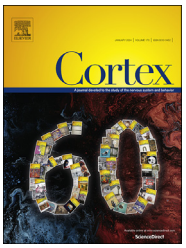
CORTEX 170 (2024) 21–25

Available online at www.sciencedirect.com

ScienceDirect

Journal homepage: www.elsevier.com/locate/cortex



Viewpoint

What is the true range of mental imagery?

Dietrich S. Schwarzkopf [a,b,*]

[a] *School of Optometry & Vision Science, University of Auckland, New Zealand*
[b] *Experimental Psychology, University College London, UK*

ARTICLE INFO

Article history:
Received 15 August 2023
Reviewed 25 August 2023
Revised 28 August 2023
Accepted 12 September 2023
Action editor Sergio Della Sala
Published online 18 October 2023

Most people say they can easily conjure mental sensations, such as mentally picturing their mother's face or having a vivid representation of a fictional world when reading a good book. Yet a considerable proportion of the population, by some estimates around 4 %, report that they cannot (Dance et al., 2022). This lack of inner perceptual sensation has been coined *aphantasia* (Zeman et al., 2010, 2015) – a "blind mind". Mental imagery is often invoked in well-being exercises, athletic training, and in treatments for psychiatric disorders (Schwartz et al., 2022). It could also be a driving factor in intrusive thoughts and post-traumatic stress disorder (Brewin et al., 2010). Aberrant mental imagery could be linked with psychosis (Glazer et al., 2013). A better understanding of neural and cognitive processes that govern mental imagery would therefore help resolve ongoing controversies (Pylyshyn, 2002; Slotnick et al., 2005), and could advance our knowledge and maintenance of mental health. Recent years, since the report of a patient who lost mental imagery abruptly in adulthood (Zeman et al., 2010), have seen an explosion of scientific studies researching aphantasia, even though the phenomenon has been known since at least the 19th century (Galton, 1880). As a quick look through the references in this Viewpoint article confirms, in its role as a pioneering outlet in cognitive neuroscience *Cortex* has also published its fair share of studies on this topic.

One issue limiting investigations of imagery and aphantasia has been its inherent subjectivity. We do not even know if different people experience imagery in the same way. We generally can only deduce the contents of a person's consciousness indirectly, based on their verbal reports or behavioural responses, but never directly experience as they do. A person with normal vision can never see the world through the eyes of people with red-green colour vision deficiency; however, we can use objective tasks to estimate perceptual threshold performance, allowing us to determine colour contrasts such individuals cannot distinguish. This allows an inference about what they perceive. In contrast, quantifying mental imagery is far more difficult, as our means of probing it are limited. One attempt at testing imagery experimentally is the Perky effect: observers sometimes fail to distinguish the experience of their mind's eye from very subtle stimuli presented to them (Perky, 1910). Recently, a massive online experiment replicated this effect and suggested mental images indeed overlap with real perception (Dijkstra & Fleming, 2023). However, while interesting, to my mind such experiments disregard just how subjective mental imagery really is.

* School of Optometry & Vision Science, University of Auckland, New Zealand.
E-mail address: s.schwarzkopf@auckland.ac.nz.
https://doi.org/10.1016/j.cortex.2023.09.013

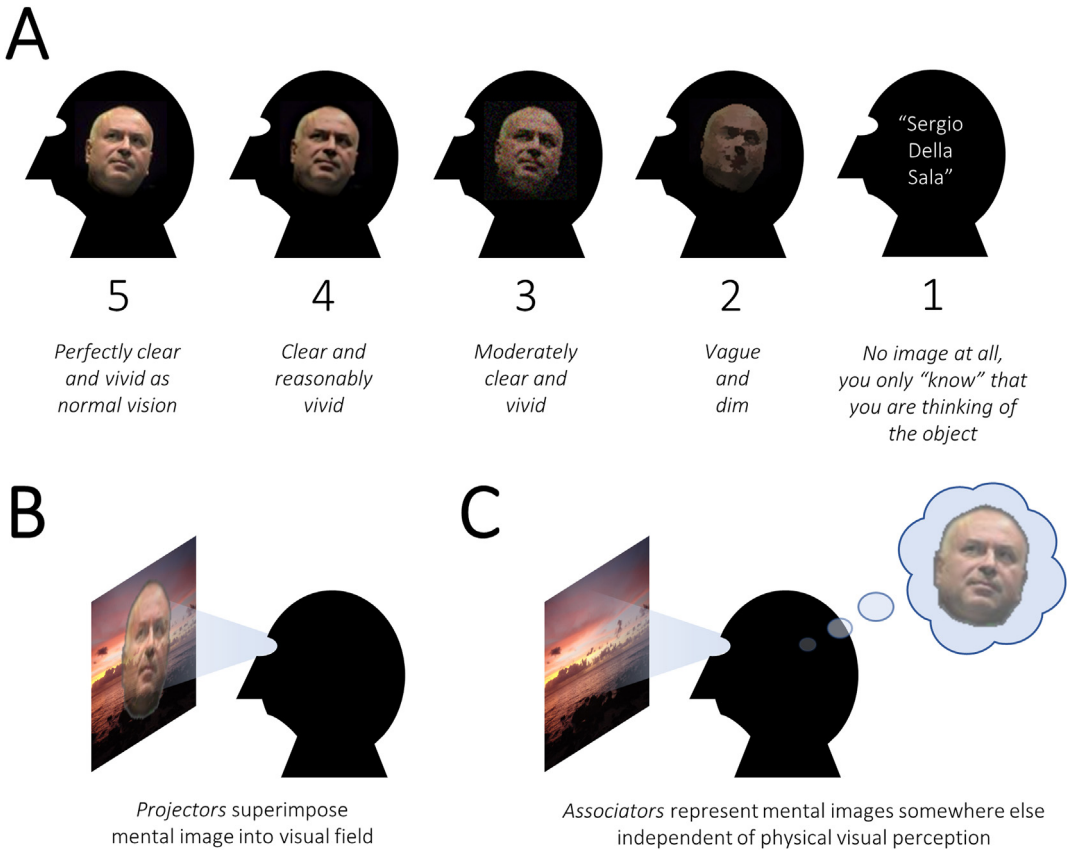


Fig. 1 – Subjective experience of mental imagery. A. Individual differences in visual imagery are typically quantified using vividness scales, e.g., the VVIQ2. As participants picture the face of a famous editor-in-chief in their mind's eye, they rate the clarity and vividness of this mental image on a one-dimensional spectrum. This ranges from seeing "as clear as normal vision" to having no visual mental representation at all. Aphantasic individuals would tend to choose the latter, reporting they merely "know" they are thinking of the person, possibly via semantic descriptors of facial features and his other characteristics. B–C. However, in addition to vividness and clarity, mental imagery could also vary in mode. *Projectors* (B) perceive their mental image as somehow superimposed onto their visual experience, possibly directly interfering with their perception. In contrast, *associators* (C) do not "see" mental images but can nevertheless have a clear visual representation of the imagined face. Such individuals may describe their mental image as being somewhere else, "off-screen", "inside", or even "behind their head".

Most studies regard imagery as existing along a one-dimensional vividness spectrum (Fig. 1A) that describes the detail and "life-likeness" of imagined experiences (Bergmann et al., 2015; Dawes et al., 2020; Jacobs et al., 2018; Keogh et al., 2020; Keogh & Pearson, 2018; Marks, 1973). This belies the vast diversity with which people characterise their mental experiences anecdotally. Some report being able to place a visual image into the external scene, literally in front of them. Others state they can conjure such images, but only with closed eyes. In contrast, some people regard mental imagery as unrelated to their eyes. They might see only blackness with closed eyes but – unlike aphantasics – they nevertheless experience detailed *mental* visual representations. You might recognise your own experience in one of these descriptions but find the others bewildering; it can be difficult to understand the inner world of others. Critically, failing to appreciate the multifaceted nature of mental imagery impedes scientific study. In my view, any conclusions researchers draw from current studies about mental imagery, whether from behavioural or neuroimaging experiments, or studies on patients with brain lesions, are therefore premature.

Interestingly, these diverse descriptions parallel what has already been suggested about synaesthesia (Dixon et al., 2004). Some synaesthetes are *"projectors"* for whom achromatic letters trigger a sensation of colour. In contrast, *"associators"* only internally link colours in their mind without any actual sensation (Amsel et al., 2017; Dance, Ward, & Simner, 2021). These differences correlate with differences in brain structure (Rouw & Scholte, 2007). Unlike synaesthesia, mental imagery is at least under some voluntary control, but similar types could exist for mental imagery; in fact, these types of synaesthesia are linked with self-reported imagery strength (Barnett & Newell, 2008; Dance, Jaquiery, et al., 2021). If this hypothesis is correct, imagery *projectors* experience mental images directly within their visual field (Fig. 1B), while *associators* instead process mental images separately from their visual input, "in a buffer," "somewhere off-screen," or even "behind" the observer (Fig. 1C). Thus far, I have only anecdotal

evidence that this distinction exists, as we currently lack formalised instruments to classify these imagery types. Yet my conversations with numerous people indicate that being an associator could be very common. It should be noted that while this description bears some superficial similarity with the idea that people can be unconscious of their mental imagery (Nanay, 2021), an associator would report being fully aware of their mental image – they merely do not experience it within their visual field, unlike dreams, the Tetris effect (Stickgold et al., 2000), or hypnagogic visual experiences. One preliminary study quantified the perceived location of mental imagery in the space around the participant, and found that while most people locate their images in front of them, many indeed feel the images are inside their head (Sulfaro et al., 2023). However, most of the described experiences still have a distinct flavour of projection, rather than association, and thus probably still do not capture the full range of experiences.

Standard methods for rating the strength of imagery, like the Vividness of Visual Imagery Questionnaire (VVIQ), are at best vague and ambiguous (Marks, 1973). What does it mean that a mental image is "clear and as vivid as normal vision", the highest score in the VVIQ2 (https://davidfmarks.net/vividness-of-visual-imagery-questionnaire-2)? Conversely, what is meant by the lowest score that you "only 'know' you are thinking of the object"? You could easily answer with either score, depending on how you interpret these questions. In my view, this dependence on criterion makes these instruments next to useless.

It seems to me that scientific studies of mental imagery are strongly geared towards projectors. People are often asked to visualise stimuli in the world before them. In one study, we asked participants to imagine a shape within placeholders displayed on the screen (Jacobs et al., 2018). Unlike my co-authors, I feel this design is completely unsuitable for testing the contents of my mental imagery. How could I possibly imagine something within in the external world, when my images seem inherently internal? You may by now have realised that I believe I am an associator. Tasks designed for projectors are likely to be inappropriate for people like me. In one commonly used paradigm, participants imagine oriented gratings and researchers test how these images affect the perception of physically presented stimuli (Dijkstra et al., 2022; Dijkstra & Fleming, 2023; Pearson, 2014; Pearson et al., 2008). This is based on the premise that people experience their mental images as somehow superimposed onto, or blended with, what their eyes see. If this is not how many of us experience their mental images, then there should not be such interference. By the same token, associators should not be susceptible to the Perky effect, simply because we do not "see" imagined stimuli at all.

Studies like these are usually motivated by the idea that mental images share a neural substrate with perceived images in visual cortex (Bergmann et al., 2015; Huang et al., 2023; Naselaris et al., 2015; Slotnick et al., 2005; Thirion et al., 2006). Under this hypothesis, mental representations evoke overlapping, albeit much weaker, patterns of activation as an actual stimulus. Interestingly though, a recent preprint argued that visual cortex activations of remembered objects are similar in strong and weak imagers, including aphantasics (Weber et al., 2023). This could indicate that these neural representations are only an epiphenomenon, not causally related to imagery at all. Experiencing imagery requires additional neural processing beyond the visual cortex (Bartolomeo, 2002). Aphantasics seem perfectly capable of thinking of visual objects – they merely report not having any internal *visual* experiences. Imagery could simply be how other brain regions read out the working memory signals from visual cortex, possibly related to the excitability of cortical neurons (Keogh et al., 2020) or the strength of connections between frontoparietal and early sensory brain regions (Keogh et al., 2021; Liu et al., 2023). Then again, previous research suggested that both imagery and visual working memory correlate with the size of primary visual cortex (Bergmann et al., 2014, 2015). This suggests that the detail of visual working memories depends on how much neural tissue is available to store them, but this is inversely related to the vividness of how they experience mental images of these memories. But crucially, any such hypotheses must hinge on whether we are all in fact talking about the same phenomenal experience.

What if instead these various candidate mechanisms relate to the distinction between projectors and associators? Most people might store mental representations using visual neurons, but only in a subset (projectors) this produces an overlap between conscious perception and imagined sensation. In others (associators), imagery might recruit the same neural circuitry but without any conscious qualia. The two groups might also differ in terms of the long-range cortical networks involved when maintaining mental images. Importantly, both these groups would differ from what I call "true" aphantasics, people who do not store mental objects using visual neurons at all. They instead code objects using semantic labels, such as thinking "a red apple" without actually picturing any fruit in their mind's eye. There is growing interest in mental sensations in non-visual modalities – we can imagine auditory experiences (Hubbard, 2010), and imagination is presumably multisensory (Nanay, 2018). Indeed, while the strength of imagery in different senses tends to correlate, there can be dissociations: visually aphantasic individuals can report having vivid mental auditory sensation, and vice versa (Hinwar & Lambert, 2021). Therefore, each of us might have our own idiosyncratic mix of imagery strengths for different sensory modalities. In this scenario, semantic labels are just one way to code memories – but for a total aphantasic (that is, with no mental imagery of any sensory domain) it is the *only* way.

Failing to account for such heterogeneity must hinder efforts to understand the neural basis of imagined sensations. Do our current measures, based on questionnaires and vividness ratings, misclassify many imagery associators as aphantasic? If so, many studies must dramatically overestimate the prevalence of aphantasia. Conversely, questionnaires might fail to detect these differences, because people vary considerably in how they interpret the questions. I wonder how many people have let themselves be classified as aphantasics simply because they feel they do not "hallucinate" like projectors seem to do. Crucially, neglecting the detailed qualia of people's imagery could explain the ambivalence of many previous findings in this field. Aphantasics are only slightly impaired on many cognitive tasks that are widely

thought to rely on imagery (Dance et al., 2023; Jacobs et al., 2018; Monzel et al., 2023; Pounder et al., 2022; Zeman et al., 2010). Aphantasics might use different strategies to solve such tasks; however, it also seems likely that associators use their imagery differently from projectors. Of course, all this variability could be explained by a one-dimensional spectrum after all. Associators could be weak imagers, whose mental images are only slightly more intense than those of aphantasics, while projectors, who report "seeing" their images, are hyperphantasic. However, this still suggests that the way we currently measure imagery intensity gives a false impression of its true distribution.

Therefore, we must change how we study imagery. Let us move beyond loaded questions about vague concepts like "vividness". We should instead devise tasks that probe the detail and intensity of mental representations more directly. Let us characterise how people experience their mental images. Do they seem like conscious external projections, separate pictures inside their mind, or possibly other forms we have not even discovered yet? And we must better understand the relationship, if any exists, between mental imagery and working memory. Even if this turns out to be a red herring, if I am wrong and there is no such thing as projectors and associators, we will have improved our methodology in the process and found better ways to quantify this highly subjective experience.

Credit author statement

Conceptualisation & Writing: Dietrich Samuel Schwarzkopf.

Acknowledgements

I would like to thank Tony Lambert, Paul Corballis, Sergio Della Sala, Juha Silvanto, and an anonymous reviewer for helpful comments on this manuscript. Moreover, I thank all the colleagues, self-reported aphantasics, and potential imagery associators too numerous to list with whom I had discussions about this topic.

REFERENCES

Amsel, B. D., Kutas, M., & Coulson, S. (2017). Projectors, associators, visual imagery, and the time course of visual processing in graphene-color synesthesia. *Cognitive Neuroscience, 8*(4), 206–223. https://doi.org/10.1080/17588928.2017.1353492

Barnett, K. J., & Newell, F. N. (2008). Synaesthesia is associated with enhanced, self-rated visual imagery. *Consciousness and Cognition, 17*(3), 1032–1039. https://doi.org/10.1016/j.concog.2007.05.011

Bartolomeo, P. (2002). The relationship between visual perception and visual mental imagery: A reappraisal of the neuropsychological evidence. *Cortex; a Journal Devoted To the Study of the Nervous System and Behavior, 38*(3), 357–378. https://doi.org/10.1016/S0010-9452(08)70665-8

Bergmann, J., Genç, E., Kohler, A., Singer, W., & Pearson, J. (2014). *Neural anatomy of primary visual cortex limits visual working memory*. New York, N.Y.: Cerebral Cortex. https://doi.org/10.1093/cercor/bhu168, 1991.

Bergmann, J., Genç, E., Kohler, A., Singer, W., & Pearson, J. (2015). Smaller primary visual cortex is associated with stronger, but less precise mental imagery. *Cerebral Cortex*, bhv186. https://doi.org/10.1093/cercor/bhv186

Brewin, C. R., Gregory, J. D., Lipton, M., & Burgess, N. (2010). Intrusive images in psychological disorders. *Psychological Review, 117*(1), 210–232. https://doi.org/10.1037/a0018113

Dance, C. J., Hole, G., & Simner, J. (2023). The role of visual imagery in face recognition and the construction of facial composites Evidence from Aphantasia. *Cortex, 167*, 318–334. https://doi.org/10.1016/j.cortex.2023.06.015

Dance, C. J., Ipser, A., & Simner, J. (2022). The prevalence of aphantasia (imagery weakness) in the general population. *Consciousness and Cognition, 97*, Article 103243. https://doi.org/10.1016/j.concog.2021.103243

Dance, C. J., Jaquiery, M., Eagleman, D. M., Porteous, D., Zeman, A., & Simner, J. (2021). What is the relationship between aphantasia, synaesthesia and autism? *Consciousness and Cognition, 89*, Article 103087. https://doi.org/10.1016/j.concog.2021.103087

Dance, C. J., Ward, J., & Simner, J. (2021). *What is the link between mental imagery and sensory sensitivity? Insights from aphantasia*, Article 03010066211042186. https://doi.org/10.1177/03010066211042186. Perception.

Dawes, A. J., Keogh, R., Andrillon, T., & Pearson, J. (2020). A cognitive profile of multi-sensory imagery, memory and dreaming in aphantasia. *Scientific Reports, 10*(1). https://doi.org/10.1038/s41598-020-65705-7. Article 1.

Dijkstra, N., & Fleming, S. M. (2023). Subjective signal strength distinguishes reality from imagination. *Nature Communications, 14*(1). https://doi.org/10.1038/s41467-023-37322-1. Article 1.

Dijkstra, N., Kok, P., & Fleming, S. M. (2022). Imagery adds stimulus-specific sensory evidence to perceptual detection. *Journal of Vision, 22*(2), 11. https://doi.org/10.1167/jov.22.2.11

Dixon, M. J., Smilek, D., & Merikle, P. M. (2004). Not all synaesthetes are created equal: Projector versus associator synaesthetes. *Cognitive, Affective & Behavioral Neuroscience, 4*(3), 335–343. https://doi.org/10.3758/CABN.4.3.335

Galton, F. (1880). Statistics of mental imagery. *Mind*, (19), 301–318. https://doi.org/10.1093/mind/os-V.19.301. os-V.

Glazer, D. A., Mason, O., King, J. A., & Brewin, C. R. (2013). Contextual memory, psychosis-proneness, and the experience of intrusive imagery. *Cognition & Emotion, 27*(1), 150–157. https://doi.org/10.1080/02699931.2012.683850

Hinwar, R. P., & Lambert, A. J. (2021). Anauralia: The silent mind and its association with aphantasia. *Frontiers in Psychology, 12*, Article 744213. https://doi.org/10.3389/fpsyg.2021.744213

Huang, Y., Pollick, F., Liu, M., & Zhang, D. (2023). Gabor and non-gabor neural representations are shared between visual perception and mental imagery. *Journal of Cognitive Neuroscience, 35*(6), 1045–1060. https://doi.org/10.1162/jocn_a_01992

Hubbard, T. L. (2010). Auditory imagery: Empirical findings. *Psychological Bulletin, 136*(2), 302–329. https://doi.org/10.1037/a0018436

Jacobs, C., Schwarzkopf, D. S., & Silvanto, J. (2018). Visual working memory performance in aphantasia. *Cortex; a Journal Devoted To the Study of the Nervous System and Behavior, 105*, 61–73. https://doi.org/10.1016/j.cortex.2017.10.014

Keogh, R., Bergmann, J., & Pearson, J. (2020). Cortical excitability controls the strength of mental imagery. *ELife, 9*, Article e50232. https://doi.org/10.7554/eLife.50232

Keogh, R., & Pearson, J. (2018). The blind mind: No sensory visual imagery in aphantasia. *Cortex; a Journal Devoted To the Study of*

the Nervous System and Behavior, 105, 53–60. https://doi.org/10.1016/j.cortex.2017.10.012

Keogh, R., Pearson, J., & Zeman, A. (2021). Aphantasia: The science of visual imagery extremes. *Handbook of Clinical Neurology, 178*, 277–296. https://doi.org/10.1016/B978-0-12-821377-3.00012-X

Liu, J., Zhan, M., Hajhajate, D., Spagna, A., Dehaene, S., Cohen, L., & Bartolomeo, P. (2023). *Ultra-high field fMRI of visual mental imagery in typical imagers and aphantasic individuals*. https://doi.org/10.1101/2023.06.14.544909 (p. 2023.06.14.544909). bioRxiv.

Marks, D. F. (1973). Visual imagery differences in the recall of pictures. *British Journal of Psychology, 64*(1), 17–24. https://doi.org/10.1111/j.2044-8295.1973.tb01322.x

Monzel, M., Vetterlein, A., Hogeterp, S. A., & Reuter, M. (2023). *No increased prevalence of prosopagnosia in aphantasia: Visual recognition deficits are small and not restricted to faces*, Article 03010066231180712. https://doi.org/10.1177/03010066231180712. Perception.

Nanay, B. (2018). Multimodal mental imagery. *Cortex; a Journal Devoted To the Study of the Nervous System and Behavior, 105*, 125–134. https://doi.org/10.1016/j.cortex.2017.07.006

Nanay, B. (2021). Unconscious mental imagery. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 376*(1817), Article 20190689. https://doi.org/10.1098/rstb.2019.0689

Naselaris, T., Olman, C. A., Stansbury, D. E., Ugurbil, K., & Gallant, J. L. (2015). A voxel-wise encoding model for early visual areas decodes mental images of remembered scenes. *Neuroimage, 105*, 215–228. https://doi.org/10.1016/j.neuroimage.2014.10.018

Pearson, J. (2014). New directions in mental-imagery research: The binocular-rivalry technique and decoding fMRI patterns. *Current Directions in Psychological Science, 23*(3), 178–183. https://doi.org/10.1177/0963721414532287

Pearson, J., Clifford, C. W. G., & Tong, F. (2008). The functional impact of mental imagery on conscious perception. *Current Biology: CB, 18*(13), 982–986. https://doi.org/10.1016/j.cub.2008.05.048

Perky, C. W. (1910). An experimental study of imagination. *The American Journal of Psychology, 21*(3), 422–452. https://doi.org/10.2307/1413350

Pounder, Z., Jacob, J., Evans, S., Loveday, C., Eardley, A. F., & Silvanto, J. (2022). Only minimal differences between individuals with congenital aphantasia and those with typical imagery on neuropsychological tasks that involve imagery. *Cortex; a Journal Devoted To the Study of the Nervous System and Behavior, 148*, 180–192. https://doi.org/10.1016/j.cortex.2021.12.010

Pylyshyn, Z. W. (2002). Mental imagery: In search of a theory. *The Behavioral and Brain Sciences, 25*(2), 157–182. https://doi.org/10.1017/s0140525x02000043. ; discussion 182-237.

Rouw, R., & Scholte, H. S. (2007). Increased structural connectivity in graphene-color synesthesia. *Nature Neuroscience, 10*(6), 792–797. https://doi.org/10.1038/nn1906

Schwartz, S., Clerget, A., & Perogamvros, L. (2022). Enhancing imagery rehearsal therapy for nightmares with targeted memory reactivation. *Current Biology*. https://doi.org/10.1016/j.cub.2022.09.032

Slotnick, S. D., Thompson, W. L., & Kosslyn, S. M. (2005). Visual mental imagery induces retinotopically organized activation of early visual areas. *Cerebral Cortex (New York, N.Y.: 1991), 15*(10), 1570–1583. https://doi.org/10.1093/cercor/bhi035

Stickgold, R., Malia, A., Maguire, D., Roddenberry, D., & O'Connor, M. (2000). Replaying the game: Hypnagogic images in normals and amnesics. *Science, 290*(5490), 350–353. https://doi.org/10.1126/science.290.5490.350

Sulfaro, A. A., Robinson, A. K., & Carlson, T. A. (2023). *Comparing mental imagery experiences across visual, auditory, and other sensory modalities*. https://doi.org/10.1101/2023.05.15.540306 (p. 2023.05.15.540306). bioRxiv.

Thirion, B., Duchesnay, E., Hubbard, E., Dubois, J., Poline, J.-B., Lebihan, D., & Dehaene, S. (2006). Inverse retinotopy: Inferring the visual content of images from brain activation patterns. *Neuroimage, 33*(4), 1104–1116. https://doi.org/10.1016/j.neuroimage.2006.06.062

Weber, S., Christophel, T., Görgen, K., Soch, J., & Haynes, J.-D. (2023). *Working memory and imagery in early visual cortex*. https://doi.org/10.1101/2023.02.13.528298 (p. 2023.02.13.528298). bioRxiv.

Zeman, A. Z. J., Della Sala, S., Torrens, L. A., Gountouna, V.-E., McGonigle, D. J., & Logie, R. H. (2010). Loss of imagery phenomenology with intact visuo-spatial task performance: A case of "blind imagination". *Neuropsychologia, 48*(1), 145–155. https://doi.org/10.1016/j.neuropsychologia.2009.08.024

Zeman, A., Dewar, M., & Della Sala, S. (2015). Lives without imagery—congenital aphantasia. *Cortex; a Journal Devoted To the Study of the Nervous System and Behavior, 73*, 378–380. https://doi.org/10.1016/j.cortex.2015.05.019