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Means-End Reasoning

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Synonyms

Means-end behavior; Means-end understanding

Definition

Broadly speaking means-end reasoning is concerned with finding means for achieving goals (Pollock 2002). More specifically, it involves the deliberate and planned execution of a chain of actions to achieve a goal and occurs in situations where an obstacle (e.g., a distance between the subject and a desirable item, person) preventing the achievement of the goal must initially be removed (Willatts 1999).

Introduction

In everyday life, we are regularly facing situations which require elaborate sequences of mediating actions to reach a distant goal at the end. For example, imagine a person opening a drawer to take a key to unlock a storeroom to get a ladder needed to reach the door to an out-of-reach vitrine where there is a candy box that can be opened to get some sweets. As this hypothetical problem-solving sequence illustrates (modified from Santos et al 2005), the individual steps within a sequence are often separated from the final goal both in time and space. To complete the sequence, problem solvers must initially ignore the primary goal (e.g., reaching the sweets) to focus on first completing the individual subgoals (e.g., getting the stepladder). Moreover, means-end behavior often requires an extensive knowledge of the causal relations between objects. In other words, an individual needs to understand both the connection between the individual steps of a chain of action (a key can open a locked door, a ladder can be used to access things that are out-of-reach, etc.) and how they relate (finding the key to the storeroom is necessary for eventually eating the sweets).

When performing a goal-directed behavior, understanding these consecutive sequences of mediating actions as the means to an end can be of significant advantage for any individual (Schmidt and Cook 2006). In fact, without such an understanding, it will be impossible for an individual to transfer an intention into an action, and arguably impossible to form an intention at all (Osthaus et al. 2005). The understanding of functional relations between an action and its consequence is thus a crucial step in cognitive development.

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Means-End Reasoning in Human and Nonhuman Animals

In human cognitive development, understanding of means-end relations develops in early infancy (Piaget and Cook 1952). Piaget was among the first to develop a task assessing this specific kind of problem-solving. In the so-called "support task," the infant must try to obtain an object, (e.g., a toy, that is out of direct reach) by pulling a piece of cloth placed underneath the toy towards itself. In this task, the piece of cloth serves as a support and correctly using the support is the means to accomplish the end of obtaining the toy. Piaget found that the infants first acquire the ability to pull supports, but they persist in doing so even when the goal does not rest on the support (on/off condition). At a later stage (after 12 months), the infants gain conceptual knowledge about the relationship between the means and the end, the spatial relationship between the two, and the features of the support used. Furthermore, they develop cognitive processing that allows subjects to have a definite goal, to persist in trying to achieve it, and thus to produce a goal-directed behavior. Even though later work massively improved and refined the model of infant cognitive development, Piaget's original model remains valid (Willatts 1999).

The question if and how animals develop means-end understanding remains one of the central questions of the modern comparative cognition research (e.g., Schmidt and Cook 2006). Analyzing the understanding of means-ends relationships in nonhuman animals requires problem-solving tasks in which a solution to the problem can in principle be perceived directly, without trial and error or previous experience of similar tasks. Means-end understanding is thought to be most clearly demonstrated if the subject shows an "insightful" solution to the problem on the first trial, ruling out possible operant conditioning. Usually, relying on means-end connections is assessed by offering a choice of two options, one of which is in physical connection to an out-of-reach object of desire. Widely used paradigms in this context include the "string-pulling task," originally applied by Köhler (1927), as well as the "support problem," originally introduced by Piaget (Piaget and Cook 1952). Both tasks involve offering a possible physical connection to an out-of-reach object of desire. In the string-pulling task, a string is attached to a piece of food. The food itself is out of reach of the animal, but the near end of the string is accessible. In the "support problem", an object is out of the subject's reach but is placed on a cloth which the subject can pull towards it. Both tasks – the string pulling as well as the support problem – are based on the assumption that if the animal understands the physical properties of the string or the cloth, it uses it as a means to an end, i.e., pulls the food into reach with the string or cloth on its first exposure to the task. In contrast, subjects who do not understand that pulling the string is the "means" for achieving the desired "ends" of bringing the reward within reach, will only be able to succeed via repeated exposure and associative learning (Range et al. 2012).

When offering a choice of two options, one of which is in physical connection to an out-of-reach object, the physical situations of these choice discriminations then can be varied in many ways. In each case, the food is out of reach, so the subjects need to recognize which of the physical arrangements would yield a reward. By analyzing the subjects' performance in such simultaneous discriminations, it can be assessed whether an animal is relying on perceptual features rather than attending to the relevant functional features of the task. In the support task, subjects can choose between pulling a cloth with a piece of food on it versus pulling another piece of cloth with the same reward closely next to it ("on/off problem"). In the "connected problem", subjects can choose between a piece of food resting on an intact piece of cloth versus a second reward resting on a cloth that is divided into two pieces and hence separated by a small gap. The nature of string-pulling task allows for a higher number of conditions since the strings can be arranged in a number of different patterns (e.g., slanted, parallel, convergent, crossed, pseudo-crossed, double-crossed and so on), commonly referred to as "patterned-string problems."

So far, animals as diverse as monkeys, great apes, dogs, cats, elephants, pigeons, corvids, parrots, and bumblebees have been tested with the string-pulling task and/or the support problem. Spontaneous apparently "insightful" solutions were found in just a few species, for example, in a number of nonhuman primates (Hauser et al. 1999; Herrmann et al. 2008), large-brained birds such as corvids and psittacids (e.g., Auersperg et al. 2009; Heinrich and Bugnyar 2005; Krasheninnikova et al. 2013), and elephants (Irie-Sugimoto et al. 2008). Various cognitive mechanisms underlying the pulling of strings and/or supports have been proposed for other animals, for example, associative learning (e.g., pigeons, *Columba livia*, Schmidt and Cook 2006, and bumblebee, *Bombus terrestris*, Alem et al. 2016), relying on perceptual feedback (New Caledonian crows, *Corvus moneduloides*, Taylor et al. 2010), or attending to perceptual contact but not necessarily connectivity (great apes, Povinelli 2000). Dogs as well as domestic cats (*Felis catus*), although able to learn to obtain food that is out of reach by means of an attached string, have failed to show understanding of means-end relationships when tested in a two-choice paradigm involving various patterned-string tasks (Osthaus et al. 2005; Whitt et al. 2009).

Other tasks requiring an understanding of means-end relationships involve tool use, but they also require other cognitive capacities as well, so that they are sometimes considered to be less appropriate as tests of means-end understanding as such (Osthaus et al. 2005). Nevertheless, an obvious parallel to the hypothetical problem-solving sequence, as described at the beginning of the chapter, is the sequential tool use, where a tool is used to acquire another tool (Santos et al. 2005). There are three difficulties arising from sequential tool using: (1) the subject must recognize that one object can be used as a tool that can be used on another nonfood item, (2) the subject also must forego the immediate motivation to use the first tool to attempt to access the food directly, and (3) the subject must be capable of hierarchically organized behavior (Wimpenny et al. 2009). Such sequenced behavior is exceptionally rare in the nonhuman animals. The only evidence of using tool sequences comes from nonhuman primate and large-brained birds (corvids and parrots). For example, wild chimpanzees have occasionally been observed using an additional stone to adjust poorly positioned stone anvils; the additional stone thus provides a leveler for the anvil (Matsuzawa 2001). These observations suggest that chimpanzees can use a means, in this case the additional stone, to act on another means, the stone anvil, even in the absence of an immediate food reward. The New Caledonian crow, *Corvus moneduloides*, a habitual tool-manufacturer and tool-user in the wild, has shown sequential tool use by using a short tool to extract a longer tool that could then be used to obtain a reward (Wimpenny et al. 2009). However, it has been shown that sequential tool use is not restricted to habitual tool users only. The rooks, *Corvus frugilegus,* a non-tool-using corvid, could use a large stone to access a small stone that could be used to release an out-of-reach food (Bird and Emery 2009). In parrots, the other large-brained avian group, sequential problem-solving has been documented in the Goffin's cockatoo (*Cacatua goffiniana*). The birds could solve a five-step sequence of multiple locking devices blocking one another demonstrating that they can execute a chain of intermediate actions unaffected by the fact that the goal was very distant (Auersperg et al. 2013).

Do Nonhuman Animals Really Perform Means-End Reasoning?

However, despite the recent impressive findings involving apparent understanding of means-end relations found in various animals, the pivotal question remains: to what degree do states of cognition characterized by terms like "means-end reasoning", "insight", "understanding", and "problem solving" contribute to an animal's behaviors as opposed to "simpler" mechanisms based on experience and associative learning (Hanus 2016; Shettleworth 2012).

Obviously, mere acquisition of the reward by pulling at the string or the cloth does not necessarily reflect means-end understanding. For example, successful performance in string-pulling tasks might be based on perceptual feedback, i.e., forming an association between pulling the string and the reward coming closer, resulting in repeated pulling (Taylor et al. 2010). Another common strategy subjects may employ when faced with patterned-string tasks or support problems is the proximity rule, i.e., pulling the string or cloth closest to the reward. Thus, it has been claimed that an animal can reasonably be said to possess means-end understanding only when pulling the support (string or cloth) is goal-directed and not dependent on such perceptual features (Jacobs and Osvath 2015).

For example, in the support task study on tamarins, the authors conclude that the subjects solved these tasks by understanding the general means-end relations mediated by the functionally relevant properties of their physical arrangement (Hauser et al. 1999). Later, this claim has been questioned by Povinelli (2000), proposing instead that primates only learn about the perceptually salient features of the task rather than about any more profound understanding of mean-ends relations. In other words, the animals were learning only how to obtain the food, based on the visually observable features of the task such as the continuous nature of the cloth or gap placement. As such, the observed transfer across different task conditions in Hauser's et al. (1999) study has been suggested to reflect the direct generalization of what was learned about these perceptual features rather than any reasoning about means-end relations. Accompanying experiments testing chimpanzees in various support and connection problems supported Povinelli's (2000) perceptual interpretation.

There are other related situations in which an animal's behavior may also suggest a failure to represent means-end relations adequately or to understand how a particular sequence of means contributes to an end (Woodward 2011). For example, animal's behavioral recipe may contain elements not necessary or superfluous for the achievement of the goal. An adequate means-end understanding would allow the animal to recognize when these superfluous elements are present and can be omitted. First evidence for such a recognition capacity comes from Goffin's cockatoos successfully responding to the functionality of each step in the chain in the five-step sequence problem-solving task. When one or more locks were missing, the birds directed their attention to the first relevant one, ruling out a rigid learned routine (Auersperg et al. 2013). Alternatively, an animal that behaves as if it recognizes that employing a means in specific situation is sufficient for achieving the desired goal, (like a crow obtaining a short tool to use it on a longer stick to obtain the desired food reward) may, in fact, may, in fact, just employ a specific behavioral recipe or routine sufficient for reaching the goal in this specific situation. However, the animal may fail to recognize that there may be alternative means besides the employed one for the achievement of the goal, or, when a changed situation has the consequence that the original means is no longer appropriate. Furthermore, some claim that most animals, maybe even all except humans, can only deal with causal information which features their own actions as causes and outcomes as effects. In other words, an animal that only has a representation of the form "If I do action A, desired outcome O results" with no general representation of intermediate steps leading from A to O (Woodward 2011).

Probably the most challenging part of animal cognition is to rule out all the alternative explanations for "intelligent" behavior, and whether or not one or the other researcher adequately do so may remain open to debate. Nevertheless, recent findings in the context of means-end reasoning in animals provide promising and tractable empirical paradigms for investigating this challenging topic of animal cognition.

Conclusions

Human behavior regularly involves elaborated sequences of means-end actions, but such sequences are quite rare in the natural behavior of nonhuman animals. Given recent reports about the performance of various nonhuman animals in different means-end tasks, it seems that at least some species may potentially possess a basic concept of means-end reasoning that is not directly reliant on perceptual features. However, given the likely perceptual origins of learning about means-end relations, researchers, in general, should be cautious in interpreting how animals solve such problems, especially when the visual characteristics of the task are salient.

Cross-References

- ► Analogical Reasoning
- ► Associative Learning
- ► Causal Reasoning
- ► Comparative Cognition
- ► Comparative Psychology
- ► Decision-Making
- ► Embodied Cognition
- ► Goal-Directed Behavior
- ► Insight
- ► Intelligence
- ► Intentionality
- ► Planning
- ► Problem-Solving
- ► Spatial Relations
- ► String-Pulling
- ► Tool Use

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