AI and Affordances for Mental Action

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Abstract. To perceive an affordance is to perceive an object or situation as presenting an opportunity for action. The concept of affordances has been taken up across wide range of disciplines, including AI. I explore an interesting extension of the concept of affordances in robotics. Among the affordances that artificial systems have been engineered to detect are affordances to deliberate. In psychology, affordances are typically limited to bodily action, so the it is noteworthy that AI researchers have found it helpful to extend the concept to encompass mental actions. I propose that psychologists can learn from this extension, and argue that human subjects can perceive mental affordances, such as affordances to attend, affordances to imagine and affordances to count.

1 INTRODUCTION

The relationship between behavioural psychology and artificial intelligence is reciprocal: just as AI researchers can apply lessons from psychology to artificial behaviour, psychologists can apply lessons from AI to human behaviour. In some cases, these interactions will have a cyclic structure, with one discipline inspiring new ideas in the other, then those ideas in turn being taken up by the original discipline. Although this reciprocal arrangement has yielded a wealth of results, there are doubtless a vast range of lessons that remain unrecognised. Put another way, there are surely insights in each discipline that could be fruitfully taken up by the other, but which have not yet been extracted. My aim in this paper is to extract one such lesson from AI and to present some proposals about how it might be applied to human behaviour. I start with an insight from psychology – the role of affordance perception in human behaviour – and consider how this insight has stimulated new ideas in AI. I then consider how one of these ideas – Raubal's [11, 12] notion of mental affordances in robotics – moves beyond the understanding of affordances offered by psychologists. Finally, I explore how the notion of mental affordances might be applied in human psychology, and how it might be further developed in AI.

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2 APPLYING AFFORDANCE THEORY TO AI

The concept of affordances was introduced by the ecological psychologist J.J. Gibson, and his most fully developed articulation of the concept can be found in his 1979 work *The Ecological Approach to Visual Perception* [1]. In that book,

Gibson introduces the concept of affordances as follows:

> The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill. The verb *to afford* is found in the dictionary, but the noun *affordance* is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment. [1, p.127]

Classic cases of affordances are those pertaining to basic bodily actions such as walking, gripping or catching. A path might afford walking, a stick might afford gripping and a ball might afford catching. Whether something has these affordances depends on the body and abilities of the agent: a ball that affords catching for one agent might not afford catching for another.

At the heart of the concept of affordances is a specific understanding of the relationship between action and perception. Gibson's key theoretical claim is that agents do not perceive an action-neutral environment then infer what actions are available to them in an environment with those properties. Instead, agents can simply *perceive* opportunities for action.

For Gibson, this claim was part of a radical understanding of behaviour according to which internal processes are unnecessary for perception, or for the transition from perception to action. Agents can pick-up affordances by directly perceiving optical patterns in the environment, and these affordances can directly guide action without the need for mediating processes.

Some in the ecological school of psychology have sought to retain this radical understanding of behaviour. However, the majority of those who have taken up Gibson's concept of affordances have left these bolder claims behind. AI is no exception to this. Horton *et al* [7] note that AI researchers understand affordance perception in terms of internal representations of opportunities for action – a concession to dualism that Gibson would doubtless have resisted. But if perceiving and acting on affordances is taken to require internal representation, what value is there in the concept? Horton *et al* outline the application of affordances to AI as follows:

> In designing artificial agents, several successful patterns for control and coordination of perception and action have emerged. Some of these approaches share an important characteristic - a clear emphasis on utilizing the environment, and the agent's interaction with it, to reduce the complexity of representation and reasoning. This characteristic is founded on an ecological view of the agent - an entity embodied in a world rich with observable cues that can help guide the agent's behavior. [2, p.71]

By programming behaviour in a way that's sensitive to environmental affordances, one can thus minimize the need for internal representations. This is a valuable result even if the Gibsonian dream of eliminating internal processing entirely is deemed unattainable [2, p.79]. An especially interesting consequence of affordance-based programming is that agents with such programming engage in exploratory behaviour. This behaviour is not directed toward any specific goal, but by interacting with items in the environment in a variety of ways the agent discovers the opportunities for action presented by that object, and by other objects of the same kind. Stoytchev [16], for instance, offers a distinctive approach to tool-learning in robotics that involves the robot engaging in random 'dabbling' behaviour toward a presented tool. The robot performs a variety of random actions on the tools and learns the results of these actions. By engaging in this behaviour, the robot is then able to perform a tool-using task that they would have been unable to perform without the lessons learned from their earlier goal-independent exploration.

3 MENTAL AFFORDANCES IN AI

The affordances discussed by Gibson (and by the vast majority of those who have picked up on his term) are affordances for *bodily* action. As mentioned above, classic affordances include affording walking, affording gripping and affording catching. The affordances explored in AI research are almost universally affordances for bodily action in the sense that they involve some kind of physical movement on the part of the artificial agent (whether it be virtual movement in a simulation or actual movement through an artificial body). Examples include affordances for poking, pushing, pulling, rotating and lifting [2, p.73]. However, in a small number of cases AI researchers talk about affordances for mental action. Consider the following passage from Raubal & Moratz:

> …a public transportation terminal affords for a person to enter different buses and trains. It also affords to buy tickets or make a phone call. A path affords remembering and selecting, a decision point affords orienting and deciding, etc. In general, such situations offer for the person the mental affordance of deciding which of the perceived affordances to utilize according to her goal. [11, p.3]

Some of the affordances cited in this passage are affordances for bodily actions, such as the

bodily act of getting on a specific bus. But the 'mental affordances' are affordances for mental action, such as the mental act of deciding what to do. Raubal & Moratz offer an affordance-oriented robot architecture that includes sensitivity to these mental affordances. They explain this architecture as follows:

> Mental affordances (M*aff*) arise for the agent when perceiving a set of physical and social-institutional affordances in an environment at a specific location and time. Affordances offer possibilities for action as well as possibilities for the agent to reason about them and decide whether to utilize them or not, i.e., mental affordances. The agent needs to perform an internal operation Op (Int) to utilize a mental affordance. Internal operations are carried out on the agent's beliefs (including its history and experiences) and lead to an internal outcome O (Int). In order to transfer such outcome to the world, the agent has to perform an external operation Op (Ext), which then leads to an external outcome O (Ext), i.e., some change of the external world. [11, pp. 95-96]

So besides being sensitive to specific affordances for physical action, the robot is sensitive to situations in which a decision is required [11, 12]. The opportunities for physical action can be understood as first-order affordances. The situations in which a decision is required can be understood as second-order affordances, as they are affordances to decide between first-order affordances. Raubal & Moratz argue that this architecture better enables robots to respond to a dynamic environment. Furthermore, the process of explicit deliberation allows them to communicate plans before they are acted upon. Although they don't draw explicitly on Raubal & Moratz, Saratha & Scheutz have also recently argued that uptake of such second-order affordances enhances performance in various ways [14].

4 DEVELOPING MENTAL AFFORDANCES

Raubal & Moratz [11] emphasise that one of the advantages of their mental affordance-based architecture is that it better corresponds to the architecture of human behaviour. However, when one looks at how the concept of affordances is used in the psychology literature, one finds virtually no reference to affordances for mental actions such as affording deliberation. Psychology did AI a service with the notion of affordances. Perhaps here AI can return the favour. I propose that the notion of mental affordances opens up a range of promising avenues of enquiry for the understanding of human behaviour.

Raubal & Moratz's [11] example of affording deliberation is an obvious initial target. Do human agents perceive opportunities to make a decision? Does the concept of affordances for deliberation allow us to offer better explanations of when and how humans engage in explicit decision making? It certainly seems to fit with our phenomenology that situations afford deliberation: just as we experience a single open path as demanding to be walked down, we experience a fork in the path as demanding an act of explicit deliberation about which path to take. Although affordance-based theories are ultimately answerable to the empirical data, their phenomenological plausibility is responsible for a great deal of their appeal [6]. If the notion of mental affordances tallies with our phenomenology, this would be an important point in its favour.

Moving beyond affordances for deliberation, we can explore the possibility of other affordances for mental action. I introduce three kinds of affordance: affording covert attention; affording covert bodily actions; and affording counting.

Certain stimuli present opportunities for us to perform the act of attending, and some of these stimuli positively call out to be attended to. Consider the experience of trying to concentrate on some work when a radio is being played outside. The radio calls out for our

attention but with effort we can keep our attention trained on our work.

The way that stimuli invite attention is naturally described in terms of affordances. Attending is an act, and the radio outside presents an opportunity to perform this act. Our sensitivity to such opportunities is perceptual. One doesn't hear the loud bang and *infer* that one ought to direct one's attention to it: one is aware of the radio as a suitable target for attention without the need for any such inference. Furthermore, if the radio's claim on our attention were just a matter of *believing* that the radio should be attended to then it would be easy to reason ourselves out of being distracted by the noise. However, like many (if not all) perceptual states the representation of the radio as demanding attention is cognitively impenetrable. Crucially though, this does not mean that attention is outside our voluntary control. When we hear a loud bang, we cannot help but attend to it, but this is not the scenario under discussion. In our scenario, we succeed in keeping our focal attention trained on our work. As such, the radio does not trigger an obligatory involuntary act of attending. What is involuntary, however, is our perception of the radio as affording attention: we are free to ignore its call, but powerless to silence that call.

These considerations indicate that we perceive opportunities to attend. But is the act of attending mental or bodily? Overt attention is the *bodily* act of directing one's sense organs toward a particular stimulus, property or region. Covert attention is the *mental* act of concentrating on a particular perceived stimulus, property or region. These two layers of attention typically coincide: the focus of our gaze is normally the focus of our covert attention. That said, the two activities must nevertheless be distinct since they are *dissociable*: one can deliberately direct one's covert attention toward things other than the target of one's overt attention. Stimuli that afford attention thus afford not just a bodily act, but a mental act. Alternatively, we might say that when stimuli afford attention they afford a complex act that is at least *partly* mental. This would still be a significant departure from the straightforwardly bodily acts normally cited in the affordance literature.

Some objections might be raised against this conclusion. First, one might object that stimuli only afford overt attention. On this view, a loud noise affords the bodily act of turning one's head toward it but does not afford the mental act of covertly attending to it. Against this objection, I would respond that when a stimulus affords overt attention is clearly affords covert attention too. We do not, for instance, find ourselves suddenly turning toward a loud noise whilst keeping our concentration firmly on a prior task. In response to this, one might object that we perceive affordances for overt attention, and that when we overtly attend to something our covert attention follows suit. As such, our covert attention is not guided by perceived affordances for to perform the mental act of covertly attending. Rather, it is guided by overt attention which is in turn guided by perceived affordances to perform the bodily act of overtly attending. The difficulty with this response is that it is at odds with the empirical data. Covert attention has been found to *precede* involuntary eye movements [9], so it cannot be the case that covert attention merely rides on the coat-tails of overt attention.

I suggest that the concept of affordances for covert attention could be of value to psychologists. And continuing the cycle of innovation, affordances for covert attention may prove useful in AI. Researchers have already programmed artificial agents with a capacity for covert attention [17]. As with any action that an artificial agent is able to perform, there are different ways of programming how and when the agent elects to exercise that capacity. We have already touched on the benefits obtained when an artificial agent is programmed to exercise its capacities for physical behaviour in response to perceived affordances in the environment. Perhaps parallel benefits could be

obtained by making an artificial agent's capacity for covert attention responsive to affordances to attend in the environment.

Moving on from covert attention, I suggest that we might also perceive affordances to mentally rehearse a bodily action. Sometimes we perform bodily acts in our mind: we rehearse them in imagination without actually performing them. Interestingly, the neural realisation of an imagined bodily act overlaps extensively with the neural realisation of actually performing that act [8]. This suggests that to imagine an action is simply to perform that action 'off-line'. If we can perceive affordances to perform a bodily action overtly, there could also be affordances to perform that same action covertly.

Consider a situation in which someone is sitting opposite you at a table, and you wish to know how the items on the table are arranged from their perspective: for instance, from their perspective is the fork to the right of their plate or the left? To work this out you could rotate your body round to the other agent's position and observe how the items appear from this new position. A more economical alternative, however, is to perform such self-rotation *mentally* and 'see' how those items appear without having to move a muscle. Psychologists such as Kessler & Thomson [8] have provided experimental evidence that when we adopt another agent's spatial perspective we perform exactly this kind of mental self-rotation. The situation described thus presents an opportunity for mental self-rotation. Do we perceive this opportunity to perform the relevant mental act or only infer it? The existing data does not offer a definitive answer to this question. Anecdotally though, it does not seem that we first perceive our situation then *infer* that mental self-rotation would reveal the desired information about the other agent's perspective. Rather, the availability of this mental act is immediately apparent to us: it is perceived not inferred.

If this line of thought is sound, then the notion of affordances to perform off-line bodily activities could be of theoretical value in psychology. Again though, there could also be interesting applications in AI. Many artificial agents exploit off-line rehearsal of physical actions [15]. Programming agents to be responsive to affordances to perform such rehearsals could yield the same kind of cognitive advantage achieved by agents that are responsive to affordances to perform overt bodily actions.

My final proposed mental affordances are affordance to count. Counting is a mental act. Sometimes we count in a way that involves a bodily act of pointing to items and numbering them out loud. Sometimes we count in a way that involves doing those bodily acts off-line e.g. by pointing and numbering in our heads. It is implausible, however, that the act of counting is exhausted by such overt or covert bodily action. We can count things without performing either of these acts, and we have a brain area – the intraparietal sulcus – that is directly associated with arithmetic without being directly implicated in those bodily acts [3]. My target here is what you might call unassisted counting: a way of counting that depends on neither overt nor covert bodily action. Our environment can present opportunities for counting. Consider a pile of pennies, or the leaves on a clover, or the cards remaining in a poker deck.

A strong consideration in favour of affordances for counting comes from pathological cases. To appreciate this evidence, we must first consider how pathological cases have informed our understanding of affordances for bodily action. Utilization behaviour is a disorder caused by specific brain damage to the frontal lobe and is characterised by subjects being compelled to 'utilize' any items that they see [1]. When presented with an apple, subjects eat it even when they are not hungry. When presented with a toothbrush, they use it to brush their teeth regardless of the context. When they are presented with pens, they draw with them even if there is no paper to draw on. This disorder has been explained with reference to affordance perception: subjects perceive an

opportunity to act but are unable to suppress the impulse to exploit this opportunity [13, 2]. Where a typical subject perceives that the apple affords eating, there is evidence that the motor pathways responsible for grabbing and eating the apple are triggered. If the agent elects to eat the apple, these motor signals result in the bodily action, but more often the agent will suppress this signal: they perceive the opportunity to eat but do not act on it. However, due to their frontal lobe damage, agents suffering from utilization behaviour are unable to suppress these signals so perform whatever act they perceive to be afforded. Parallel claims have been made in the context of OCD: the compulsive behaviour of sufferers of OCD can be described in terms of the distinctive ways in which they perceive and act on environmental affordances for bodily action [5].

How do these considerations about the role of affordance perception in certain kinds of pathological behaviour help us in our project of exploring the possibility of mental affordances? Many of the pathological behaviours discussed by researchers are bodily acts and, correspondingly, are explained in terms of affordances for bodily action. Some behaviours, however, are more plausibly regarded as pathological mental actions. Plausibly, such behaviour could be explained in terms of how subjects perceive and act on affordances for mental action. The patient suffering from utilization behaviour discussed by Brazzelli & Spinnler also showed a 'compulsion to count' [1, p. 350].[2] If her compulsive consumption of a presented apple is to be explained in terms of her perception of the apple as affording eating, and her subsequent failure to suppress the impulse to eat, then her compulsive counting should be explained in terms of her perception of items as affording counting, and her subsequent failure to suppress the impulse to count.

It is worth noting that the patient's symptoms are not naturally explained in terms of atypical behavioural urges: the characteristic feature of the disorder is that the patient's behaviour is *environment led*, meaning that she acts on perceived opportunities for actions even if she has no desire to perform those actions. Consequently, the fact that she performs the act of counting on certain stimuli indicates that she *perceives* those stimuli as presenting an opportunity to count. Again, parallel conclusions can be reached about the explanation of compulsive counting in OCD patients [10].

Whether stimuli afford counting is ultimately answerable to empirical evidence that is not yet available. Again though, it seems that there would be something *ad hoc* about countenancing affordances for bodily action and not for mental action. If the compulsive bodily actions of Brazzelli & Spinnler's patient are to be understood in terms of affordance perception then, other things being equal, the same view ought also to be taken toward her compulsive mental actions [1].

If there can be affordances for counting, why not for other arithmetical actions? A pile of sweets, for example, might present an opportunity for division. And stimuli in the language of mathematics can present opportunities for far more sophisticated arithmetical actions. A maths exam paper, for instance, might present opportunities to square, to factorise and to exponentiate.

Many artificial agents have within their repertoire the ability to perform mathematical operations on their environment. Armed with the concept of affordances for mathematical action, perhaps programmers could create artificial

[2] A complication here is that the cases of counting observed by Brazzelli & Spinnler are, of course, cases of overt counting. One might claim that it is this bodily act that is afforded rather than the mental act of counting. However, the burden of proof would be on the objector to say why this is so. Ordinary subjects perform these bodily acts to *assist* a mental act of determining how many of something there is, and there is no obvious reason to doubt that the patient is doing the same. Put another way, the patient is most likely compelled to make bodily gestures that aid counting precisely because she is compelled to perform the mental act of counting.

agents that are responsive to environmental opportunities to perform this mental act, with all the cognitive advantages entailed by such responsiveness.

5 CONCLUDING REMARKS

Psychology's introduction of the concept of affordances has had valuable applications in artificial intelligence. One of these applications has been to extend the notion of affordances beyond bodily action to include mental acts such as deliberating about a choice. I have argued that this notion of mental affordances promises to have fruitful applications in human psychology, and to have useful further applications within artificial intelligence. To put this to the test, further work must be done on the ways in which agents recognise opportunities for mental action.

In artificial intelligence, there is an opportunity to develop new cognitive architectures. Just as artificial agents programmed to perceive and act on affordances for bodily action have shown a range of advantages over more traditionally structured artificial agents, artificial agents programmed to perceive and act on affordances for mental action will enjoy parallel advantages.

In human psychology, there is an opportunity to test whether and how human subjects perceive and act on opportunities for mental actions. A variety of experimental paradigms have been employed to establish whether and how we perceive affordances for bodily action, and many of these paradigms can be applied to investigate affordances for mental action.

When considering affordance perception in both organic and artificial subjects, one important question is what value there is to perceiving affordances rather than inferring what opportunities for action are available from action-neutral perceptual inputs. One particularly promising line of enquiry is to explore the link between affordance-based architectures and exploration-based learning. If goal-independent physical dabbling with external objects allows agents to learn the affordances for physical action offered by external objects [16], perhaps goal-independent mental dabbling with external objects allows agents to learn the affordances for mental action offered by those objects. Many mental actions are performed on symbols, including linguistic and mathematical symbols. When we 'play' with symbols might we be learning about the mental actions they afford? One might even move beyond perceptible external stimuli and speculate that we can perform goal-independent mental dabbling with our own internal states. Perhaps such dabbling reveals opportunities for self-directed mental action that would not otherwise be recognised.

This is just one of a host of promising avenues of enquiry opened up Raubal's innocuous concept of affordances for deliberation. I hope that the full theoretical import of mental affordances will emerge over time, and yield valuable insights in psychology and AI alike.

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