First Sources - Relationship between Aphantasia and Embodied Cognition

PRIMARY SOURCES

1. **Dawes, A.J., Keogh, R., Andrillon, T. *et al.* A cognitive profile of multi-sensory imagery, memory and dreaming in aphantasia. *Sci Rep* 10, 10022 (2020).**

    1. Here we found that individuals with aphantasia report signifcant reductions in sensory simulation across a range of volitional and non-volitional mental processes, and overall appear to demonstrate a markedly distinct pattern of cognition compared to individuals with visual imagery. Notably, aphantasic individuals reported signifcantly reduced imagery across all sensory modalities (and not just visual). However, only 26.22% of aphantasic participants reported a total absence of multi-sensory imagery altogether, raising important questions about the primary aetiology of aphantasia and suggesting possible sub-categories of aphantasia within a heterogeneous group (8).
    2. Despite these demographic discrepancies, the results of our replication analysis with control group 2 revealed a remarkably similar pattern of between-group effects to our main analysis (see Tables S2–6 in Supplementary Information). Additionally, a majority of the signifcant changes to our results that did occur are congruent with established efects of age and gender on cognitive outcomes. For example, our fnding that undergraduate participants reported signifcantly more frequent memory intrusions and avoidance behaviours than aphantasic participants in response to stressful life events may be explained by the typically higher prevalence of PTSD diagnosis and symptomatology amongst females (and younger females in particular) (8-9).
    3. Visual imagery, or seeing with the mind's eye, contributes to essential cognitive processes such as episodic memory, future event prospection, visual working memory, and dreaming. By allowing us to re-live the past and simulate hypothetical futures, visual imagery enables us to fexibly and adaptively interpret the events we experience in the world, and by extension appears to be an important precursor to our ability to plan effectively and engage in guided decision-making. Consequently, the frequency and content of maladaptive visual imagery are ofen defning features of mental illness and mental imagery is ofen elevated in disorders characterised by hallucinations (1).
    4. The aim of the present study was to investigate the subjective impact of visual imagery absence on cognition. To achieve this, we compared self-reports of aphantasic individuals with those of general population individuals (with self-reported intact visual imagery) on several cognitive domains including multi-sensory imagery episodic memory, trauma response, dreaming and daydreaming, and spatial abilities (4).

5. Interestingly, our data aligns with that of previous studies demonstrating unafected spatial imagery abilities in aphantasia, suggesting an important distinction between object imagery (low-level perceptual features of objects and scenes) and spatial imagery (spatial locations and relations in mental images)... Strikingly, cognitive diferences in aphantasia were not limited to processes where visual imagery is typically deliberate and volitional, with aphantasic individuals in our study reporting signifcantly less frequent and less vivid instances of spontaneous imagery such as night dreams. These data suggest that any cognitive function (voluntary or involuntary) involving a sensory visual component is likely to be reduced in aphantasic individuals, and it is this generalised reduction in the sensory simulation of complex events and scenes that is most striking in aphantasia (8).

2. **Ganczarek, Joanna & Żurawska-Żyła, Renata & Rolek, Aleksandra. (2020). "I remember things, but I can't picture them." What can a case of aphantasia tell us about imagery and memory?. Psychiatria i Psychologia Kliniczna. 20. 134-141.**

    1. The relationship between aphantasia and memory is mentioned in Zeman's account of the M.X. patient. In fact, it seems that aphantasia may provide an interesting opportunity to study the relationship between memory and imagery. Usually, in order to separate memory from imagery, researchers have to employ complex experimental procedures and consider the vividness of mental imagery as a correlate of performance in memory tasks (e.g. Baddeley and Andrade, 2000; Gur and Hilgard, 1975; Keogh and Pearson, 2011, 2014). Instead, in aphantasic individuals we can observe how memory works in the absence of mental imagery. To the best of our knowledge, among the different types of memory, aphantasia has been studied in the context of visual working memory and autobiographical memory (135).
    2. Moreover, she scored very low in object imagery, but had a higher score in spatial and verbal subscales of OSIVQ. This suggests that A.B. experiences no vivid images and has a preference for spatial and verbal reasoning. Her good performance in spatial tasks is further supported by a higher than usual score in the mental rotation test. Also, despite a clear lack of visual imagery, she performed normally in both the forward and backward span of the Corsi Block-Tapping Task, suggesting good capacity and performance of her working memory, including visuospatial working memory (138-139).
    3. These compensatory strategies may be difficult to assess through introspection, therefore, neuroimaging may be very useful in gaining insight into the nature of these strategies. Moreover, aphantasia can provide an insight into the role of imagery in perception, memory, attention and other cognitive processes. Also, it could shed light on the relationship between imagery and social functioning as well as emotional processing of past, present and future experiences (140).
    4. It seems that aphantasia might be related to severely deficient autobiographical memory (SDAM), which refers to a lifelong inability to vividly recollect or re-experience personal past events from a first-person perspective. The link

between SDAM and aphantasia was described by Watkins (2018), who claims that even though visual imagery is not absolutely necessary for self-awareness, its impairment can lead to difficulties with autobiographical memory and the sense of self. This conclusion is also supported by research showing that the lack of ability to create mental images is connected with limited access to episodic and emotional information about past personal experiences (Palombo et al., 2015) and even with problems with identity (Simeon et al., 2000; de Vito and Bartolomeo, 2016). (136).

5. Our brief review of research on aphantasia and memory suggests that mental imagery might be a form of a mnemonic strategy to boost one's performance in working memory tasks. Good imagers would use this pictorial strategy to help them solve tasks, whereas poor imagers would rely on a non-image based, possibly verbal or propositional strategy (Keogh and Pearson, 2011). Therefore, aphantasia seems to be a condition where working memory is operating well, but visual imagery is unavailable. Furthermore, if we consider mental imagery as a compound of different processes (e.g. visual, spatial), then aphantasia would not mean a loss of imagery, but only its partial impairment or even a cognitive style that operates on spatial and verbal rather than object-related information (139).\

3. Wilson, M. (2002). Six views of embodied cognition. Psychonomic Bulletin & Review, 9(4), 625–636.

1. Rather than continue to treat embodied cognition as a single viewpoint, we need to treat the specific claims that have been advanced, each according to its own merits. One benefit of greater specificity is the ability to distinguish on-line aspects of embodied cognition from off-line aspects. The former include the arenas of cognitive activity that are embedded in a task-relevant external situation, including cases that may involve time pressure and may involve off-loading information or cognitive work onto the environment. In these cases, the mind can be seen as operating to serve the needs of a body interacting with a real-world situation (635).
2. Simply put, situated cognition is cognition that takes place in the context of task-relevant inputs and outputs. That is, while a cognitive process is being carried out, perceptual information continues to come in that affects processing, and motor activity is executed that affects the environment in task-relevant ways. Driving, holding a conversation, and moving around a room while trying to imagine where the furniture should go are all cognitive activities that are situated in this sense (626).
3. Despite the fact that we frequently choose to run our cognitive processes off line, it is still true that in some situations we are forced to function on line. In those situations, what do we do about our cognitive limitations? One response, as we have seen, is to fall apart. However, humans are not entirely helpless when confronting the representational bottleneck, and two types of strategies appear to be available when one is confronting on-line task demands. The first is to rely on preloaded representations acquired through prior learning (discussed further in

Section 6). What about novel stimuli and tasks, though? In these cases there is a second option, which is to reduce the cognitive workload by making use of the environment itself in strategic ways—leaving information out there in the world to be accessed as needed, rather than taking time to fully encode it; and using epistemic actions (Kirsh & Maglio, 1994) to alter the environment in order to reduce the cognitive work remaining to be done (628).

4. The insight that the body and the environment play a role in assisting cognitive activity has led some authors to assert a stronger claim: that cognition is not an activity of the mind alone, but is instead distributed across the entire interacting situation, including mind, body, and environment… The claim is this: The forces that drive cognitive activity do not reside solely inside the head of the individual, but instead are distributed across the individual and the situation as they interact. Therefore, to understand cognition we must study the situation and the situated cognizer together as a single, unified system (629-630).
5. Our mental representations, whether novel and sketchy or familiar and detailed, appear to be to a large extent purpose-neutral, or at least to contain information beyond that needed for the originally conceived purpose. And this is arguably an adaptive cognitive strategy. A creature that encodes the world using more or less veridical mental models has an enormous advantage in problem-solving flexibility over a creature that encodes purely in terms of presently foreseeable activities (632).

4. Gibbs, R. W., Jr., & Berg, E. A. (2002). Mental imagery and embodied activity. Journal of Mental Imagery, 26(1–2), 1–30.

1. Most generally, both blind and sighted individuals' haptic abilities are constrained by a complex coordination between tactile senses, proprioception, and the involvement of the motor cortex. The large range of imagery evidence for the blind clearly rejects the idea that mental images are amodally visual or amodally spatial (Intons-Peterson & Roskos-Ewoldsen, 1989). These findings suggest that there is no reason to believe a visual representation is necessary for mental imagery (7).
2. Our claim that there are fundamental links between embodied activity and mental imagery rests on the idea that perception itself is fundamentally based on kinesthetic action. As Gibson (1979) famously argued, movement is essential to perception. When people merely touch an object, they understand little of what is perceived unless they move their hands and explore its contours and texture. Although our hands contain sensory transducers, the musculature with which we control movement allows us to explore objects in ways that make it easy to identify what is being felt. When we lift an object, this reveals something about its weight, rubbing our fingers across it tells us about its texture, and its overall shape, and squeezing it says something about its compressibility (2).
3. For instance, Ahsen (2000) argues that traditional empirical work on the vividness of mental imagery has dramatically downplayed, or even ignored, how

imagery works in dynamic operations. Although it is widely believed that vivid mental images are quite useful in learning and memory, there are significant demonstrations that vividness may interfere with people's concrete and abstract problem-solving abilities (Ahsen, 1985, 1990, 2000). Thus, traditional scaling methods used to assess the vividness of mental imagery often fail to tell us much about those functions arising from the interplay between vividness and unvividness... (22).

4. Our exploration of the embodied nature of mental imagery fits in nicely with recent work on the role of imagery in learning, particularly as it concerns dynamical aspects of imagery in enhancing personal learning and growth. For instance, Ahsen (2000) argues that traditional empirical work on the vividness of mental imagery has dramatically downplayed, or even ignored, how imagery works in dynamic operations. Although it is widely believed that vivid mental images are quite useful in learning and memory, there are significant demonstrations that vividness may interfere with people's concrete and abstract problem-solving abilities (Ahsen, 1985, 1990, 2000). Thus, traditional scaling methods used to assess the vividness of mental imagery often fail to tell us much about those functions arising from the interplay between vividness and unvividness (22).
5. However, mental imagery is intimately tied to the ongoing activity of perceptual/motor exploration of the environment. People have the phenomenological experience of having a mental image whenever a schema that is not directly relevant to the exploration of the present environment momentarily takes control of the body's exploratory apparatus. Perceptual activity theory explains various traditional mental imagery findings (Thomas, 1999). Mental scanning parallels real-world visual scanning in that it takes longer to scan through a large visual angle than a smaller one (9).

5. Takahashi, J., Saito, G., Omura, K., Yasunaga, D., Sugimura, S., Sakamoto, S., ... Gyoba, J. (2022, May 25). Diversity of aphantasia revealed by multiple assessments of the capability for multi-sensory imagery.

1. There is a large discrepancy between the criteria for VVIQ and self-identification of the absence of visual imagery. Although the criteria for identifying aphantasia have not yet been determined, many studies have used the VVIQ criteria to identify aphantasia and have conducted perceptual and cognitive experiments to reveal the characteristics of people with aphantasia, focusing on tasks associated with visual imagery (4).
2. Our data showed a ratio of 3.67% under the VVIQ criteria (VVIQ ≤ 32) and 12.24% under the self-identification criterion. We found a large discrepancy between these proportions, in which participants reported self-identification of the absence of visual imagery even with higher VVIQ scores (33 ≤ VVIQ) (21).
3. Due to the discrepancy between the proportions of aphantasia calculated by the two methods, and due to the existence of a case that showed the absence of multi-sensory imagery, the VVIQ is not sufficient to identify people with

aphantasia. If visual aphantasia is identified only by the VVIQ, we may overlook people who show a high VVIQ score with awareness of an absence of visual imagery or who show a low VVIQ score with unawareness of the absence of visual imagery. Furthermore, we may overlook multi-sensory aphantasia. Thus, we propose that evaluations made with self-identification of the absence of visual imagery and with multi-sensory imagery may help further characterize multiple types of aphantasia (6-7).

4. We used the QMI in addition to the visual imagery criteria for VVIQ and self-identification, and we were able to observe not only visual aphantasia but also multi-sensory aphantasia. If we had adopted only the VVIQ, we would not have been able to distinguish multi-sensory aphantasia from visual aphantasia. This indicates that visual aphantasia, defined by the VVIQ, includes both visual and multi-sensory aphantasia… Each subtype of aphantasia or multi-sensory aphantasia needs to be classified using the criteria for multi-sensory imagery (22).
5. We can observe multiple types of visual aphantasia by using self-identification of the absence of visual imagery in addition to the VVIQ. Moreover, we can classify multi-sensory aphantasia and visual aphantasia by using multi-sensory imagery (QMI). Considering the diversity of imagery in people with aphantasia, we should use multiple tools to identify aphantasia. These would lead to a consideration of subtypes of aphantasia in terms of multi-sensory imagery (24).

6. Jacobs, C., Schwarzkopf, D. S., & Silvanto, J. (2018). Visual working memory performance in aphantasia. *Cortex*, 105, 61–73.

1. In order to investigate the functional role of mental imagery in visual working memory, we compared performance of a congenitally aphantasic individual to that of a group of age-matched controls on a number of different (visual) working memory aspects. The first surprising result was that her performance in the mental imagery task did not differ from controls. However, her metacognitive performance on this task was lower than that of controls; specifically, she overestimated her own performance on inaccurate trials. Thus, although she was able to perform a task that was designed to require mental imagery, she lacked insight into her performance (9).
2. Visual working memory and mental imagery are two processes that both depend on the representation and manipulation of visual mental content not driven by current visual input. Even though they share this important feature, within the field of cognitive psychology the two processes have been mostly researched independently (e.g., Tong, 2013), although some investigations on the link between visual working memory and visual imagery have been published (2).
3. A more speculative explanation is that aphantasic individuals in fact use mental imagery to perform mental imagery tasks, but without conscious awareness of the resultant mental representation. A distinction has been made between the underlying structure of the representation and its conscious experience. In some views, the term "imagery" does not refer to subjective experience, but, rather, to a

hypothetical picture-like representation (or inner representation of any sort) in the mind and brain that can give rise to quasiperceptual conscious experience (Block, 1983). Possibly, aphantasic individuals are capable of the former but not the latter (11).
4. Altogether, we conclude that even though overall task performance on neither one of the tasks is any different for AI than for control participants, her metacognitive accuracy is lower when a task involves mental imagery, but not when it simply requires visual working memory. Surprisingly, however, AI's visual working memory seems to be less precise than controls', as reflected by her performance drop in the most difficult condition; a property which does not transfer to the mental imagery version of the task (9).
5. So far, we have considered what role mental imagery potentially plays in working memory, but in fact the association could be reversed. Then the mental imagery difficulties that AI experiences would originate from a visual working memory deficit... However, if impaired executive processing would underlie aphantasia, then instead of only affecting high-precision visual working memory, AIs scores on other (working memory) tasks would have been hampered as well. But both her score on the working memory subscale of the WAIS-IV (WMI) and her working memory capacity proved similar or better than controls' (11).

7. **McNorgan, C.(2012). A meta-analytic review of multisensory imagery identifies the neural correlates of modality-specific and modality-general imagery. *Frontiers in human neuroscience*, *6*, 285.**
    1. Activations were seen bilaterally in the general imagery analysis, and in some modalities (auditory, motor, gustatory, visual form and visual motion), but were primarily left-lateralized. It was noted earlier that perceptually-based representational theoriesassume that multisensory imagery underlies semantic retrieval (10).
    2. One challenge for this interpretation concerns the failure to show recruitment of primary sensorimotor perceptual cortices for the auditory and motor modalities. The ALE analyses showed imagery in these modalities does reliably recruit posterior superior temporal gyrus (STG) and premotor cortex, respectively. These results are consistent with Kosslyn et al. (2001) review finding that auditory imagery does not activate primary auditory cortex (A1), but does activate auditory associative areas (10).
    3. Perception describes our immediate environment. Imagery, in contrast, affords us a description of past, future and hypothetical environments. Imagery and perception are thus two sides of the same coin: Perception relates to mental states induced by the transduction of energy external to the organism into neural representations, and imagery relates to internally-generated mental states driven by representations encoded in memory. Various forms of mental imagery have been implicated in a wide array of cognitive processes, from language comprehension (Bottini et al., 1994), to socially-motivated behaviors such as perspective taking (Ruby and Decety, 2001), to motor learning (Yágüez et al., 1998). (1)

4. Similarly, an asymmetrical relationship existed among the three visual modality subtypes: First, form imagery clusters additionally overlapped the color ROI, but not vice versa. Second, motion imagery clusters additionally overlapped the form ROI, but not vice versa. This second asymmetry plausibly reflects our visual experience of moving objects: Form processing may be commonly implicated in motion processing because one typically perceives motion of an object with form (11).
5. Finally, and perhaps most importantly for investigations of perceptually-grounded representations, in no modality were imagery clusters restricted to brain regions immediately involved in perception. Those clusters that did overlap with primary somatosensory regions generally extended beyond these areas. In contrast to perception or imagery-based accounts of knowledge representations, amodal models of semantic memory assume concept knowledge is maintained as an abstraction bearing no connection to perceptual processing (Pylyshyn, 1973; Tyler and Moss, 2001). It is no less reasonable to suppose that a modality-specific representational system encodes information in sensory association areas, but not necessarily in primary sensorimotor areas (11).

8. 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*, 103087.

1. Since visual imagery has been linked to a number of aspects important in everyday life (e.g., autobiographical memory recall; short term memory recall; task-oriented motivation; Keogh & Pearson, 2014; Schacter & Addis, 2007; Vasquez & Buehler, 2007), it may seem surprising that many aphantasics live their lives without knowing they are different (Watkins, 2018; Zeman, Dewar, & Della Sala, 2016). However, some aphantasics describe problems with autobiographical memory and face recognition (Zeman et al., 2020), and the condition may have implications for visual processing strategies and even career choices (e.g., aphantasics are less likely to enter the arts, and more likely to work in science and maths; Zeman et al., 2020). (p. 2).
2. We note here that if synaesthesia were not causally linked to heightened imagery, we would anticipate finding cases of grapheme-colour synaesthesia in aphantasic individuals (and vice versa). Alternatively, if high imagery is necessary for synaesthetes, we would expect synaesthesia in aphantasic individuals to be absent. A related hypothesis is that aphantasia might influence the type of synaesthesia experienced. This hypothesis is built on the distinction between 'projector synaesthetes' and 'associator synaesthetes' (Dixon, Smilek, and Merikle, 2004). For projectors, synaesthetic colours feel like part of the outside world (e.g., projected onto the written typeface in grapheme-colour synaesthesia). For associator synaesthetes, colours are less 'veridical', often feeling internal to the body (e.g., appearing in the 'mind's eye') or are simply "known" in some intrinsic way (Ward, Li, Salih, & Sagiv, 2006). (p. 3).
3. Our results also show that even individuals who report the most extreme experience of aphantasia (i.e., no visual imagery whatsoever) can still have

synaesthesia, indicating that high imagery (or indeed any imagery) is not a pre-requisite. Nonetheless, we found that low imagery influences the type of synaesthesia experienced: aphantasic individuals reported a synaesthesia that was more associator-like (i.e., more negative scores on the PA questionnaire) compared to non-aphantasics. (p. 8).

9. 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.

1. The experience of voluntary imagery is associated with activity in fronto-parietal 'executive' systems and in posterior brain regions which together enable us to generate images on the basis of our stored knowledge of appearances (Bartolomeo, 2008). The relative contributions of lower and higher order visual regions to the experience of visual imagery are debated (Bartolomeo, 2008). Clinical reports suggest the existence of two major types of neurogenic visual imagery impairment: i) visual memory disorders, causing both visual agnosia and imagery loss, and ii) 'imagery generation' deficits selectively disabling imagery (Farah, 1984). (p. 2).
2. Despite their substantial (9/21) or complete (12/21) deficit in voluntary visual imagery, as judged by the VVIQ, the majority of participants described involuntary imagery. This could occur during wakefulness, usually in the form of 'flashes' (10/21) and/or during dreams (17/21). Within a group of participants who reported no imagery while completing the VVIQ, 10/11 reported involuntary imagery during wakefulness and/or dreams, confirming a significant dissociation between voluntary and involuntary imagery ($p<.01$, McNemar Test). (p. 3).
3. We suspect, however, that aphantasia will prove to be a variant of neuropsychological functioning akin to synaesthesia (Barnett & Newell, 2008) and to congenital prosopagnosia (Gruter, Gruter, Bell, & Carbon, 2009). Indeed, aphantasia may have some specific relationship to these disorders, as congenital prosopagnosia is associated with unusually low (Gruter et al., 2009), and synaesthesia with unusually high (Barnett & Newell, 2008), VVIQ scores. (p. 4)

10. Schendan, H. E., & Ganis, G. (2012). Electrophysiological potentials reveal cortical mechanisms for mental imagery, mental simulation, and grounded (embodied) cognition. *Frontiers in psychology*, *3*, 329.

1. Notably, the mechanisms proposed in these theories of mental imagery resemble those in grounded (embodied) cognition theory, which proposes that cognition is grounded in modal processing of sensorimotor information and introspective states (e.g., emotion, motivation, intention; Pulvermuller, 1999; Barsalou, 2008). Like imagistic theories of mental imagery, grounded cognition theory challenges the dominant symbol systems paradigm inspired by formal theories of logic, language, and computation that proposes that amodal symbol representations, which are independent from the sensorimotor processes, support language, thinking, attention, memory, and meaning (Fodor, 1983; Johnson-Laird, 1983; Pylyshyn, 2003). (p. 1).
2. The findings reveal the cortical dynamics of ongoing top-down processes of mental imagery of visual shape during later knowledge, meaning, and decision

processing of a perceived picture. Further, the pattern differs between categories: Faces show adaptation; objects show rapid priming effects in the opposite direction. Altogether, these findings indicate that top-down processes of mental imagery can induce a powerful imagistic mental representation of visual shape that mimics top-down processes recruited also for picture perception and facilitates knowledge, meaning, and categorization processes. (p. 14).

3. The time precision of ERPs offers advantages over fMRI and behavior for characterizing such similarities and differences between perception and imagery. Specifically, perception results dissociate between categories, consistent with the domain-specificity of object and face processing (Downing et al., 2006): Perceptual repetition adapts processing of perceived faces from categorical perception onward, as predicted, but instead unexpectedly primes processing of objects during categorical perception, visual knowledge processing, and strategic semantic analysis. Critically, identification time for the first picture is similar for objects and faces and so cannot explain differences in congruity effects. (p. 17).

11. 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.

1. The data supports Zeman et al. (2015) findings that aphantasic participants rate their imagery as very poor or non-existent on the VVIQ. These data also show that participants also rate their spontaneous use of visual imagery as very low on both the SUIS and Object component of the OSIQ. Interestingly, the aphantasic participants' spatial component of the OSIQ was almost double that of their object score. To further assess this finding 15 non-age matched participants also completed the OSIQ. There was a significant interaction between the spatial and object components of the OSIQ and the participant group (aphantasic/control), Mixed repeated measures ANOVA: F(1, 28) 1⁄4 45.25, p < .001 (see Fig. 2D). (p. 56-57).
2. An interesting finding from our results is that while the aphantasic participants were impaired on all measures of visual object imagery (lower VVIQ, SUIS, Object OSIQ and imagery priming scores), they were not impaired on their spontaneous use of spatial imagery, in fact on average they rated their spontaneous use of spatial imagery higher than a control group (although this effect was not significant). This measure of spatial imagery has been shown to correlate with performance on mental rotation tasks (Blajenkova et al., 2006). Interestingly, a case study by Zeman et al. (2010) found that their patient who developed aphantasia after surgery was still able to perform perfectly on a mental rotation task. (p. 58).

12. Sheehan P. W. (1967). A shortened form of Betts' questionnaire upon mental imagery. *Journal of clinical psychology*, *23*(3), 386–389.

1. The findings of Betts' original study were confirmed. Few Ss lacked the ability to evoke images when required and there were considerable individual differences in the degree of clearness and vividness of Ss' images. Table 1 reports the means and standard deviations for each

modality. Females typically reported more vivid imagery than males for items of a given modality, but these differences were not as large as some inter-modality differences. The data provided no support for the notion of imagery types (visual, auditory, et,c.). 8s' imagery was not exclusive to particular modalities. (p. 387).

2. Results established that the shortened form measures a general ability to image in a variety of sensory niodalities. Analysis of the scale indicated that when 43 components were extracted, one single component accounted for as much as 39% of the total variance of scores on the test. All 35 items in the scale loaded highly on the factor, with an average loading of .57. The validity of the new scale was indicated by the high correlation bctwecri scores on the short form and original form for an independent sample of Ss. Thc correlation of the two total scores was spuriously high because the saiiie items were included in both tests, but the relationship demonstrates that, for all practical purposes, thc short test can prcdict S's ability to image as well as the original qucstionnairc.

SECONDARY SOURCES

1. **Iachini, T. (2011). Mental imagery and embodied cognition: A multimodal approach. *Journal of Mental Imagery, 35*(3-4), 1–66.**

    1. It was argued that data about the neural bases of mental imagery would overcome the indeterminacy problem and resolve the imagery debate (Kosslyn, 1994). Indeed, neural data, unlike behavioral data, are not ambiguous because they locate the basis of imagery in the same areas underlying visual perception. The neural theory distinguishes between low level visual perception (a bottom-up process that is driven by on-line external stimulation) and high level visual perception (a top-down process that is driven by information stored in long-term memory). Mental imagery belongs to the latter category. Stored perceptual information can be used both to assist in recognition of stimuli being perceived (e.g., when stimuli are degraded) and to generate mental images in the absence of external stimulation (9).
    2. Cognition is grounded in the body in two ways: it emerges from the brain; and, it emerges from the dynamic body/environment interaction. A transversal argument in embodied cognition theories is that cognition is grounded in thebrain. This assumes that cognition emerges from neural activation and is constrained by the cerebral anatomy and physiology; it implies that cognitive models should be constrained by neural data, according to the principle of neural plausibility. However, it is important to regard the relationship as reciprocal. Not only does neural data put constraints on cognitive models, but cognitive methods are fundamental for the advancement of neuroscience (Barsalou 2010) (11-12).

3. Much of the early history of the imagery literature focused on the format of mental images; specifically, whether it is analog/depictive or propositional/descriptive (see Farah, Hammond, Levine & Calvanio, 1988; Pinker, 1984). Known as the analog/propositional debate (Kosslyn 1980, 1981, 1983, 1994; Pylyshyn 1973, 1981, 1984), the propositional position (e.g., Pylyshyn) holds that mental images have a sentence-like (i.e., descriptive) format while the analog position (e.g., Kosslyn) claims that mental images are a kind of picture-like (i.e., depictive) representation. The central point of the debate is not about demonstrating the existence of mental images, of which we are introspectively aware and that correspond to conscious percept-like representations (2).
4. The characterization of mental images as multimodal representations implies that purely depictive or pictorialist models are no longer tenable. Mental images are not only pictures in the mind; they can represent a larger spectrum of experiences from static pictures to moving objects to moving or resting bodies and selves. Depictive models not only are limited to visual images, but often they do not consider the situated character of represented objects or scenes. If cognition is based on the re-enactment of sensorimotor experiences, the question arises as to whether mental simulations incorporate the spatial structure of perceived events. Whatever we perceive and whatever we act upon occurs in space. Increasing evidence suggests that the situated character of experience in the environment is reflected in the situated character of the representations that underlie simulation (Barsalou, 2009). (19-20).
5. More precisely, mental images are voluntarily generated and maintained in a system of short-term memory called the visual buffer, which is conceived of as a spatial array similar to a surface matrix composed of pixels. Images are depicted in this medium by filling in pixels on the basis of information stored in long-term memory. In long-term memory two kinds of symbols — analog (literal) and propositional (abstract) — give rise to conscious mental images in short-term memory. Analog symbols capture literal information in the visual appearance of images, including their schematic shape and details about their parts, while propositional symbols contain abstract information that describes the images and specifies their size and superordinate category (6).

2. Palmiero, M., Piccardi, L., Giancola, M., Nori, R., D'Amico, S., & Olivetti Belardinelli, M. (2019). The format of mental imagery: from a critical review to an integrated embodied representation approach. *Cognitive Processing*.

1. Since mental images generally rely on representations of things that are not actually present to senses, their activation vary widely according to two characteristics: the individual ability to evoke subjective perceptual and motor experiences manifested in terms of diferences in the vividness of images, and the strategy preferentially used in the individual processing of the related sensory information. This does not mean that imagery ability and imagery strategy are involved into organizing principles and mechanisms of imagery, but that they are

fundamental characteristics of imagery that can be also added on the top of the integrated embodied representation approach (6).

2. In general, it rejects the idea that cognition works by processing abstract symbols. It focuses on the role of the body, action, environment and sensorimotor experience. The basic assumption is that perception is direct and serves to guide actions in cooperation with the environment, ofering afordances of interactions in relation to the sensorimotor capacities of the organism, either for good or ill (Garbadini and Adenzato 2004; Gibson 1966, 1979). For example, a set of stairs represents an afordance that they be used for going up or down to a human adult, but not for a crawling infant that is not yet able to walk. Thus, cognition is grounded in the body because it emerges from both the brain and the dynamic interaction between the body and its environment (2).
3. The attunement to sensorimotor laws is a state that changes continuously to determine the contingency between sensory inputs and movement outputs. In this way, mental imagery relies on a state of familiarity and harmony with sensorimotor laws, without rehearsing the exploration mechanisms of the environment. What is being activated during imagery is ultimately the knowledge of the potential applicability of the law that describes the event corresponding to the content of imagery (Foglia and O'Regan 2016). In general, this approach entails two basic factors: (1) the possession and exercise of sensorimotor know-how; and (2) no reenactment of perceptual experience is required, but rather the expectation as to how the sensory input changes as a function of movements (4).
4. From the literature reviewed, it appears that mental imagery is supported by mental representations. The extent to which perceptual and motor components are part of the format of mental imagery depends on both imagery ability (e.g., vividness) and imagery strategy (e.g., object vs. spatial style). In this view, semantic components should also be considered, because mental images are penetrable by conceptual processing. Specifcally, (1) a high ability of sensory mental imagery preserves mostly perceptual components, whereas a high ability of motor mental imagery preserves mostly motor components… (2) The imagery strategy relies on diferent types of components (e.g., object imagery mainly relies on pictorial and semantic components, whereas spatial imagery relies on amodal and motor components) (8).
5. Since mental images generally rely on representations of things that are not actually present to senses, their activation vary widely according to two characteristics: the individual ability to evoke subjective perceptual and motor experiences manifested in terms of diferences in the vividness of images, and the strategy preferentially used in the individual processing of the related sensory information. This does not mean that imagery ability and imagery strategy are involved into organizing principles and mechanisms of imagery, but that they are fundamental characteristics of imagery that can be also added on the top of the integrated embodied representation approach (6).

3. Adams, F. (2010). Embodied cognition. *Phenomenology and the Cognitive Sciences*, *9*(4), 619-628.

1. Influenced by Barsalou (1999) and Gibson (1979) and being among those who are helping to develop the view that cognition is embodied, Glenberg and colleagues (for example, Glenberg and Kaschak 2002) accept the view meaning is embodied and "consists in a set of affordances…a set of actions available to the animal."(558) On this view, words and phrases are indexed or mapped to perceptual symbols— calling this the Indexical Hypothesis (IH) about meaning. And they see perceptual symbols as modal and non-arbitrary. That is, the affordances are derived from perceptual symbols and the meanings of these symbols are grounded in the sensorimotor system (620).
2. In a second experiment (Borghi et al. 2004), subjects took the perspectives inside (driving the car) or outside (filling the tank). Then subjects were asked to identify car parts that would be near or far from those perspectives. From inside the license plate would be far. From outside the steering wheel would be far, and license plate near. From the inside perspective, subjects were faster (50 ms) to identify near inside car parts than far inside car parts. From the outside perspective, subjects were faster (100 ms) to identify near outside car parts than far outside car parts (622).
3. First, perceptual/motor experiences have a phenomenal content, a *what it's like* …that belief that p does not have. One may believe something more or less strongly, of course, but that is quite different than the taste of sugar or smell of a rose or feel of moving one's feet in the sand. There is no phenomenology of the sort associated with perceptual-motor activity in cognition. This should not be overlooked. Second, perceptual states generally admit of more or less intensity… knowledge that p (which involves belief) does not…believing can be more or less intense, but not the that p. And third, perceptual states have a particularity (this blue, that bitter). Beliefs have a generality (blueness, bitterness) that perceptual/motor states lack (627).
4. In the embodiment literature, we find the empirical step consisting of empirical correlations between certain kinds of cognitive processing and sentence comprehension and certain kinds of perceptual/motor performance. Then we find that the logical step is an argument to the conclusion that the best explanation of the empirical correlations is that cognitive processing of this type just is processing that includes perceptual/motor processing. It is simpler if cognition exploits representations already in the perceptual-motor system. And it helps to solve the symbol-grounding problem (or so it is claimed) if understanding is grounded in knowledge of sensori-motor contingencies recorded in the perceptual-motor system (620).
5. I report this contra-indicating data cited by Camarazza and Mahon (2006) to record the negative results found on the other side of the EC issue. These data seem to indicate that there are at most causal correlations between perceptual-motor activity and cognition, but that such activity is not constitutive

of cognition and that such activity may not even be necessary for normal levels of cognitive competence.

4. Gallagher, S. (2011). Interpretations of embodied cognition.

1. In contrast to G&D, who rule out anatomy and bodily movement as important, non-trivial factors for cognition, other theorists suggest that anatomy and movement are important contributors to the shaping of cognition prior to brain processing (pre-processing) and subsequent to brain processing (post-processing) of information in the cognitive system (e.g., Chiel and Beer 1997; Shapiro 2004; Straus 1966; see Gallagher 2005a). Embodiment in this case means that extra-neural structural features of the body shape our cognitive experience (5).
2. Many of these insights are still cast in terms of information processing, and as such may be consistent with the general principles of classical cognitivism. As Shapiro notes: "steps in a cognitive process that a traditionalist would attribute to symbol manipulation might, from the perspective of EC, emerge from the physical attributes of the body" (2007, p. 340). In addition, even if the body is doing some of the work, cognitivists could easily claim that pre‐processing is in fact feeding the more central processing that is certainly more constitutive of cognition, just as post‐processing is to some degree determined by instructions from the brain as central processor (5).
3. In this regard, the physical body functions as a non-neural vehicle for cognitive processes, in much the same general way that the physical processes of neurons do. The body is part of an extended cognitive system that starts with the brain and includes body and environment. As he puts it, "the larger systemic wholes, incorporating brains, bodies, the motion of sense organs, and (under some conditions) the information‐bearing states of non‐biological props and aids, may sometimes constitute the mechanistic supervenience base for mental states and processes"(2008b, 38) (7).
4. Similar to Clark and the idea of extended cognition, enactive approaches argue that cognition is not entirely "in the head," but distributed across brain, body, and environment. In contrast to Clarke's functionalist view, however, enactive theorists claim that the (human) bodily processes shape and contribute to the constitution of consciousness and cognition in an irreducible and irreplaceable way. Specifically, on the enactive view, biological aspects of bodily life, including organismic and emotion regulation of the entire body, have a permeating effect on cognition, as do processes of sensori-motor coupling between organism and environment (9).
5. Thompson and Varela (2001) agree on Clark's (1999) three‐point summary of the enactive view: (1) understanding the complex interplay of brain, body and world requires the tools and methods of nonlinear dynamical systems theory; (2) traditional notions of representation and computation are inadequate; (3) traditional decompositions of the cognitive system into inner functional subsystems or modules ('boxology') are misleading, and blind us to arguably

better decompositions into dynamical systems that cut across the brain–body–world divisions (9).

5. **Anderson, M. L. (2003). Embodied cognition: A field guide. *Artificial intelligence*, *149*(1), 91-130.**

    1. Simply put, cognitivism is the hypothesis that the central functions of mind—of thinking—can be accounted for in terms of the manipulation of symbols according to explicit rules. Cognitivism has, in turn, three elements of note: representation, formalism, and rule-based transformation. First and foremost is the idea that cognition centrally involves *representation*; cognitivism is committed to the existence of "distinct, identifiable, inner states or processes"—that is, the symbols—"whose systemic or functional role is to stand in for specific features or states of affairs" [20, p. 43]. However, just as is the case in modern logic, it is the *form* of the symbol (or the proposition of which the symbol is a part) and not its meaning that is the basis of its rule-based transformation (93).
    2. As an illustration of how a given example of higher-order cognition can be traced back to its bodily bases, consider the metaphorical mapping "Purposes are Destinations", and the sort of reasoning about purposes which this mapping is said to encourage. We imagine a goal as being at some place ahead of us, and employ strategies for attaining it analogous to those we might use on a journey to a place. We plan a route, imagine obstacles, and set landmarks to track our progress. In this way, our thinking about purposes (and about time, and states, and change, and many other things besides) is rooted in our thinking about space. It should come as no surprise to anyone that our concepts of space—up, down, forward, back, on, in—are deeply tied to our bodily orientation to, and our physical movement in, the world (105).
    3. Along with research in situated cognition, EC further suggests that intelligence lies less in the individual brain, and more in the dynamic interaction of brains with the wider world—including especially the social and cultural worlds which are so central to human cognition—and therefore suggests that fields like sociology and cultural studies can themselves be important resources for (and in some guises are part of) the cognitive sciences (126).
    4. As we have already seen, another important dimension of embodiment, and an important part of the physical grounding project, is the evolutionary history of the agent Although, of course, the evolutionary history of an agent is physiologically stored, it expresses its effects in a somewhat less direct manner. First the sentiment, as expressed by Lakoff and Johnson: Reason is evolutionary, in that abstract reason builds on and makes use of forms of perceptual and motor inference present in "lower" animals. The result is a Darwinism of reason, a rational Darwinism: Reason, even in its most abstract form, makes us use of, rather than transcends, our animal nature. The discovery that reason is evolutionary utterly changes our relation to other animals and changes our conception of human beings as uniquely rational. Reason is thus not an essence

that separates us from other animals; rather, it places us on a continuum with them (p. 4). (106).

5. Likewise, Merleau-Ponty argues that perception and representation always occur in the context of, and are therefore structured by, the embodied agent in the course of its ongoing purposeful engagement with the world. Representations are therefore 'sublimations' of bodily experience, possessed of content already, and not given content or form by an autonomous mind; and the employment of such representations "is controlled by the acting body itself, by an 'I can' and not an 'I think that' " ([59, pp. 108–109], see also [33]). (104).

6. Tibbetts P. E. (2014). Where does cognition occur: in one's head or in one's embodied/extended environment?. *The Quarterly review of biology*, *89*(4), 359–368.

1. For C/CM, the focus is on the neurally encoded representations associated with cellular, network, systems, and behavioral levels of analysis and, by implication, the neurocircuitry associated with these representations (Binder et al. 2009; Kandel et al. 2013; Squire et al. 2013; Mayor and Gomez 2014). An example of cellular-level computations is the temporal and spatial summation of excitatory and inhibitory postsynaptic potentials, where "each segment of the neuronal membrane can perform selective integrative functions . . . and . . . logical operations" (Byrne 2013:229). An example of network-level computations is the role of spinal cord excitatory and inhibitory interneurons synapsing on motor neurons "forming the rhythm generating circuitry of the CPG [central pattern generator neurons]" associated with locomotion (Mentis 2013:624). (p. 360).
2. For E/EM, the online (i.e., current, sensory-based) cortical processing associated with cognitive representations is physically embodied, and socially and contextually embedded (Chemero 2009; Noe 2009; Smith and Conrey 2009; Clark 2011; Shapiro 2011). The common denominator here is the concept of "cognitive extension" or the extended-mind thesis according to which cognitive systems reach "beyond individuals into their physical and social environments. . . . [Accordingly,] an individualistic psychology, at best, can only tell part of the story about cognitive processing: the inside story" (Wilson and Clark 2009:58; Clark and Chalmers 1998). Non-neural resources in the physical, technological, and social/cultural environments "are incorporated into extended cognitive behaviors, dispositions, and activities . . . and [in some instances] become functionally integrated into a larger cognitive system" (Wilson andClark 2009:62–63).
3. Perhaps the problem here is that both sides to this "Where Does Cognition Occur?" debate are taking this box metaphor too literally. Additionally, not including the intricate and exquisite assembly of components and assemblies in modeling cognition is to ignore the evolutionary contexts and opportunities in which nervous systems and cognition evolved. Accordingly, evolutionary and comparative neurobiology are valuable for C/CM as well as for E/EM because "the study of diverse nonhuman brains can lead to the discovery of design rules

for brains” (Striedter 2009:6) and, with any luck, the design rules underlying cognition in animals and humans as well. (p. 366).

7. Rucińska, Z., & Gallagher, S. (2021). Making imagination even more embodied: imagination, constraint and epistemic relevance. *Synthese*.

1. She argues that imagination, "thought of as a recreative capacity that stands in a close relationship to our perceptual capacities, provides us with information about experiential possibilities" (ibid., p. 210). She proposes that there is a "tight relationship between imaginings and perceptual experiences" (p. 220), as perceptual experiences provide us with "evidence about which objects there are in our immediate external environment ... [as well as with] evidence about how things look to us, whether or not things in our external environment actually are the way they look" (ibid). Since perception is taken to be a paradigmatic source of justifcation for our everyday beliefs, Balcerak Jackson writes that imagination provides justifcation "in virtue of being a recreativist or simulationist cognitive capacity" (p. 216) and "in virtue of being by their very nature derived from or parasitic on perceptual experience" (p. 221). (p. 8149).
2. Rooted embodiment contributes to the justifcatory power of imagination, as it can make imagination more accurate and reliable, even though it does not guarantee truth. In case of belief, it is not ’body as content’ but the actual body-schematic motor capabilities that guide beliefs and imaginings. Drawing on actual motoric habits and skills justifies the idea that imagining can be close to real experiences, without having to involve a strong will to imagine correctly. In the case of perception, on our view, perceptual simulations of possibilities for action represented ’as possible’ are not needed, as perception re-activates learned patterns of action. There is also the added value for strongly embodied imagination connected with processes of explicit embodiment. We have shown that imaginings may be closely coupled to the dynamic constraints involved in interacting in the world just so far as bodily movement and action are constrained by how we relate to our environment and engage with others. (p. 8166).

8. Ziemke, T. (2016). The body of knowledge: On the role of the living body in grounding embodied cognition. *Bio Systems, 148*, 4-11.

1. To sum up this section, before we move to the next, there are a number of overlapping theoretical frameworks that take cognition to be a genuinely biological phenomenon occurring in living organisms, and therefore emphasize the fundamental role played by the living body in general, and mechanisms of homeostatic/allostatic self-regulation in particular, in natural embodied cognition in living organisms. This clearly goes beyond the somewhat mechanistic view of the physical body as the computational mind’s sensorimotor interface to the world, which pervades much of mainstream (embodied) cognitive science and in particular embodied AI. While the controversial issue of ‘representation’ naturally is too complex to discuss in detail – let alone resolve – in this paper, the above discussion hopefully illustrates at least to some degree the potential role and nature of non-traditional ‘representations’1 – in the sense

of predictive models – in biologically-based, non-functionalist conceptions of embodied cognition. (p. 9).

2. As discussed in Section 2, most work in embodied cognitive science falls into the category Chemero (2009) refers to as mainstream embodied cognitive science, which still is more or less compatible with traditional computationalist and representationalist conceptions of cognition, which to some degree reduce the body to the computational mind's physical/sensorimotor interface to the world that it represents internally. Radical embodied cognitive science rejects these traditional notions, but at least in Chemero's formulation of the main claims/tenets of radical embodied cognition, it also does not emphasize the biological nature of embodied cognition as such, but focuses on explaining perception and action in dynamical-systems terms rather than representational terms. (p. 9).