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Commentary

Time to act and attend to the real mechanisms of action and attention

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We discuss Humphreys' article in the context of two challenges that exist in regards to future research on the link between action and attention: (1) determining the cognitive and neural mechanisms responsible for an action–attention link and (2) demonstrating that the action–attention links observed in the laboratory reflect the same links between action and attention observed in the complexities of everyday life.

Humphreys' *et al.* (2010) article 'The interaction of attention and action: From seeing action to acting on perception' summarizes a complex and fascinating relationship between human visual attention and potential for action on objects. Humphreys' review discusses a multi-facetted approach to investigating this relationship, including behavioural studies with healthy and brain-damaged individuals, as well as investigations involving the use of imaging techniques such as functional magnetic resonance imaging (fMRI) and event-related potentials. Humphreys also leads a thought-provoking discussion on possible mechanisms underlying this relationship, raising important issues of broad theoretical interest.

Considering the importance and novelty of this line of research, we hope that the article by Humphreys *et al.* (2010) will serve as a catalyst for future investigations to move beyond simply cataloguing instances where attention and action affordances are linked. Humphreys case is made, and the challenges are now to (1) determine the cognitive and neural mechanisms responsible for an action–attention link and (2) demonstrate that the action–attention links observed in the laboratory reflect the same links between action and attention observed in the complexities of everyday life.

Regarding this first challenge, much of Humphreys' own work is inspired by various disorders of visual attention, such as visual–spatial neglect, yet it is the experiences of these patients that raise questions about the anatomy underlying the action–attention relationship. For example, neglect patient M. P. introspected that he is better able to find

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objects in his neglected field when he thinks of how the object is used. This anecdotal account was supported by controlled experiments performed by Humphreys and Riddoch (2001), which showed that M. P. was indeed better at finding targets in his neglected field when those targets were identified by an associated action compared to when they were identified by name. Similarly, Forti and Humphreys (2008) found that healthy individuals were more affected by object orientation when they searched for a target on the basis of the object's function compared to the object's name.

What is of particular interest here is that patient M. P., with damage to the parietal lobes and associated dorsal 'action' stream, benefits from action-related cueing rather than semantic or object identity cueing, which are traditionally thought of as ventral stream functions. Put more simply, M. P. is using action information over object information even though his action system is compromised! Upon closer inspection, M. P.'s lesions actually extend to parts of the ventral stream, including the temporal lobes (Humphreys & Riddoch, 2001), suggesting that his ventral object recognition stream may also be compromised. This leaves alluring questions about the relative contribution of these two neural systems to object processing, action, and attention. Interestingly, two other parietal lobe patients in the Humphreys and Riddoch study, M. B. and G. K., did not show the same advantages as M. P. for action cues. Because M. P.'s use of action cues was similar to that of healthy participants in Forti and Humphreys (2008), it suggests that M. P.'s abilities may be supported by preserved, normal, functional pathways, while these systems may be compromised in M. B. and G. K. Investigations into the relative locations of the lesions in these patients could therefore be particularly informative with regards to normal dorsal/parietal lobe function and its contribution to attention.

Similar to the results regarding neglect patient M. P., Castiello, Scarpa, and Bennett (1995) found that simultanagnosic patient L. P. showed uncoordinated movements when trying to bring together cards representing two unrelated objects but showed improved coordination when the objects were related. L. P. has bilateral parietal damage, and therefore, like M. P., M. B., and G. K., one can reasonably infer that there is damage to her action pathways. How then, is she performing these coordinated actions?

To explain these paradoxical results, Humphreys *et al.* (2010) suggests that these abilities may be accounted for in one of two ways: (a) adaptation following the lesion or (b) the novel use of a residual system. Humphreys also suggests that these results would not be informative about attentional processes in normal populations. Considering the link between M. P. and L. P.'s behaviour and the behaviour of healthy individuals (Forti & Humphreys, 2008), perhaps the patient behaviour is more informative to healthy brain function than may be immediately apparent. The issue of how the *damaged* brain is linking action for objects with visual attention (i.e. through adaptation vs. the use of residual system) is of great interest with regards to the functioning of the visual attentional system, as well as recovery from brain damage, and brain plasticity. Humphreys' first alternative, the idea of adaptation from brain damage, can be investigated through behavioural tests with patients who are tested soon after injury. A patient whose brain has not had time to adapt can inform us about whether adaptation is necessary for the link between potential for action and attention to be restored. Indeed, it is not even clear from current research that this link is necessarily lost.

If the action–attention link in parietal patients is *not* related to adaptation, (i.e. patients with recent damage to the dorsal 'action' stream show behavioural evidence of connections between visual attention and potential for action), this might support the second alternative, the use of a so-called 'residual system'. The idea of a residual system is often suggested when other anatomical explanations do not fit with our current understanding of brain function. However, the existence of a preserved connection between attention and action in parietal patients could have important theoretical implications for brain function and anatomy and is worth investigating. One possible avenue for such an investigation is diffusion tensor imaging (DTI): the imaging of white matter in the brain, which allows for analysis of location, direction, and orientation of parallel bundles of myelinated axons (Basser, Mattiello, & Le Bihan, 1994). Implemented in this context, DTI might allow the direction of information flow to be traced when the action/attention link is made. Combined with fMRI, this technique could reveal whether patients are using the same brain areas to perform action-related tasks as healthy individuals, or whether new connections are made. More broadly, this would provide useful information about how the brain forms new connections when old connections are lost.

A final point of interest regarding cognitive and neural mechanisms is raised in the last section of Humphreys' review. Here, he sketches out two ways that action may impact attention: statistical learning and motor feedback. This motivates more questions about the anatomy underlying these processes. For example, is statistical learning specific to a certain areas of the brain, or is it a more distributed function? If it is distributed, this may explain why the action–attention link is preserved in patients like M. P. and L. P., but begs the question as to why it may be lost in-patients M. B. and G. K. It will be interesting to see what inroads are made on these possibilities in the next several years.

Regarding the second challenge associated with our understanding of the relationship between action and attention, i.e. the connection between laboratory and real-world circumstances, it is sobering to note that there is little, if any, evidence that the results of the experiments described by Humphreys *et al.* (2010) are predictive or explanatory of action–attention links in everyday life. If one accepts the main thrust of Humphreys paper – and we certainly do – that action affects attention, then it is also the case that laboratory-based findings are rarely (if ever) going to generalize to the more complex real-life situations in which many more actions are being performed and signalled for than when a person is in the laboratory. In real life, there are many actions that may be in operation, and many objects vying for other actions, that are not typically in play in the laboratory. For instance, when one walks into a kitchen to prepare some food, one is performing many actions with the body, including moving through space, swinging arms and legs, and possibly turning the trunk, head, and eyes, while concurrently selecting the items necessary to achieve one's goal (Land, 2004). The challenge for researchers is to test when there is a link between laboratory and life, and when there is not. Too often there is the implicit, if not explicit, assumption that the findings in the laboratory will be informative to the ones in real life. Indeed, even in the few situations when a report from a real-life experience predicts an effect that is observed in the laboratory (as is the case with M. P.) it is still very much a leap of faith that the laboratory result is tapping into the same mechanisms that mediate the real-life report. (This becomes even more so for follow-up paradigm-driven studies and manipulations; it is an extraordinary leap of faith to think that subsequent laboratory-based manipulations on the laboratory-based paradigm are still making contact with the original behaviour that motivated the original study). This line of argument has been put forward recently by Kingstone (Kingstone, 2009; Kingstone, Smilek, & Eastwood, 2008) and stresses the importance of establishing and testing the link between cognitive/behavioural research and real-life situations.

We are encouraged by the growing body of evidence compiled by Humphreys *et al.* (2010) supporting the link between human visual attention and action. We hope more progress will be made on this line of work in the future, specifically with regards to understanding the mechanisms underlying this link and its operation in the real world. Various tools in the laboratory can help us understand the mechanisms, but these mechanisms are only meaningful if they are put into action in the real world.

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