & Haxby, 2000; O'Craven & Kanwisher, 2000a). Moreover, activation of the visual cortex positively relates to VIV (Albers, Kok, Toni, Dijkerman, & de Lange, 2013; Lee, Kravitz, & Baker, 2012). And more specifically, activation within the ventral temporal cortex was stronger on the left side during visual imagery, whereas perception induced stronger activation on the right side (Ishai et al., 2000).

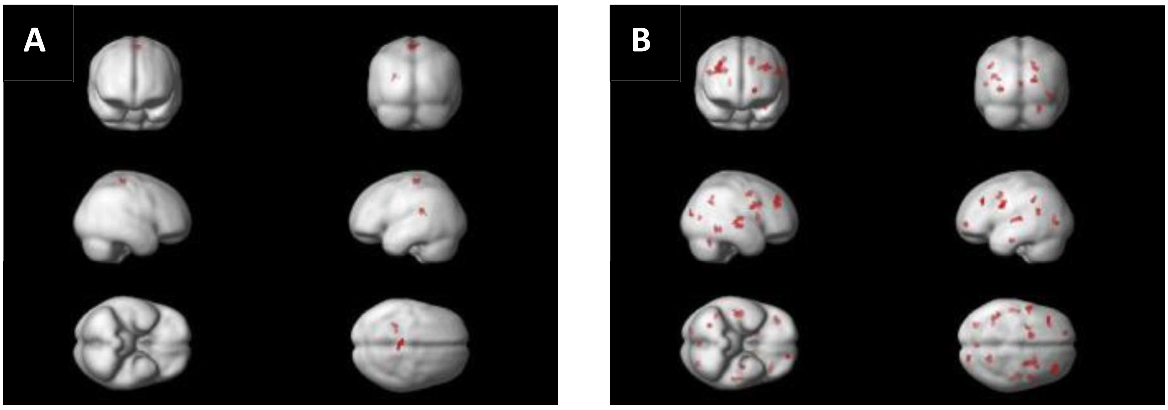

Figure 3: Activation of brain regions that are higher during fMRI imagining during a whole brain analysis *for A) individuals with high visual imagery vividness and B) individuals with low visual imagery vividness. Red colour means activation. Numerous regions, widely distributed across both hemispheres, were activated more strongly during imagination in the low vividness group than in the high vividness group. Only brain regions in the medial frontal lobe and insula were activated more strongly during imagination in the high than the low imagery group* (Fulford et al., 2018).

The left side of the ventral temportal cortex is thought to contain visual categorization, thus apparently this categorization is more important in imagery compared to perception. Furthermore, the size of the primary visual cortex was found to be negatively correlated with VIV, while the early visual cortex size was not (Bergmann, Genc, Kohler, Singer, & Pearson, 2016). Remarkably, the individuals with the most vivid imagery and also the smallest primary visual cortex did not have the most precise imagery, suggesting that, when imagery becomes stronger, it also becomes less precise.

Primary visual cortex size has also been linked to schizophrenia, as schizophrenic patients show an 25% decrease in primary visual cortex surface area compared to heathy adults (Dorph-Petersen, Pierri, Wu, Sampson, & Lewis, 2007). In addition, VIV is overall more strong in schizophrenic patients, indicating a link between primary cortex surface area, VIV and schizophrenia (Sack, van de Ven, Etschenberg, Schatz, & Linden, 2005).

Although, variability in human visual cortical surface area was in another study found to be related to sensitivity to visual details and susceptibility to visual context (Song, Schwarzkopf, & Rees, 2013). Specifically, individuals with a larger primary visual cortex can discriminate finer orientation differences, whereas individuals with a smaller primary visual cortex experience stronger perceptual modulation by global orientation contexts. Thus, the bigger surface area of the visual cortex in aphantasic individuals is not necessarily a disadvantage, but it can explain the different strategies that aphantasics use in visual imagery tests.

Top-down model. The distinction between visual imagery and actual perception is that there is no bottom-up (forward, from the retina) and way stronger top-down (backward) coupling in visual imagery compared to perception (Dijkstra, Zeidman, Ondobaka, van Gerven, & Friston, 2017). Therefore, it is hypothesised that voluntary mental imagery is based on combinations of information retrieved from stored memory. This model also feels instinctively logical as it is almost impossible to imagine something you have never seen before and therefore have no memories of at all. The vividness of the visual imagery is also positively correlated with top-down connectivity to the early visual cortex, as can be seen in figure 4, which supports this theory as well (Dijkstra et al., 2017).

Relation between VIV and the parietal cortex

The medial superior parietal lobe, which is involved in mental imagery and recall of personal experiences, was found to be more connected to VIV than the early visual cortex (Andersson, Ragni, & Lingnau, 2019; Johns, 2014). In addition, it was found that the lateral parietal region is activated more during mental imagery than to during visual perception, regardless of imagery modality (Daselaar, Sander M., Porat, Huijbers, & Pennartz, 2010). In addition, activation of the right posterior parietal region was specific to only visual imagery and not to perception.

An existing theory is that the parietal cortex provides top-down signals to the visual cortex, keeping the visual image active over an extended period of time (Andersson et al., 2019; Dentico et al., 2014; Mechelli, Price, Friston, & Ishai, 2004). Moreover, more vivid visual imagery was linked to stronger excitatory influence from the parietal cortex to

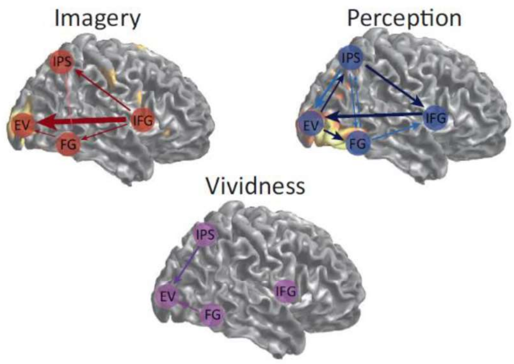

Figure 4: Neuronal connectivity during perception and imagery. *Dynamic causal modelling of fMRI data during perception and imagery on the early visual cortex (EV), high-level visual cortex/fusiform gyrus (FG), intraparietal sulcus (IPS), and inferior frontal gyrus (IFG). The arrows reflect connectivity, with the widths indicating connection strength. Light arrows show inhibitory while a dark arrows show excitatory connections.* (Dijkstra et al., 2017; Dijkstra et al., 2019)

the occipital cortex during imagery, which is in line with this theory (Dijkstra, Bosch, & van Gerven, 2017; Dijkstra et al., 2017).

Contribution of the medial temporal lobe to VIV

The medial temporal lobe includes a system of anatomically related structures that are essential for declarative memory (conscious memory for facts and events; Squire, Stark, & Clark, 2004). As with the visual cortex, there is a lot of overlap in mechanism in the medial temporal lobe between perception and mental visualisation. In a study where single neuron activation was recorded, it was found that there are neurons in the medial temporal lobe that fire during both perception and visual imagery, but also neurons that only fire during perception ór imagery (Kreiman, Koch, & Fried, 2000). These three different types of neurons were found in all medial temporal regions (hippocampus, amygdala, entorhinal cortex and parahippocampal gyrus), even though there are patients that experience deficits in only perception ór imagery after a neurological lesion, which would have suggested regional segregation of the neuron types (Bartolomeo et al., 1998; Behrmann, Winocur, & Moscovitch, 1992). Furthermore, the firing rates of the single neurons during imagining were found to be dependent on what the subjects were imagining, indicating a very specific underlying mechanism (Kreiman et al., 2000).

Hippocampus. As the hippocampus is highly activated during autobiographical memory retrieval (Addis, Moscovitch, Crawley, & McAndrews, 2004) and it was hypothesised that that voluntary mental imagery is based on combinations of information retrieved from stored memory, it would be expected that the hippocampus also plays a significant role in visual imagery. And indeed, the hippocampus showed high activation during visual imagery tests (figure 5; Huijbers, Pennartz, Rubin, & Daselaar, 2011). In addition, hippocampal activation was found to be positively correlated with VIV (Fulford et al., 2018). Interestingly, patients with hippocampal amnesia, who have difficulty remembering past experiences had also more difficulty with imagining new experiences, compared to control (Hassabis, Kumaran, Vann, & Maguire, 2007). Although, this is could also be caused by their lack of spatial coherence, instead of a lack of creating the visual images themselves.

In addition, a specific part of the hippocampus, which is more active during the perception of scenes compared to the perception of faces, is also more activated during imagining scenes compared to

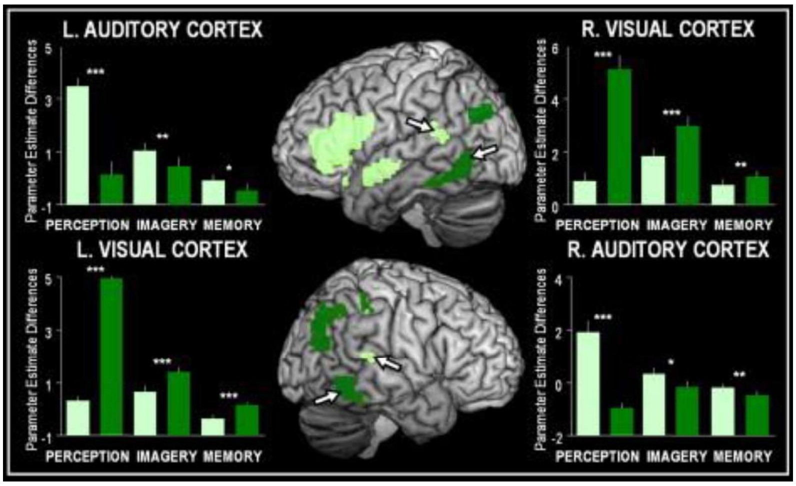

*Figure 5: Modality-specific effects of imagery and retrieval: Light green: activation of auditory regions related to perception, imagery and retrieval. Dark green: activation of visual regions related to perception, imagery and retrieval. Bar graphs (y-axis), indicate mean cluster activity (parameter estimates) for each regions, respectively from left to right: (1) auditory perception > visual perception, (2) auditory perception < visual perception, (3) auditory imagery > visual imagery (4) auditory imagery < visual imagery, (5) auditory retrieval > visual retrieval, and (6) auditory retrieval < visual retrieval. Lines reflect the standard error of the mean and asterisks annotate the significance of the difference between the auditory and visual contrast. Number of asterisks denotes P-values (*P < 0.05, **P < 0.01, ***P < 0.001). (Huijbers, Pennartz, Rubin, & Daselaar, 2011)*

imagining faces, indicating a stimulus specific activation (O'Craven & Kanwisher, 2000b). Although, the extent of the activation was found to be lower during imagery compared to perception, which would be expected as visual imagery is for most individuals not as vivid as perception. On the contrary, other studies have failed to show any role for the hippocampus in imagery creation (Kim et al., 2013; Maguire, Vargha-Khadem, & Hassabis, 2010).

Amygdala. The amygdala that is primarily involved in emotional processing, has also been linked to consolidation and retrieval processes of autobiographical memories (Markowitsch & Staniloiu, 2011; Stein, Simmons, Feinstein, & Paulus, 2007). A purpose of being able to imagine could be to enhance emotionality for thoughts and memories, which can be helpful in making emotional connections with other humans and in making decisions about future events. Activation of the amygdala was indeed found to be positively correlated with VIV during memory tests (Stephan-Otto et al., 2017). Aphantasic individuals were also found to give almost no physiological response to reading and imagining frightening stories, while this was not the case during perception of frightening pictures (figure 6; Wicken, Keogh, & Pearson, 2021). This indicates that the correlation between amygdala activation and VIV is not due to an emotional dampening, but really by a lack of visualization. This also complies with the finding that schizophrenic patients experience hyperconnectivity between the amygdala and the visual cortex during visual hallucinations (Ford et al., 2015).

Relation between VIV and the posterior cingulate cortex

The posterior cingulate cortex, which is supposedly connected to cognition, has also shown high activation during visual imagery (Huijbers et al., 2011; Leech & Sharp, 2014). Moreover, the caudal part of the left posterior cingulate cortex was the most strongly activated region during retrieval of autobiographical memories (Maddock, Garrett, & Buonocore, 2001). Although, the posterior cingulate cortex was found to be more engaged during the recall of real episodic memories compared to imaginary memories, indicating that its role has more to do with information retrieved from stored memory (Hassabis & Maguire, 2007). This is however in line with the top-down theory that was discussed earlier ("Occipitotemporal variances: connecting visual imagery and perception", page 5).

Thus, the neuronal mechanism of visual imagery is very complicated, and it involves activity across a large neural network. FMRI

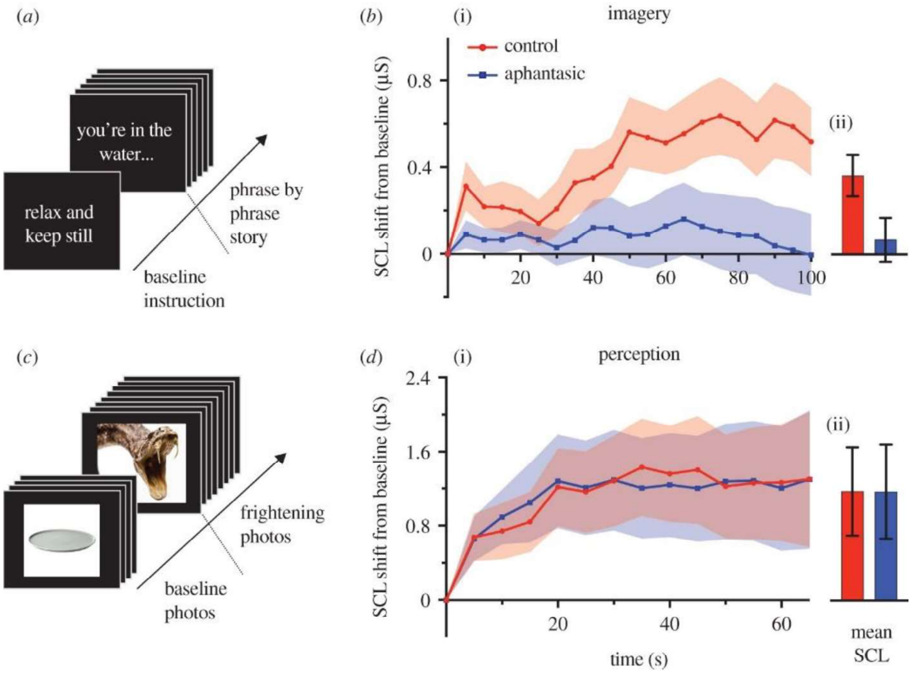

Figure 6: Skin conductance data for imagery and perception experiments. A) Imagery experiment. Participants had to read emotional scenarios. B) Skin conductance level (SCL) shift from baseline while reading the scenarios, with the Mean and SEM across time bins. C) Perception experiment. Participants saw photos with emotional scenarios. D) SCL shift from baseline while perceiving the scenarios, with the Mean and SEM across time bins. (Wicken, Keogh, & Pearson, 2021)

research shows a clear distinction in the neuronal activation between phantasic and aphantasic individuals as low VIV correlates with the activation of significantly more brain regions. Furthermore, visual imagery is comparable with top-down perception in the visual cortex and medial temporal lobe. Additionally, parietal cortex probably provides top-down signals to the visual cortex, keeping the visual image active over an extended period of time. Moreover, hippocampal and amygdala activation was found to be positively correlated with VIV. And lastly, the posterior cingulate cortex has also shown high activation during visual imagery.

As there seem to be distinct differences in phantasic and aphantasic brains, perhaps these are also causing some changes in behaviour that can give an individual an advantage or disadvantage in their daily life. These will be explored in the next sections.

Disadvantages of aphantasia

As visual imagery seems to be a defining feature of human cognition (Dunbar, 2004), it would be expected that weak VIV or a complete absence could result in disadvantages. As previously discussed ("Effect of VIV on different types of memory performance", page 3), aphantasic individuals can have difficulties with working memory (Jacobs et al., 2018), autobiographical memory (Zeman et al., 2020) and face recognition (Milton et al., 2021). These disadvantages can all interfere with daily life, but seem still quite insignificant. Primarily because most aphantasic individuals use different strategies to work around their shortcomings. However, VIV was also found to be connected to mental disorders.

Weak VIV might be linked to autism spectrum disorders, although science is not quite in agreement on this subject. Hughes et al. (2018) found no difference between autistic participants and controls regarding imagery ability, while Kana, Keller, Cherkassky, Minshew, & Just (2006) found that autistic individuals were more reliant on visualization to process information compared to control, indicating increased visual imagery in autism. On the contrary, Marothi, Csigo, & Keri (2019) found that VIV was instead weaker in autistic individuals. Moreover, young children with autism seem to engage less in imaginative behaviour such as pretend play (Baron-Cohen, Simon, 1987; Davis, Simon, Meins, & Robins, 2018) and have deficits in imaginative drawing (Low, Goddard, & Melser, 2009; Scott & Baron-Cohen, 1996). However, we have to keep in mind that visual imagery and imagination are on many aspects distinct concepts. Aphantasic individuals have also shown more traits that are associated with autism, like impaired social skills, compared to controls (Dance et al., 2021; Dance et al., 2021; Milton et al., 2021) and fall more often within a range that is suggestive of autism (Baron-Cohen, S., Wheelwright, Skinner, Martin, & Clubley, 2001; Dance et al., 2021).

Surprisingly, visual imagery also positively correlates with sensory sensitivity (Dance et al., 2021). Aphantasic individuals showed significantly lower sensory sensitivity compared to phantasic individuals. This could perhaps be explained by an enhanced cortical excitability during less vivid visual imagery (Cattaneo, Pisoni, Papagno, & Silvanto, 2011; Keogh, Bergmann, & Pearson, 2020). However, this is still a fascinating finding as sensory sensitivity is a common symptom of autism spectrum disorders (Sapey-Triomphe, Leiros Costa, & Wagemans, 2019), which we just discussed ("disadvantages of aphantasia", page 7) to be more often connected to weaker visual imagery instead of stronger.

Thus, aphantasia is linked to difficulties with memory performance and also with autism spectrum disorders. Together these can have a huge impact on everyday life experience.

Treatment of aphantasia

Thus, if there are some major disadvantages of aphantasia, the question arises if aphantasia could be treatable. Although no research has been done on the genetic make-up of aphantasia as of yet, first degree relatives of aphantasic individuals do experience more often aphantasia than would be expected by chance, suggesting a possible genetic basis for imagery vividness (Zeman et al., 2020). Still, environmental factors very likely do play a part in establishing someone's VIV. Research on the origin of aphantasia is difficult as it is usually only discovered in adult-life or sometimes is not discovered at all due to an overall lack of awareness of differences in VIV.

However, there are multiple cases known of acquired aphantasia, although these were all due to medical causes. A 62-year-old male with refractory IgG kappa multiple myeloma became aphantasic after receiving an autologous stem cell transplant (Bumgardner, Yuan, & Chiu, 2021), a 65-year-old male became aphantasic after surgery (without any obvious neurological damage) (Keogh & Pearson, 2018) and an architect who reported almost complete loss of his before very vivid visual imagery following bilateral stroke in the areas supplied by the posterior cerebral artery (Thorudottir et al., 2020).

Treatment of aphantasia is relatively unexplored as aphantasia is not seen as an official mental disorder and the condition does not pose any significant risks. Still, some aphantasic individuals do want to improve their visual vividness. However, just simply practicing imagery, showed no improvements of VIV, but did increase metacognition of imagery (Rademaker & Pearson, 2012).

In a 2017 case study, a more extensive attempt was made to treat the aphantasia of a 31-year-old patient with vision therapy (Shank & McDowell, 2017). The patient attended a 1-hour vision therapy session each week for a total of 18 weeks and was encouraged to perform home activities in between. Some of the session activities included block pattern activities, object visualization and recall exercises. While the patient's test scores did not improve, they did report a slight improvement in creating mental imagery right before sleeping, however there was no significant difference throughout the day. Therefore, it is still unclear if aphantasia is treatable, and if so, how long it may take and what method could be used best.

Disadvantages of phantasia

But even if aphantasia is possibly treatable, we have to ask ourselves the question if we even want to treat aphantasia. Although it seems like phantasic individuals have advantages over aphantasics, there are also negative aspects of being able to see visual mental images. Visual imagery can provoke stronger emotional responses than comparable verbal thoughts (Holmes & Mathews, 2005). Intrusive emotionally loaded visual images are a common aspect of a range of mental disorders and high VIV may contribute to the development of the intrusive images following exposure to traumatic events (Morina, Leibold, & Ehring, 2013). Patients with a posttraumatic stress disorder (PTSD), other anxiety disorders, depression, eating disorders, and psychosis frequently experience involuntary visual intrusions that are usually extremely vivid, detailed, and with highly distressing content (Brewin, Gregory, Lipton, & Burgess, 2010).

PTSD has most often been connected to imagery. PTSD is a disorder that can develop after experiencing a traumatic event and often comes in hand with the experience of flashbacks which can be as vivid and intense as real-life experiences (Birrer, Michael, & Munsch, 2007). Remarkably, PTSD patients displayed weaker VIV when imagining non-trauma related visual images compared to control (Bryant & Harvey, 1996). The ability to experience visual imagery seemed to diminish as anxiety of the PTSD patients increased. Therefore, anxiety might interfere with the cognitive processes required for visual imagery, but anxious patients could also subconsciously be avoiding imagery to prevent potential associations with traumatic imagery, as we do know that the PTSD patients are able to create more vivid imagery during flashbacks. Another study specifically looking at anxiety found that there was no difference in vividness for non-trauma related imagery, but found negative imagined future scenarios to be more vivid in individuals with anxiety compared to control (Tallon, Ovanessian, Koerner, & Dugas, 2020).

Vivid intrusive memories are not a unique feature of PTSD, but are also a common feature of major depressive disorder (Reynolds & Brewin, 1999). Negative mental images can influence both its onset and maintenance (Wesslau & Steil, 2014). Depressed individuals show higher VIV compared to non-depressed controls (Newby & Moulds, 2011), but show lower levels of vividness when imagining positive future events (Morina, Deeprose, Pusowski, Schmid, & Holmes, 2011).

Mental imagery is also related to psychotic disorders. Increased imagery vividness has been reported in individuals with schizophrenia and elevated schizotypal traits (Oertel et al., 2009). However, the connection between imagery vividness and hallucinations is still unclear. Vividness was found to be independent of predisposition towards hallucinations by Oertel et al. (2009). However, subjects reporting hallucinatory experiences were found to show higher imagery vividness in the study of Aleman, Bocker, & Haan (1999).

Hyperphantasia or eidetic imagery

Around 2.6% of the population has the opposite of aphantasia: hyperphantasia, or previously called eidetic imagery. Individuals who have hyperphantasia are able to imagine so vividly that it appears photorealistic. RsfMRI reveals stronger connectivity between the posterior visual network and prefrontal regions among people with hyperphantasia than those with aphantasia (Milton et al., 2021). Hyperphantasia is also associated with enriched autobiographical memory.

However, the previously discussed disadvantages of being able to visualize (“Disadvantages of phantasia”, page 9), can be more profound in individuals with hyperphantasia although this is not specifically researched yet. In addition, hyperphantasics are more likely to report synaesthesia (Zeman et al., 2020). Synaesthesia is a condition in which stimulation of one sensory modality causes unusual experiences in a second, unstimulated modality, like the perception of colours when viewing letters and numbers (Hubbard & Ramachandran, 2005). It has been linked to more vivid mental imagery in the senses involved in the person’s synaesthesia (Spiller, Jonas, Simner, & Jansari, 2015), better episodic memory (Ward, Field, & Chin, 2019) and higher creativity (Chun & Hupe, 2016).

Thus, even considering the disadvantages of aphantasia, being able to visually imaging does come with some less beneficial traits. Aphantasic individuals are not able to experience flashbacks that are an important symptom of mental disorders like PTSD. In addition, schizophrenia is more common in phantasic individuals and hyperphantasic individual report more often to also have synaesthesia. There might however be more disorders connected to visual imagery vividness that have not yet been studied.

Limitations and future prospects

We suspect that aphantasia and hyperphantasia will prove to have balanced advantages and disadvantages, perhaps reflecting an equilibrium between two ways of information processing: one episodic and sensorily-rich, the other semantic and factual. Research on both extremes can teach us a lot about the underlying mechanism of visual imagery and even visual perception. As visual perception contains both bottom-up and top-down coupling, whereas visual imagery only contains top-down coupling, we can solely focus on researching the top-down mechanism with imagery and translate this further into visual perception.

Understanding the mechanism behind visual imagery can also shine more light onto mental disorders that contain intrusive visual images. Although, it has to be considered that most research on the mechanism of imagery has been focussed on voluntary imagery, while disorders are mainly concerning involuntary imagery. Emotionality was for example already found to be higher in involuntary imagery compared to voluntary imagery (Homer & Deeprose, 2017). Thus, more research should be performed on how comparable both forms of imagery actually are.

Besides vividness, there can be other differences in perception of visual imagery. Visualizing autobiographical memories can be experienced in first- and third-person perspective. Dissociation and anxiety were associated more with third-person view (Sutin & Robins, 2010). Likewise, first-person memories were higher on vividness, coherence, accessibility, sensory detail, emotional intensity, and time perspective compared to third-person memories. Still, most studies on imagery have not taken this important factor into consideration when interpreting the results of their experiments.

It is also worth noting that by solely focussing on the visual aspect of mental imagery in this review, and within the scientific community in general, our overall understanding of mental imagery is restricted. It is perhaps too often assumed that findings from visual imagery will naturally generalize to the other senses.

Furthermore, the human mind contains way more than only imagery. A small study did try to get a better picture of how people think, by using Descriptive Experience Sampling (Heavey & Hurlburt, 2008). When a beeper went off, subjects had to describe what was going on inside their heads at that exact moment. The most frequently occurring phenomena that were described by the subjects were: inner monologue, mental imagery, conceptual thinking, emotions, and sensory awareness. The frequency of those occurring was highly different between subjects and just like with visual imagery, not all subjects experienced all phenomena. These differences in thinking could possibly affect the way people are experiencing reality.

Thus, there is still a lot to take into consideration when researching inner thoughts like visual imagery. As interest from the scientific community in aphantasia has only been growing since the term was established in 2015, it is exciting to think of all the future imagery research waiting to be performed.

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