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CONCEPTS AND ACTION: WHERE DOES THE EMBODIMENT DEBATE LEAVE US?

The behavioural evidence of sensorimotor activity during conceptual processing, along with that from neurological research, ignited the debate around the extent to which concept representations are embodied or amodal. Such evidence continues to fuel the debate but it is open to interpretation as being consistent with a variety of the theoretical positions and so it is possible that further, similar evidence may not lead to its resolution. In this paper we propose that independent value accrues from following this line of research through the enhanced understanding of the factors that influence agents' conceptual processing of action and how this interacts with the agent's goals in real environments. This approach is in line with broad principles of embodied cognition and is worthy of pursuit regardless of what the results may (or may not) tell us about conceptual representation.

Key words: embodied concepts; categorisation; language comprehension; action; goals

The embodied cognition paradigm has led to a debate around the putative nature of concept representation that theoretically runs through a spectrum of positions from the strongest claim of 'full embodiment' (Glenberg, 2015; Glenberg & Kaschak, 2002) to 'no need to posit embodiment at all' (Goldinger, Papesh, Barnhart, Hansen, & Hout, 2016). In this debate, the term 'embodied' refers to a claim that the representations we have come to refer to as 'concepts' are of a sensorimotor nature (i.e., that concept representations *are* sensorimotor representations and therefore modality-specific). This claim stands in contrast to long-standing beliefs, or perhaps assumptions,

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that concepts are abstracted from modality specific experiences, and that the process of abstraction results in a symbolic representation of a different form (i.e., amodal). The supposition of a symbolic representation had the important advantage of rendering the topic tractable to computational and statistical accounts of how concepts underpin classification (e.g., Krushke, 1992; Shin & Nosofsky, 1992).

However, arguments around how these symbolic representations (including words) come to be reliably evoked by the external stimuli to which they refer have persisted over many years in both philosophy (Kripke, 1972; Putnam, 1973) and psychology (Harnad, 1990). This is despite claims by some that the grounding problem can easily be dismissed, or is no more an issue of major concern than many other similar problems in cognition (Mahon, 2015a, 2015b; Mahon & Hickok, 2016). Drawing on support from neuroimaging evidence that challenged amodal representations (Damasio, 1989; Pulvermüller, 1999), Barsalou (1999) offered an alternative theory of what happens when a concept is activated that obviated the need for amodal representations, proposing instead that concepts are "represented in the same systems as the perceptual states that produced them" (Barsalou, 1999, p.579). This work has since been considerably developed to a 'grounded concepts theory' which, for Barsalou (2016), commits to the proposal of 'neural reuse'.

The key evidence that fuels the debate, and interpreted as supporting an embodied view of concepts, is that of the seemingly 'unnecessary' activation of the sensorimotor systems during tasks where previous explanations for performance made no reference to such networks. Much of this evidence centres around sensorimotor activity related to action (Aziz-Zadeh, Wilson, Rizzolatti, & Iacoboni, 2006; Chao & Martin, 2000; Hauk, Johnsrude, & Pulvermüller, 2004; Martin, Haxby, Lalonde, Wiggs, & Ungerleider, 1995; Pulvermüller, Hauk, Nikulin, & Ilmoniemi, 2005), specifically in cases when, as Mahon (2015a) puts it, "across a range of situations that would not seem to necessitate sensorimotor activation" (p. 172). The reaction to this body of evidence itself indicates that it would not have been widely predicted from a pre-existing understanding of concept representation. The issue that arises largely from this evidence is whether it calls for modification (or even outright rejection) of thinking of concept representations as amodal.

Following from this 'unnecessary' activation of sensorimotor networks, the aim of this paper is to acknowledge the role of the debate in continuing to inspire research along these lines but, moreover, to make a case for the independent value of behavioural investigations of the circumstances under which the sensorimotor system 'unexpectedly' influences performance on cognitive tasks that do not obviously require action. This includes, but is not limited to, documenting the type of action invoked by the task and the way in which this may be mediated by the participants' goals. The next section will outline the key theoretical positions in the debate, after which a selection of behavioural studies will be presented demonstrating the type of task-irrelevant activity of the sensorimotor system during conceptual processing that has, for some, excited the debate. This material is not presented for the purpose of assessing its evidential value concerning concept representation, but because it sheds light on the conditions under which action knowledge has a direct (and measurable) influence in cognitive tasks and suggests that these conditions can be seen as mediating the influence of action via perceived goals.

Representing Concepts: The Debate

The substantive question addressed by the embodied concepts debate is "*why* does the sensorimotor system become active when not obviously required in cognitive tasks?". One response is to theorise that concept representations themselves are sensorimotor in their format (embodied) and consequently influence any cognitive process that depends upon concepts. The positions in the embodied concepts debate have come to be broadly characterised according to the extent to which concept representations are considered to be amodal or modality-specific. The 'fully embodied' (radical) position entails a commitment to the view that concepts *are* sensorimotor in format (i.e., entirely constructed from sensory-motor representations), and that there is no reason at all to posit any form of amodal representation. It seems that very few are prepared to make this strong argument.

One of the findings that is most cited as seriously, if not fatally, undermining this extreme view is that it would logically follow that damage to the sensory-motor system would have 'catastrophic' effects on the individual's ability to use concepts to achieve a range of tasks that involve conceptual processing. This does not appear to be the case and it is reported that such damage has minimal effect on tasks assumed to rely on the activation of concepts (Binder & Desai, 2011; Mahon, 2015a) suggesting that sensorimotor systems cannot be solely responsible for representing concepts. However, it can be argued that such minimal effects can be accounted for by far less radical positions (Binder & Desai, 2011). On the other hand, if a fully amodal view is adopted, then no impairment to conceptual processing should follow from sensorimotor damage. The other key argument for positing concept representation that is independent of both perception and action is to serve as an explanation for the distinctly human ability to engage in 'off-line' thinking. This calls for conceptual representations that support thinking in the complete absence of external stimuli, or any action on the part of the agent.

Positions classified as 'interactive' typically propose the combination of amodal areas and sensorimotor systems such that interaction will flow from the former to the latter during conceptual processing (Leshinskaya & Caramazza, 2016; Machery, 2016; Mahon, 2015a, 2015b; Mahon

& Caramazza, 2008). It is noted that in this description a move has been made from *concept representation* (i.e., the format of concepts) to *conceptual processing* (i.e., the sensorimotor activation drawn upon under task performance) and, as Mahon (2015b) points out, this is a crucial distinction that frequently goes unacknowledged. Mahon suggests that an interaction between amodal and sensorimotor representations is non-controversial, however, further argues that concepts are amodal and utilise sensorimotor activity during task processing as a result of spreading activation. In taking an interactive stance, it is quite possible to acknowledge the role of the sensorimotor system in *conceptual processing*, while maintaining a view of concepts being in a different *representational* format (i.e., amodal). These positions can be seen as 'weak' embodiment views of concepts, but in acknowledging the representational difference these positions may as well not be considered embodied at all. Such positions are, in Mahon's view, not embodied in any meaningful way in as much as they do not dispute the amodal nature of the concept representation.

In terms of what we may refer to as a concept, Mahon (2015b) can be seen as adopting an 'amodal only' position since he emphasises the primary nature of the amodal component in representation when claiming that activation of the sensorimotor system is "subsequent to, and contingent upon semantic analysis of the input" (p. 422). A more explicitly extreme position is taken by Goldinger et al. (2016) who argue, drawing on a number of well-established phenomena in cognitive psychology, that the entire paradigm of embodied cognition offers no explanatory power for many phenomena of interest. With respect to concepts, these authors see a theory of embodiment as being proposed 'simply for the sake of embodiment' (Goldinger et al., 2016, p. 967).

Barsalou's position of Grounded Concepts (2008, 2016) has been interpreted as proposing one of the strongest forms of embodied concepts by virtue of claiming 'neural re-use', i.e., that concepts are represented through reactivation of the same, modality-specific, neural patterns evoked by the encoding experience. In this rejection of 'amodal' symbols, he has been taken to be embracing radical embodiment (Leshinskaya & Caramazza, 2016) but 'grounded cognition' allows for (indeed, insists upon) the need for abstraction; what is disputed is that 'abstracted' equates to 'amodal' (Barsalou, 2016). In Barsalou's view, amodal theories are considered as the 'default' having dominated the field for many years, and when research does not fall in line with the embodied view they are thus described as demonstrating amodal concepts. This is the case even when there is no direct evidence supporting the amodal view of concepts.

Since the evidence that largely motivated the debate arose from neuroimaging techniques, it may be anticipated that these methods may hold the key to resolving the debate. However, it seems that advances in that area are also open to interpretation. Evidence has been reported of areas of the brain that may serve to generalise across modality specific regions (Martin, 2016). These could potentially support the type of abstracted 'information'that virtually all positions recognise as being necessary if 'fully embodied' concepts are to be rejected. These have been referred to as *high level convergence zones* or *high level association areas* (Binder, 2016; Binder & Desai, 2011; Damasio, 1989), which are located in the inferior parietal lobe and ventral and lateral temporal lobe. These convergence zones are claimed to support amodal representations as patterns of cross-modal conjunctive representations drawing on input from a number of modality specific systems; these areas can capture overlapping neural patterns in response to stimuli and hence underpin conceptual knowledge. They are not themselves, modality specific but supervene upon areas that are. In allowing for activation from more than one modality, these areas may present as candidates for amodal representations since they cannot presumably retain the same format as the representation. However, they equally can be argued to be increasingly high-level abstractions from modality specific streams that still retain some aspects of modality specific representation.

Concepts in the Service of Action

The embodied concepts debate has served to focus attention on action in relation to concepts and has helped to considerably extend research and theory away from an approach that initially focussed largely on the organisation and use of feature-based knowledge. Of course, assertions that concepts are integrally related to action or even have developed to support action, have long formed part of the raft of claims that constitute an embodied approach to cognition (Glenberg, 1997: Wilson, 2002). In this section, it is argued that aside from the part played by behavioural experiments in the embodied concepts debate, this line of experimental research draws independent value from identifying particular factors that expand our understanding of *when* we would expect to see action exerting significant influence on task performance, and when it may appear to play a comparatively small role compared to other parts of the conceptual system.

Contrary to an early notion of context-independent properties (Barsalou, 1982), Barsalou (2016) highlights reasons to believe that there are no aspects of conceptual knowledge that are automatically activated across all contexts (Kemmerer, 2015; Lebois, Wilson-Mendenhall, & Barsalou, 2015), including action (Tomasino & Rumiati, 2013). Indeed, it is clear that action may not be recruited and used in all experimental tasks, as its influence has been shown to be dependent on the task, the stimuli, and the goal instantiated by the participants (Borghi et al., 2007; Borghi, Flumini, Natraj, & Wheaton, 2012; Bub & Masson, 2006). For example, Borghi et al. (2007) found a congruency effect between the type of priming used (a hand showing a pinch or a power grasp) and objects denoting either a precision or power grasp, but only when participants completed a motor training phase. While it may be the case that the motor system is neuronally activated during experimental tasks, such activation does not always exert a measurable influence on behavioural performance. From an experimental point of view, it becomes important to explicitly define the circumstances under which action knowledge is most influential in order to gain a better understanding of its influence beyond the laboratory setting.

One of the contingent issues that arises from the debate is what now can be thought of as 'the concept' of any given entity. Is the concept of *trumpet* the perceptual features; the function of being able to produce music; the emotion (positive or negative); the motor programme activated when playing (or thinking about playing); or is it to be all of these? Mahon and Hickok (2016) have proposed that "…there is no single notion of a concept, only clusters of information that are called upon in the service of the task at hand, and different tasks will dictate the utility of different types of information" (p.950). It is in this spirit that the research addressed next will focus on action as the 'cluster of information' of key interest and to consider *when* the motor system is influential during conceptual processing.

It should be noted that the particular focus in the work to be discussed is on action in relation to concepts of items having concrete referents in the environment, having a function relevant to everyday human goals and that require a physical, motor-based interaction with an agent to fulfil that function. This may cut across the artefact/natural kind distinction in that most artefacts and some natural kinds (fruits, vegetables, some animals) may fit these criteria.

Action-Irrelevant Tasks

Neuroimaging has shown that areas of the brain related to action execution, namely areas of the premotor cortex, become active across a range of relatively 'simple' tasks, such as looking at pictorial stimuli or reading short sentences (Aziz-Zadeh et al., 2006; Canessa et al., 2008; Chao & Martin, 2000; Hauk et al., 2004; Martin et al., 1995; Pulvermüller et al., 2005; Tettamanti et al., 2005). In line with this, behavioural evidence has also shown that action knowledge influences task performance in *action-irrelevant* tasks where recruiting of action information is not necessary to complete the task. In such tasks, the action is classed as 'irrelevant' because participants are not required to mimic or perform an action related to the stimuli used in the experiment. Tucker and Ellis (1998) demonstrated that objects possess 'micro-affordances' which facilitate action responses even when unnecessary task performance. In their experiment, participants were presented with images of objects either inverted or in the correct orientation and responded to the orientation of the object through a key press with the left or right hand. The direction of the handle was manipulated (pointing to the left or right of the screen) and despite not being relevant for task performance, the participants were faster to respond when the handle was oriented to the congruent response hand. In other words, when the handle of the objects pointed to the right participants were faster and more accurate to respond with the right hand; conversely, when the handle pointed to the left participants were faster to respond with the left hand. Tucker and Ellis take this to be the evidence that objects contain micro-affordances; object perception influences the preparation and execution of actions. Subsequent research supported the micro-affordance explanation of stimulus-response compatibility (SRC) effects when participants mimic physical actions (Ellis & Tucker, 2000; Tucker & Ellis, 2001, 2004). However, this explanation has been criticised by Proctor and Miles (2014) on the basis that SRC effects cannot be explained through affordances and that not all SRC effects are compatible with the predictions of the affordance approach. For example, Phillips and Ward (2002) found SRC effects when participants responded with foot pedals, a finding that would not be predicted by an affordance explanation. However, despite questions about the nature of the mechanisms involved, the results of Tucker and Ellis demonstrate a clear influence of the motor system in behavioural tasks even when not required for the task.

Using a different approach, a number of studies have demonstrated similar activation in tasks that require direct conceptual processing such as those frequently used in the categorisation literature (Borghi, 2004, Borghi et al., 2012; Iachini, Borghi, & Senese, 2008). Borghi (2004) showed that during property generation tasks, participants were more likely to generate properties of objects directly related to action when they were thought of in the context of direct physical interaction. The participants were given a series of objects and asked if they could imagine either using, building or seeing the objects. On seven critical objects participants were then given a property generation task and asked to list relevant parts of the objects. The protocols were analysed according to the context in which participants were asked to think of the objects and it was found that properties relevant to physical interaction were produced earlier and more frequently when participants were asked to think about using the objects compared to building or seeing. Importantly, there were no differences between the properties generated in the use condition and a control condition where participants were simply asked to perform the property generation task. In the latter condition, participants still produced action-based properties earlier and with more frequency. This would indicate that within a general context, concepts are intricately linked to actions given that no difference was found between the use and neutral conditions. These results are further supported by Iachini et al. (2008) who used a category sorting task demonstrating that participants sorted objects based on how they are 'gripped' over the shape and size of the objects. Such results therefore show that action knowledge is influential in categorisation tasks, even when this is irrelevant for task performance.

In further support of the influence of action in tasks where no physical action is required, Campanella and Shallice (2011) showed that action can exert a negative influence during picture matching. In their first experiment, they employed a word-to-picture matching task where participants were shown a word (denoting an object) followed by two object images with the task of identifying if the object matching the word was seen on the left or the right side of the screen and to answer as quickly as possible. The distractor item was manipulated in how it was related to the target item such that it either shared no relation (pincers + candle), a visual relation (pincers + compass) or an action relation such that the pairs were manipulated in the same manner (pincers + nutcracker). Participants showed a very high level of accuracy when the distractor shared no relation to the target. Most interesting, accuracy significantly decreased with a visual distractor, and decreased even more so with a manipulability distractor. In Experiment 2 they not only replicated the effects of Experiment 1, showing that a manipulable distractor decreases accuracy, but also showed that such distractors had a continual detrimental effect on performance. Participants repeated the same task as in Experiment 1, only this time the trials were repeated so that participants saw each pair three times. The results showed that, as expected, a learning effect was seen on the visual distractor pairs such that after three presentations accuracy had significantly improved from the initial presentation. However, the opposite was shown for the manipulable distractor pairs in that after three presentations the accuracy had significantly decreased compared to the initial presentation of the manipulable pairs. The authors explain this pattern as the continued activation of action having a negative effect of subsequent presentations and describe this as a 'negative serial position effect'. However, it is important to note a confound here in the results (that can also be applied to other studies in this field) in that there is a large degree of perceptual overlap between the manipulability pairs. Therefore, while it is true that the shared action between the objects could explain the discrepancy, the negative effect found could be the result of both shared action and perceptual characteristics combined.

Studies into language comprehension have also shown action effects on task performance (Glenberg & Kaschak, 2002; Masson, Bub, & Newton-Taylor, 2008; Myung, Blumstein, & Sedivy, 2006). Myung et al. (2006) demonstrated that action information is recruited during a lexical decision task (Experiment 1). In their experiment, objects shared an action based on hand positions and body movements for the intention of using the objects for their functional purpose. For example, *typewriter* and *piano* share an action because of the finger movements required to type or play the keys. In the lexical decision task, participants were aurally presented with word-word and word-nonword pairs where the relation between the target and prime was manipulated for the congruency of action. For example, the target of *typewriter* followed the prime of either *piano* (action-related) or *blanket* (non-related). Participants were faster to correctly identify the target as a word when the prime shared an action compared to the unrelated prime. It should be noted at this point that, as with the criticism of Campanella and Shallice (2011), a typewriter and a piano share overlapping perceptual features, and therefore it is possible that identification was not actually based on the shared action properties. Furthermore, a piano and a typewriter may share a 'generic' action but such similarities are limited; both objects require a different level of motor-coordination to use them. These results should be interpreted with some caution given such confounds.

Performing Actions

The experiments outlined above have clearly shown that even in action-irrelevant behavioural tasks where participants are not required to perform a physical action, knowledge of action(s) can have a significant influence on task performance. In addition to this, research where participants are instructed to make physical actions should not be ignored here. Interference effects arguably provide stronger evidence of the influence of the motor system given that research has demonstrated differences between the intention to act and physically doing so (Jax & Buxbaum, 2010; Osiurak, Roche, Ramone, & Chainay, 2013; Rueschemeyer, Lindemann, van Rooji, van Dam, & Bekkering, 2009).

Taylor and Zwaan (2010) demonstrated that visual presentation of objects can modify grasp responses. The authors presented participants with images of spheres and cubes at varying diameters of 4, 6, 12 and 16cm. Attached to the computer were two pressure bulbs with a 6cm diameter. Participants were instructed to depress keys to start each trial and grasp the bulb on the left if it was a sphere or the bulb on the right if it was a cube (counterbalanced). The authors predicted that if participants were influenced by the affordances of the objects then they should apply more pressure to the bulb when the visual display was smaller than the bulb itself (i.e., greater pressure for the 4cm image, but no difference between the 6, 12 and 16cm images). The results followed this prediction where participants applied more pressure when the image was smaller than the grasp to be made, but no difference was found when the image was the same size or larger than the response. Taylor and Zwaan further demonstrated that these effects were based on perceiving affordances in two follow up experiments where the compatibility effect was eliminated when the spheres had spikes or were labelled as 'planets'. Under these conditions the size of the spheres made no difference to the participant's grasp responses because they were rendered ungraspable based on either visual (spikes) or semantic information (planets). These findings are important in light of the fact that the intention to act on the response bulbs interacted with the conceptual processing of the stimuli, hence participants applied greater pressure to the 'graspable' spheres than they did not 'non-graspable' spikes and planets.

Glenberg and Kaschak (2002) provided strong evidence for the recruitment of the motor system during language comprehension tasks, notably using sentence 'sensibility' judgements. In their experiment, participants listened to sensible and nonsense sentences where the former described concrete transfer actions implying directions either toward or away from the body (e.g., "Andy delivered the pizza to you/You delivered the pizza to Andy") or abstract transfer actions (e.g., "Liz told you the story/You told Liz the story"). Participants responded using a box with three buttons arranged perpendicular to the body. The middle button was held down at the start of each trial and counterbalanced instructions were given for the participant to indicate whether the sentence was sensible or not, requiring participants to make physical movements either toward or away from the body. Embodied views predict that understanding sentences should facilitate physical responses in the congruent direction. The data supported this prediction; on both the concrete and abstract sentences, participants were faster to respond when the direction of movement was congruent with the action in the sentence. The authors term this finding as the *action-sentence compatibility effect* (*ACE*). This effect was replicated when participants used their non-dominant hand (Experiment 2A), but only when they performed a physical movement (Experiment 2B). In the latter experiment, participants sat poised with their arms arranged near or far from their body, and their index fingers resting on the yes/no buttons (i.e., participants did not have to make physical movements away or towards the body in order to respond). Under such conditions, the ACE was not found suggesting that the interaction between action and language comprehension only occurs when there is the intention to act, emphasising the previous distinction made that action is activated but not necessarily influential in behavioural tasks.

Research on the ACE has demonstrated that it occurs not only when participants have to make a physical action, but when the intention to act is processed simultaneously alongside the sentence. Borreggine and Kaschak (2006) used stimuli from Glenberg and Kaschak (2002), but moderated whether a response cue (indicating either moving forward or backward) was presented at the onset or offset of the sentence. The results showed that the ACE effect was only demonstrated when the response cue occurred at onset of the sentence, and not when the cue appeared at the offset[1]. Furthermore, the ACE has been shown only when the task is self-referential and the sentences take on a first person perspective ("Andy delivered the pizza to you") rather than a third person perspective ("Andy delivered the pizza to Liz") (De Scalzi, Rusted, & Oakhill, 2015; Schwarzkopf, Weldle, Müller, & Konieczny, 2011, see also Bergen & Wheeler, 2010, for evidence of the ACE with third person progressive sentences). Overall, the ACE demonstrated by Glenberg and Kaschak, and replicated by others (Borreggine & Kaschak, 2006; De Scalzi et al., 2015; Kaschak & Borreggine, 2008; Schwarzkopf et al., 2011) suggests that understanding language is grounded within action, more specifically within the *intention* to act.

Different Types of Action

What is clearly important to keep in mind when designing experimental stimuli, is that various actions can be applied to objects including those linked to function and general movement. Objects can be described as being either conflict or non-conflict items based on whether the action to manipulate the object is the same as the action to functionally use it (Jax & Buxbaum, 2010; Osiurak et al., 2013). For example, objects such as *calculator* and *blender* require a different action to grasp them (clench) as they do to functionally use them (poke) and are hence referred to 'conflict objects'. In contrast, objects such as *baseball* and *screwdriver* require the same (clench) action to grasp and use them and are hence referred to as 'non-conflict objects'. Jax and Buxbaum (2010) presented participants with both conflict and non-conflict items, instructing them to put their hand on the object as though they would either use the object (use-action) or pick it up to pass to the experimenter (grasp-action) and included the task order as a factor. Overall, the authors found that participants' took significantly longer to initiate use-actions than to initiate grasp-actions. In addition, they found a significant three-way interaction between task, object and order. When participants were asked to put their hand on the object to grasp it there was no difference between the conflict and non-conflict objects when they were asked to perform the grasp task first. However, when they were asked to perform the use task first, they were then significantly slower to put their hands on the conflict objects than the non-conflict in the grasp phase. This shows that the use of the objects interfered with the later grasp task.

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[1] It is noted that these results are in contrast to the work of Bub and Masson (2012) who found greater congruency effects when the prime was presented during the middle or at the end of the spoken word. Such differences can easily be explained by the nature of the experimental tasks. Participants in Borreggine and Kaschak's experiment made simple movements (backwards/forwards) whereas those in Bub and Masson's performed more physically complex functional and volumetric gestures. Therefore, the presentation-priming effect may relate to the type/complexity of the actions performed.

The authors define this as a 'long-term use-on-grasp interference' effect. This interference was found to exist at both the early and later stages of the grasp task and lasted for approximately 20 minutes (the length the experiment took to complete). The authors explain this as being part of the "race effect" (Jax & Buxbaum, 2010, p.354) between functional and structural information. Functional information is 'stronger', requiring activation of object property knowledge to complete the task. Whereas structural knowledge, not requiring such, is quicker to instantiate, hence "wins the race", but dissipates quickly.

Osiurak et al. (2013) challenged the results of Jax and Buxbaum (2010) on the grounds that participants were not required to perform a physical action, and conducted two experiments designed to replicate their findings. The purpose of this was to directly compare the difference between the intention to use an object (as in Jax and Buxbaum) and physically doing so. Experiment 1 replicated the results of Jax and Buxbaum in which participants were faster to make grasp movements to transport the object than they were to use them. However, the results of Experiment 2 were in direct contrast to this showing that the actions to use the objects were significantly faster than those to grasp and transport them. The authors argue that this is most likely caused by the fact that having to grasp and transport an object not only evokes information related to an object's properties such as weight and solidity, but also relating to the destination such as where the experimenter's hand was to receive the object. Such characteristics would not have been evoked in Experiment 1 since they were not needed. Clearly in Experiment 2, the goal of the task becomes very different as the destination (i.e., the hand of the experimenter) needed to be taken into consideration for task completion.

Bub, Masson and colleagues (Bub & Masson, 2010, 2012; Bub, Masson, & Cree, 2008; Masson et al., 2008) have researched differences in what they term as *functional* (the action required to use an object for its intended purpose) and *volumetric* actions (manipulating an object for generic movement, similar in meaning to Jax and Buxbaum's 'structural' terminology). Masson et al. (2008) demonstrated that reading sentences including an object noun activated information regarding how to physically use them. Participants were instructed to read sentences out aloud which included an object noun and an abstract verb (e.g., "*John thought about the calculator*"). After reading the sentence, and a delay of either 300ms or 750ms, participants saw a prime of a hand gesture that either matched the functional or the volumetric action of the object. The initiation time was measured between onset of the prime and the time it took to mimic the gesture. The prediction was similar to that of the experimental work above: if language is embodied within actions then reading the sentences containing abstract verbs should facilitate congruent responses where the action mimicked was congruent with the actual use of the objects. At both priming delays, participants were faster to mimic the functional actions when they were related to the objects in the sentence. This is an important finding in light of the fact that the sentences made no direct reference to the manual manipulation of the objects. Therefore, this shows that reading sentences activates property knowledge including action, particularly functional actions. When participants mimicked the volumetric actions after a 300ms delay, there was no difference in initiation times when the gestures were related or unrelated to the object. However, at the longer delay participants were faster to initiate the volumetric actions when they were related to the object. The differences found support claims that functional actions are longer lasting compared to volumetric actions which are relatively 'weaker' in comparison (Bub & Masson, 2010, 2012; Bub et al., 2008; Jax & Buxbaum, 2010; Osiurak et al., 2013).

Goals

The factors identified from the research presented above indicate that priming, context and the intention to act all raise the salience of action in task performance. Each of these can be seen as directing the participants' attention to a particular goal within the experimental task. The influence of goals is highlighted by Pellicano, Iani, Borghi, Rubichi, and Nicoletti (2010) who showed participants a torch in either a passive (turned off) or an active (turned on) state and found response compatibility effects for the handle direction and the response hand only when shown in the active state. In this case, performance was driven by a goal-directed compatibility effect.

In the real-life environments and situations, actions are most usually purposive and so to consider the influence of action in conceptual processing without taking into account the goals associated with it is to understand only part of the process of interest. To take a real-world example, in order to use a tool to achieve a goal, one must know both how to identify it within the environment and what to do with the object in order to fulfil its purpose (action). The identification of the object is sometimes a sufficient goal in its own right; a tool may be correctly identified from a toolbox and passed to someone who knows how to use it. It may also be just the first stage in the 'goal' of using the object. To identify the object, certain 'features' (knowledge) must be drawn upon; most obviously perceptual, and probably most frequently, visual. However, knowledge of an object that is restricted to this will not allow the agent to fulfil a very wide range of goals in the world. Knowledge of functional features such as what X is used for (or, what could this tool do for me) will extend the usefulness of the 'concept' for the agent and capability for acting in the world will be further enhanced by knowing how to interact with capability for acting in the world will be further enhanced by knowing how to interact with the object to make it fulfil this function. While previous research shows that action can aid in the initial identification process (Helbig, Graf & Kiefer, 2006; Helbig, Steinwender, Graf & Kiefer, 2010; Lee, Middleton, Mirman, Kalénine & Buxbaum, 2013; Sim, Helbig, Graf & Kiefer, 2015; Tucker & Ellis, 2001; Vainio, Symes, Ellis, Tucker & Ottoboni, 2008) it is not necessarily needed to do so, but is required in the next sub-goal of using the object. There are two potential different sources to draw on in achieving this; the instructional 'knowledge' of what actions are required, and the fine-grained sensori-motor experience arising from personal interaction with an object that would allow for an agent to successfully interact with it. These are potentially separable; an agent may have learnt/been told how to make an item work without ever having engaged in the motor routines involved in doing so. You may know what you need to blow a trumpet to produce a sound, but the sensorimotor activation as a result of the physical experience will inevitably differ from purely instructional information allowing knowledge of how to shape lips and how to 'blow'. In the absence of the latter, a concept can be considered 'impoverished' in that it cannot service successful action. Patient data has shown dissociations between action and function knowledge that also suggests that these areas are separable (Buxbaum & Saffran, 2002; Buxbaum, Veramonti, & Schwartz, 2000) with the inferior parietal cortex being associated with action and the left anterior temporal lobe with function (Leshinskaya & Caramazza, 2016).

Primary activation of the motor cortex through interaction will therefore add to conceptual knowledge that allows the agent to successfully make use of real world items to achieve goals. None of these claims are perhaps novel, but taking into consideration the specific role of distinguishable 'clusters of information' that are active in conceptual processing in relation to goals, may become crucial for behavioural researchers to better understand the many cognitive processes that have been believed to rely upon 'concepts'. Leshinskaya and Caramazza (2016) suggest the neurological underpinnings of purpose and goals may be located in areas associated with non-sensory motor concepts. These areas represent similarity in function across object categories as defined by a conceptually related outcome and suggest themselves as supporting the process of "selecting and using objects and movements to achieve goals" (Leshinskaya & Caramazza, 2016, p.998). Interestingly, these could present as areas likely to be active in the creation of goal-directed, or ad hoc, categories created 'on the fly', the members of which do not necessarily share many perceptual attributes (Barsalou, 1983) but are commonly used in everyday problem-solving situations. For example, finding an alternative to wedge a door open if a door-stop was not available (e.g., anything heavy and relatively 'unmoveable' – brick, rock), coming together under the new category of "things to hold a door open with".

Thelen, Schöner, Scheier, and Smith (2001), as strong proponents of embodied cognition, have claimed that "cognition *depends* [emphasis added] on the kinds of experiences that come from having a body with particular perceptual and motor capacities” (p. 1). This could more specifically be applied to concepts in that having a ‘full concept’ that supports action in the world depends upon having a body with these same capacities. Hence, whilst ‘catastrophic’ damage to conceptual processing may not be seen in patients with impairment to the motor system on certain tasks in laboratory sessions, their ability to engage successfully with items in the environment could be considered to be more than minimally damaged. There is often talk of ‘rich’ concepts but less consideration is given to the real-life implications of an impoverished concept.

Conclusions

The focus of the discussion above has been on action in relation to concepts that have a function relevant to everyday human goals and that require a physical, motor-based interaction with an agent to fulfil that function. The behavioural work that has been presented can be drawn together to demonstrate how the intention to act, (Glenberg & Kaschak, 2002; Taylor & Zwaan, 2010), physical priming (Iachini et al., 2008; Masson et al., 2008 Osiurak et al., 2014) and context (Borghi, 2004; Campanella & Shallice, 2010) influence action during a range of cognitive tasks. It has been suggested that these factors can be perceived by participants as setting goals within the experiments.

The continued search to identify factors that predict when, and to what extent the engagement of the sensorimotor system will affect conceptual processing, of course, creates a potentially ‘messy’ set of variables that presents a challenge to experimental methods that seek isolation of specific causes in mainly artificial settings (as has often been the methodological approach to studying concepts and categorisation). As a variable, goals are extremely hard to control or manipulate experimentally in a manner that may capture their influence in everyday thought, not least because of their hierarchical nature and the relationship between sub-goals. Goals are therefore seldom intentionally manipulated, and within most behavioural experiments the goal that is (presumably) instantiated by the participants is an overarching one, such as (i) completing the task, (ii) doing it ‘right’, and (iii) doing it, possibly, for material gain (e.g., payment, course credits). When ‘action’ is described as ‘task-dependent’, what this may mean is that it is dependent on the goal that the participants perceive to have been set for them.

What, then, can be drawn from the embodiment debate with regard to action? The accumulation of evidence for sensorimotor activity during tasks that do not appear to require any physical action related to the stimulus is likely to continue to fuel the debate concerning the nature of conceptual representations. It is suggested here that without requiring resolution of the representation debate, investigation of the relative influence of action under differing circumstances may (and should) proceed meaningfully with a view to documenting the factors that determine *when* action is most likely to play a role in explaining cognitive performance. Neuroscience is rapidly supporting a picture of a complex and integrated conceptual system with areas that have the facility for drawing across a range of modalities (Binder, 2016; Binder & Desai, 2011; Damasio, 1989). Although this is open to theoretical interpretation, it directs behavioural researchers to continue to broaden their focus of investigation to include separable factors that have perhaps been hitherto recognised but accounted for under the broad umbrella of 'context'; we have particularly argued for the importance of understanding the role of goals.

Whilst the value of the results from this line of research may, or may not, ultimately be helpful in resolving the debate around the modality of concept representations, taking action (and its relation to other variables) to be a key contributor to conceptual processing may enhance the chances of achieving our own goal of extending understanding of cognition beyond the laboratory.

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