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Letter

Emotion may indirectly link rendering and social reasoning

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In their letter [1], Zeman *et al*. raise the intriguing suggestion that visual imagery (which we argued should be understood as graphical rendering [2]) has a central role in social cognition. Specifically, they point to an association between aphantasia and deficits in autobiographical memory [3,4] and lower empathy to verbal descriptions of distressing events [5]. To be clear upfront, we agree with Zeman *et al*.'s bottom line that visual imagery might have social implications, and that this idea deserves thought and exploration. We would like to give it some thought and exploration here.

Before discussing the social domain specifically, we emphasize that we do not think that graphical rendering is entirely an ineffectual veneer. We accept that rendering has measurable effects (e.g., [5–8]), and explanations of aphantasia as 'lack of higher-order access to intact visual imagery' must contend with such empirical findings. We take as common ground that physics-centered mental simulation can achieve most of what was originally attributed to imagery tasks [2], and that graphical rendering is linked to autobiographical memory [1]; the question for now is whether graphical rendering is significantly useful for our daily lives and, specifically, our social lives. We note that Zeman *et al*.'s novel suggestion is far from where the imagery debate started and offers a radical rethinking of the main role of visual imagery.

Zeman *et al*. ask us to consider evolutionary history, and they contend that the trajectory that led to machine-based simulation is different from the one that produced the human brain. While we accept the obvious differences between the two, we note that both systems might have arrived at some similar solutions, because they may both be working with similar constraints to produce similar results [9]. We also turn the evolutionary argument around and ask: to the degree that graphical rendering is not a spandrel, it seems unlikely that its main functions have only been seized on so recently in evolutionary history and for autobiographical memory. Nonhuman animals either (i) do not have graphical rendering; or (ii) have graphical rendering, but it is largely a spandrel; or (iii) have graphical rendering, and it has a functional role, which is autobiographical memory; or (iv) have graphical rendering, with a functional role that is not autobiographical memory. We think that (i) is weak on evolutionary-continuity grounds, (ii) is reasonable, (iii) is shaky, and (iv) is most likely prima facie, but suggests that the role of human rendering is mostly nonautobiographical, whatever the role is.

Continuing the theme of evolutionary history, it is striking that people with aphantasia have presumably been around for a long time, but it was only a decade ago that the phenomenon started to be studied in earnest, owing largely to the work of Zeman and colleagues [10]. If visual rendering is so crucial (for social lives or something else), we would likely have noticed its absence much sooner. We did not need to wait until 2015 to notice that some people are born without the ability to see. So, even if (iii) or (iv) are right, either the link is not strong, or the role is noncrucial and nonautobiographical, or autobiographical memory is not that crucial.

While we disagree with the parceling of physics-and-objects versus graphics-and-agents, we accept the existence of a link between visual rendering, autobiographical memory, and social cognition. We also agree with the need to study this further. Part of this further study should examine the specific mechanistic link between these domains. While a direct link is possible, it seems unlikely: not every person with aphantasia has autobiographical memory deficits; some memory deficits in aphantasia are not episodic [11]; and, contrary to some expectations, even episodic task differences are not necessarily about level of detail [12]. An alternative, indirect link may be through emotional activation, which is not directly about social factors. Consider the finding that people with aphantasia have lower empathy for verbal descriptions of events, but not for visual presentations [5]. This can make it seem like rendering serves a social function. But a similar pattern was reported for physiological fear responses to distressing stimuli (say, seeing a scary wolf vs. reading about it [6]). It seems reasonable that there are evolutionarily conserved modules in the mind that cannot take the word or concept 'scary wolf' as input, but rather speak the language of pixels, and that seeing an image of a scary wolf (whether real or rendered) causes those modules to respond. Such a pathway between pixel-based input and emotional output is then reasonable as the basis of one evolutionarily shared functional role for rendered images and possibly a later building block in autobiographical memory.

So, the emotional response of imagining a scary wolf may be subserved by rendering, with the rendering-emotion pathway shared evolutionarily between us and the wolf. This pathway may, in turn, be important in the story people tell themselves about the time they met a wolf, and such stories are more the occupation of people than wolves. But even if the scientific story sketched here is true, we think much of the functional role of

the imagination for all involved is still done via physical simulation.

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