Associative Learning as Higher Order Cognition: Learning in Human and Nonhuman Animals From the Perspective of...

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RUNNING HEAD: PROPOSITIONS AND RFT

Associative learning as higher-order cognition: Learning in human and nonhuman animals from the perspective of propositional theories and Relational Frame Theory

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Abstract

We aim to provide a new perspective on the old debate about whether evidence for higher-order cognition in nonhuman animals can be reinterpreted in terms of associative learning. Our starting point is the idea that associative learning is best thought of as an effect (i.e., the impact of paired events on behavior) rather than a specific mental process (e.g., the formation of associations). This idea allows us to consider (a) propositional theories according to which associative learning is mediated by higher-order mental processes akin to problem solving and (b) Relational Frame Theory that allows one to think of seemingly simple associative learning effects as instances of a complex phenomenon known as arbitrarily applicable relational responding. Based on these two theories, we argue that (a) higher-order cognition and associative learning are not necessarily mutually exclusive and (b) a more sophisticated conceptualization of higher-order cognition is warranted.

Keywords: associative learning, cognition, relational frame theory

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Almost since the conception of (comparative) psychology as a scientific discipline, a debate has been raging about whether nonhuman animals possess higher-order cognitive abilities such as language and reasoning. Virtually each time that a new piece of evidence for higher-order cognition in nonhuman animals was put forward, attempts were made to account for it in terms of associative learning (e.g., Haselgrove, this issue; Heyes, 2012). In this paper, we aim to provide a new perspective on this old debate. As a first step in the development of our argument, we point out that associative learning is best conceived of as an effect rather than as a mental learning mechanism. This highlight the fact that associative learning might be mediated by higher-order mental processes and might be similar to higher-order phenomena such as problem solving and verbal behavior. We then review two ways in which associative learning has actually been thought of in terms of higher-order cognition. First, propositional models postulate that associative learning is mediated by propositional processes that have much in common with those involved in problem solving. Second, Relational Frame Theory (RFT) implies that associative learning might have a lot in common with phenomena such as language and reasoning. We therefore conclude that higher-order cognition and associative learning are not necessarily mutually exclusive. Based on ideas put forward in RFT and propositional models, we also highlight the need for more fine-grained ideas about higher-order cognition.

Associative learning as an effect

In line with previous proposals (e.g., Eelen, 1980; Rescorla, 1988), we define "associative learning" as an effect, more specifically, as the impact of paired events on behavior (see De Houwer, Barnes-Holmes, & Moors, 2013). Whereas all types of learning involve an impact of regularities in the environment on behavior, associative learning refers to that subclass of learning effects in which the change in behavior is due to a regularity in the presence of multiple events (rather than regularities in the presence of one stimulus as is the case in nonassociative forms of learning). Associative learning itself encompasses different subclasses, most importantly classical conditioning (i.e., changes in behavior that are due to the pairing of stimuli) and operant conditioning (i.e., changes in behavior that are due to the pairing of stimuli and behavior).

Importantly, as an effect, associative learning could be mediated by a variety of mental processes. It is often assumed that associative learning is due to the formation of associations in memory, be it the formation of associations between stimulus and response representations (i.e., so-called S-R theories; e.g., Byrne & Bates, 2006) or associations between two stimulus representations (i.e., so-called S-S theories; see Bouton, 2007, for a review). When conceived of as an effect, however, associative learning could be mediated by other, more complex mental processes. Later on in the paper, we described propositional models as one set of models that actually postulates the involvement of complex mental processes in associative learning.

Separating effect from mental mechanism also highlights that much can be learned about associative learning as an effect independent of what we know about the mechanism that drives associative learning. In fact, within the functional tradition in psychology, researchers focus on environment-behavior relations rather than on the mental processes that mediate these relations. From this empirical knowledge about the relation between environment and behavior, they try to distill general behavioral principles that have precision (it should be clear when the principle applies), scope (the principle should apply to a wide range of individual behaviors), and depth (it should not contradict known principles at other levels of explanation; see Chiesa, 1992, 1994; Hayes, Barnes-Holmes, & Wilson, 2012). As we will see later on, complex phenomena such as language and reasoning have also been conceptualized as instances of specific behavioral principles. More importantly for the present purposes, it has been argued that associative learning, language, and reasoning might be instances of the same principle. This claim implies that associative learning might depend on the same environmental factors as language and reasoning.

In sum, when conceptualized as an effect, it is not only possible to think of associative learning in terms of higher-order cognition; it has actually been thought of in this manner, namely in two specific ways. First, within cognitive psychology, it has been proposed that associative learning as an effect is mediated by higher-order mental processes that are similar to the processes that mediate higher-order phenomena such as problem solving. Second, within functional psychology, it has been argued that associative learning effects might be functionally similar to higher-order phenomena such as language and reasoning. Please note that we use the term “higher-order phenomena” at the functional level to refer to a particular set of behavioral phenomena whereas the term “higher-order mental processes” is used at the cognitive level to refer to a set of mental processes that are assumed to mediate those higher-order phenomena. The term “higher-order cognition” will be used whenever a statement could apply to both levels. We realize that the qualifier “higher-order” lacks precision and has little meaning at the functional level of analysis but we continue to use it because it is central within the debate that we address in this paper.

In the following sections, we review these cognitive and functional accounts with the aim of sketching how associative learning can be thought in terms of higher-order cognition.

This sketch also allows us to highlight the need for a more sophisticated understanding of higher-order cognition.

Propositional theories of associative learning

Core assumptions of propositional theories

Propositions can be defined as informational units that specify not only elements but also the type of relation between those elements (see Lagnado, Waldmann, Hagmayer, & Sloman, 2007, for an excellent discussion). For instance, the propositions “substance X in the blood causes cancer” and “substance X in the blood is the effect of cancer” are both propositions about the elements “substance X” and “cancer”. However, both convey different information because they diverge in the way that those elements are said to be related. This difference is far from trivial. For instance, a medic would undertake entirely different actions depending on whether substance X is the cause or an effect of cancer (e.g., only in the former case would it make sense to filter the substance from the blood in order to cure the cancer). Whereas propositions can encode relational information, associations do not specify the way in which elements are related. Hence, one could argue that propositions can be informationally richer than associations. Moreover, whereas propositions are statements about a state of affairs in the world, associations are not statements but (hypothetical) structures in the (mental) world. Propositions therefore have a truth value (i.e., correspond to a certain extent to states in the world) whereas associations do not (Lagnado et al., 2007).

Propositional models of associative learning have in common the assumption that the impact of paired events on behavior is mediated by the formation of propositions in memory (e.g., De Houwer, 2009; Mitchell et al., 2009). For instance, if someone experiences the systematic pairing of a tone and a shock, these paired events will result in fear for the tone only after a proposition about the relation between the tone and shock has been formed (e.g., “the tone predicts the shock”). Typically, it is assumed that propositions are formed in a nonautomatic manner, that is, only when organisms have the time, motivation, and resources to do so. Moreover, the proposition has to be entertained consciously at some point in time. Hence, from a propositional point of view, associative learning typically depends on an active, purposeful, effortful, and conscious process of discovering relations in the world, much akin to the process of problem solving. Just like problem solving, sometimes the solution (e.g., the discovery of a relation) can arise seemingly without effort, but most often it does require intention and time (De Houwer, 2009). In sum, propositional models postulate that associative learning as an effect depends on a mental process that could well qualify as a higher-order mental process.

Although the assumption that proposition formation is nonautomatic has been emphasized in the literature (e.g., Mitchell et al., 2009), we believe that the core of propositional models lies in the informational content of propositions as compared to associations. The fact that propositions specify how events are related is in two ways crucial for determining the properties of associative learning. First, it necessitates that associative learning are mediated by a constructive mental process. As discussed by Lagnado et al. (2007), the mere co-occurrence of events most often provides too little information to determine how events are related. For instance, the fact that substance X is found more often in cancer patients than in healthy controls does not allow one to determine whether X is a cause of cancer or an effect of cancer. More generally, covariation in the environment does not fully constrain inferences about the structure of the environment (Lagnado et al., 2007). In order to determine how events are related, the organism must draw upon additional information such as elements in the current context or events in the history of the organism. Hence, propositional models imply that associative learning is highly context dependent and constructive. Just like perception and memory, learning depends not only on the events in the environment but on how these events are constructed (De Houwer, 2014; also see Dwyer & Waldmann, this issue).

Second, because relational statements about the world have a truth value, propositions allow for inferences. That is, new propositions can be derived from existing propositions in such a way that the new propositions inherit a truth value based on the truth value of the existing propositions. The fact that propositions allow for inferences again highlights the constructive nature of associative learning. The current context and past history of an organism determine not only propositions about the way in which currently paired events are related but also provide a wealth of prior propositional knowledge that can be combined with newly acquired propositions in order to generate new propositions.

It is important to realize, however, that although propositional theories *allow* for the possibility that behavior is in line with inferences, they do not imply that behavior is *necessarily* based on logical inferences (see De Houwer, 2014, for a more detailed discussion). Most importantly, after they have been formed and stored in memory, propositions can be retrieved automatically. For instance, retrieval could occur even when there is little time, resources, or motivation to retrieve those propositions. Hence, it is certainly not the case that propositional models allow only for instances of learning in which the change in behavior can be inferred in a logical, rational manner from the propositions that have been formed (see Shanks, 1990). Instead, learned behavior can be irrational, for instance, because it reflects automatically retrieved propositions that are no longer endorsed (De Houwer, 2014; Mitchell et al., 2009). Hence, although rational learning effects (i.e., changes in behavior that can be logically inferred from the paired events) support propositional models (because propositions allow for inferences), irrational learning effects do not invalidate propositional models. One could, however, argue that propositional models that allow for an automatic, non-inferential activation of propositions, are in a sense associative in that they incorporate an associative (i.e., similarity-based) retrieval mechanism, albeit an associative mechanism that operates on propositional rather than associative representations. More generally, it is important to realize that distinctions in terms of representational content (e.g., propositions or associations) do not necessarily map directly onto distinctions in terms of processes that operate on representations (e.g., associative activation or rational inferences; see Moors, 2014). Propositional models (which focus on the content of the representation) cannot therefore be equated with inferential models (which focus on the nature of the operating process).[1]

Evidence for propositional models in human and nonhuman animals

Given that the core of propositional models concerns the relational content of the representations that mediate associative learning, it is unsurprising that the strongest evidence for propositional models comes from studies that examined the impact of relational information on associative learning. Most of these studies were conducted in the context of research on blocking in human contingency learning (see De Houwer & Beckers, 2002, and Shanks, 2010, for reviews). In human contingency learning studies, participants receive information about a series of events in which cues and outcomes can be present. Based on this information, they afterwards judge the strength of the relation between a cue and

[1] One could also argue that current propositional models and association formation models are situated at different levels of analysis. Although they both refer to the mental processes and representations that mediate associative learning effects, propositional models focus on the informational content of representations without specifying the representational format of those representations whereas association formation models focus on the representational format of representations (i.e., the way in which information can be represented and processed). From this perspective, it might be possible to develop an association formation model that represents and processes propositional information. Such a model would qualify as a propositional model if it successfully encodes the informational content that is central to propositional models (i.e., relational information; see De Houwer, 2014).

outcome. In a highly influential paper, Dickinson et al. (1984) put forward the idea that human contingency learning might depend on the same association formation processes as those that operate in animal conditioning. If this is the case, then phenomena discovered in animal conditioning studies should also arise in human contingency learning. Dickinson et al. looked to the phenomenon of blocking because it had been crucial in the development of association formation theories of classical conditioning in nonhuman animals (e.g., Rescorla & Wagner, 1972). Blocking refers to the finding that AX+ trials (stimuli A and X are followed by the unconditioned stimulus or US) do not lead to changes in responding to X if the AX+ are preceded by A+ trials (stimulus A alone is followed by the US). Most association formation models explain this effect by postulating that the prior formation of the A-US association in memory blocks the formation of the (redundant) X-US relation. Dickinson et al. demonstrated that blocking can be found also in human contingency learning, which they saw as support for the idea that human contingency learning depends on the same association formation processes as classical conditioning in nonhuman animals.

From a propositional point of view, however, blocking effects could be due to causal reasoning. If organisms conceive of A and X as potential causes of the US and if they assume (based on their prior experience with causal stimuli) that the effect of different causes is additive, then they can infer on the basis of A+ and AX+ trials that X is not a cause of the US. If X was a cause of the US, then the US should be different (e.g., more likely to occur or more intense) on AX+ trials than on A+. Hence, counterfactually, the fact that the US is identical on A+ and AX+ trials indicates that X is not a cause of the US. Waldmann and Holyoak (1992) pointed out that this explanation implies that blocking should depend on information about the relation between the cues and the US. More specifically, if participants are told that the cues A and X are potential effects of the US (e.g., A and X are substances in the blood that might be effects of cancer) rather than potential causes of the US (e.g., A and X are potential causes of cancer), then blocking should not occur. When A and X are potential effects, there is no reason to expect that the US should be different on A+ than on AX+ trials. Hence, the fact that the US is identical on A+ and AX+ trials cannot be used to dismiss X as a potential effect of the US. Waldmann and Holyoak (1992; Waldmann, 2000) showed that blocking in human contingency learning is indeed reduced when cues are said to be potential effects of the US (but see López, Cobos and Caño, 2005). In a similar vein, Beckers, De Houwer, Pineno, and Miller (2005) reasoned that blocking should not occur when organisms have reasons to doubt the assumption that the impact of causes should be additive. In line with this prediction, blocking was greatly reduced when they exposed human participants to a pretraining phase in which cues other than A and X were shown not to have additive effects (e.g., by showing C+, D+, CD+ trials).

This and other evidence (see De Houwer, Beckers, & Vandorpe, 2005, Mitchell et al., 2009, and Shanks, 2010, for reviews) led to a general consensus amongst scholars of human contingency learning that at least some instances of associative learning in humans are mediated by propositional knowledge (e.g., McLaren et al., 2014; Mitchell et al., 2009). The main debate now centers on whether all instances of associative learning are propositionally mediated or whether some instances are due to the formation of associations in memory (see De Houwer, 2014, and McLaren et al., 2014, for opposing positions in this debate). More relevant for the present purposes, the development of propositional theories of associative learning also led to the proposal that at least some instances of associative learning in nonhuman animals might be mediated by propositional knowledge. In line with this idea, Beckers, Miller, De Houwer, and Urushihara (2006; also see Wheeler, Beckers, & Miller, 2008) observed that nonadditivity pretraining (C+, D+, CD+) reduces blocking after A+ and

AX+ trials in rats. Attempts have been made to explain the findings of Beckers et al. (2006) in terms of association formation models (e.g., Haselgrove, 2010; Schmajuk & Larrauri, 2008), although these have taken the form of "existence proofs" of associative accounts of the observed data rather than direct refutations of propositional accounts. In addition, questions have been raised about the adequacy of the associative alternatives (see Guez & Stevenson, 2011; Mitchell et al., 2009, pp. 194-195). Hence, the data of Beckers et al. cannot simply be dismissed as evidence for the claim that nonhuman animals can reason causally on the basis of propositional knowledge (see Blaisdell, Sawa, Leising, & Waldmann, 2006, and Laurent & Balleine, 2015, for additional evidence).

Summary

From the perspective of propositional models, associative learning itself might (sometimes) be mediated by higher-order mental processes. Even in nonhuman animals, it might well be "that lower-order associative learning should be reduced to higher order causal induction, rather than vice versa" (Waldmann & Holyoak, 1992, p. 235). As we discuss in more detail later on, this argument forces us to rethink the question of whether evidence for higher-order cognition in nonhuman animals can be explained in terms of associative learning.

Relational Frame Theory

Core assumptions of RFT

Whereas propositional models evolved within the cognitive tradition in psychology, Relational Frame Theory is situated within the functional tradition. Functional researchers are interested primarily in environment-behavior relations because their aim is to predict-and-influence behavior (Chiesa, 1992; Hayes & Brownstein, 1986). Although cognitive and functional researchers typically have different scientific goals and values, this does not mean that they cannot fruitfully interact. For instance, cognitive theories might be useful to help generate new predictions about environment-behavior relations. Vice versa, functional knowledge (i.e., knowledge of environment-behavior relations) constrains cognitive theories because those theories should specify a mechanism via which elements in the environment have specific effects on behavior under specific conditions. As such, contrary to what is often assumed, functional and cognitive psychology are not mutually exclusive but could even be mutually reinforcing (De Houwer, 2011).

Although cognitive researchers necessarily also deal with environment-behavior relations in their research (if only by manipulating independent variables and registering dependent variables), functional researchers are committed to a specific functional approach that can be described as analytic-abstractive. More specifically, the aim of functional researchers is to formulate general principles about the relation between environment and behavior that subsume many specific instances of environment-behavior relations. One such principle is reinforcement. It refers to an increase in the frequency of behavior that results from the relation between the behavior and its outcome. This principle can be verified in a precise manner by examining the impact of variations in outcomes on behavior. It has a broad scope in that it can be used to explain a wide variety of behaviors, ranging from lever pressing by rats in a Skinner box to temper tantrums in children. It has depth in that it is in line with known principles in other sciences such as the selection of behavior during the evolution of a species.

Skinner (1957) famously attempted to explain higher-order phenomena such as verbal behavior in terms of learning principles such as reinforcement. This account has been criticized heavily (e.g., Chomsky, 1959; Hayes et al., 2001), although it should be acknowledged that a number of relatively successful language remediation programs have emerged from Skinner's work. What is less well known, at least outside of functional psychology, is that the functional analysis of language did not stop with Skinner's analysis of verbal behavior. For example, during the 1980's and 1990's, Relational Frame Theory (RFT) was developed as a novel functional account of language and thinking (Hayes et al., 2001; see Dymond & Roche, 2013, for recent reviews, and Törneke, 2010, for an accessible introduction to RFT). The core of RFT is the idea that human language and thinking are instances of a complex behavioral principle known as Arbitrarily Applicable Relational Responding (AARR).

AARR is one type of relational responding, a phenomenon that is often studied in the context of operant behavior, more specifically operant behavior that is controlled not by an individual stimulus (e.g., the presence of a light in a Skinner box) but by the relation between stimuli. Consider the task depicted in Figure 1. On each trial, a sample stimulus is presented in the middle of the screen together with two comparison stimuli that appear at the bottom of the screen. Imagine that food is given when the organism selects the key that is situated below the comparison stimulus that is identical to the sample stimulus (as represented by the arrows in Figure 1). Following a number of training trials with different types of stimuli (i.e., multi-exemplar training), test trials are presented with stimuli that had not been presented during the training phase. Many studies with many species have shown that on the test trials, organisms select at above chance levels the comparison stimulus that is identical to the sample even though they have never before been reinforced for selecting this stimulus. Such a result demonstrates that organisms can respond relationally, in this case based on whether the sample and comparison stimulus are physically identical (Stewart & McElwee, 2009). Research has shown that human and nonhuman organisms can respond to a variety of relations between the physical properties of stimuli, including identity and size (see Lazareva, 2012, for a review).

Relational responding that is based on nonarbitrary properties such as the physical form of stimuli, and/or the temporal sequences in which the stimuli are presented, qualifies as nonarbitrarily applicable relational responding (NAARR; see Honey & Watt, 1998, for another demonstration). Verbally-able humans, however, can respond relationally even if stimuli do not share any consistent physical properties or are unrelated in terms of specific sequential or temporal parameters. Consider the task depicted in Figure 2. On each trial, a sample and two comparison stimuli are presented that do not share a physical property or training history in any systematic manner. The experimenter randomly picks for each sample stimulus one of the two comparison stimuli and always reinforces participants if they select the comparison stimulus that was randomly assigned to a sample stimulus. During subsequent test trials, participants are confronted with novel choice situations. Nevertheless, their choices in those situations typically reflect a systematic pattern. More specifically, during the test trials, participants behave *as if* the stimuli are equivalent (Sidman, 1994, for a review). For instance, after being reinforced for selecting "ù" in the presence of "*" and selecting "%" in the presence of "ù", during a test (i.e., without any reinforcers, prompts or instructions), participants may well select "*" in the presence of "ù" and "%" in the presence of "*". That is, participants respond as if "*" is the same as "ù", "ù" is the same as "%", and "*" is the same as "%". This pattern of choices qualifies as one instance of AARR, namely acting as if stimuli are equivalent to one another.

Research has shown that humans can act not only as if stimuli are equivalent but also as if they are opposite, as if one is smaller than the other (i.e., a comparative relation), as if one encompasses the other (i.e., a hierarchical relation) and so on (see Hughes & Barnes-

Holmes, in press, and Dymond & Roche, 2013, for recent reviews). It has also been demonstrated that the type of relational response depends on contextual cues in the environment. Assume, for instance, that participants are first trained to select physically identical stimuli in the presence of contextual cue A but to select a physically different stimuli in the presence of cue B. When they are afterwards given the training described above (i.e., reinforced for selecting "ù" in the presence of "*" and selecting "%" in the presence of "ù") in the context of cue A, they will respond as if those three stimuli are equivalent (e.g., increased probability of selecting "*" in the presence of "ù" and "%" in the presence of "*"). However, when that same training is given in the presence of cue B, a completely different pattern of choices emerges. In this case, people will respond as if "*" is opposite to "ù", "ù" is opposite to "%", and "*" is the same as "%" (Steele & Hayes, 1991). Hence, contextual cues can dramatically alter the type of relational responding (e.g., acting as if stimuli are equivalent or as if they are opposite). Importantly, it has been demonstrated that these contextual cues cannot only be discrete stimuli but even the mere fact that stimuli are paired in some manner can function as a cue for acting as if those stimuli are related in a certain way (i.e., as if they are equivalent, see Smyth, Barnes-Holmes, & Forsyth, 2006). Finally, RFT also postulates that AARR depends on the presence of an extensive learning history that most humans go through as a child and that changes them into verbal beings (see Hayes et al., 2001). Some support for these ideas comes, for example, from studies showing that anomalies in AARR that arise in certain (e.g., developmentally delayed) individuals can be remediated by providing additional training that is thought to be essential for AARR to emerge.

RFT entails that language and thinking are instances of this general principle known as AARR. It is well beyond to scope of this paper to explain how exactly language and thinking can be conceptualized in this manner. We limit ourselves to pointing out that this functional analysis involves more than simply redescribing language and thinking. Similar to an analysis of unwanted tantrums in a young child in terms of reinforcement contingencies, which attempts to identify the environmental variables that control the behavior in question, the RFT analysis attempts to specify the relevant environmental variables that produce and moderate language and thinking. Both types of analyses aim to explain a particular behavioral event (i.e., the effect of a verbal instruction on salivation, or tantrums in a young child) in terms of a general principle (i.e., AARR, reinforcement). In so doing, such principles serve to highlight potential ways to predict-and-influence the phenomenon (e.g., by changing the outcomes of tantrums or by providing specific types of training to remediate language problems; see Rehfeldt & Barnes-Holmes, 2009, for a detailed treatment of how RFT may be applied to language deficits).

RFT and associative learning

In the context of the present paper, it is important to highlight two potential implications of RFT. First, given that the mere pairing of stimuli can function as a relational cue signaling that stimuli are related in a certain way, it is possible that even seemingly simple instances of associative learning are actually instances of AARR. Imagine that you repeatedly see an unknown person A in the company of your friend whereas you see another unknown person B together with your enemy. As a result of these pairings, you like person A more than person B. Before RFT, most functional researchers would probably have argued that these changes in liking are instances of classical or Pavlovian (evaluative) conditioning (i.e., changes in liking due to the mere pairing of stimuli; see Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010, for a review). However, from the perspective of RFT, the change in liking could also be an instance of AARR in which the pairing of stimuli is a contextual cue for the equivalence of person A and your friend, on the one hand, and person B and your enemy, on the other hand. In the latter case, the change in liking would not simply be a function of the pairings but would also depend in very specific ways on contextual cues and the learning history that gives rise to AARR. As such, it would be much more akin to complex phenomena such as language and thinking than to "simple" associative learning.

This novel perspective has important implications for research on (evaluative) conditioning (see Hughes, De Houwer, & Barnes-Holmes, in press, for a review). For instance, in contexts where pairings signal a relation of opposition rather than equivalence (e.g., in competitive situations where adversaries are singled out to settle their differences), pairing a neutral person with a liked person might result in a disliking of the neutral person (see Fiedler & Unkelbach, 2011, for evidence in line with this prediction). Such a result would support the idea that stimulus pairings are not a mere cause of changes in liking but a cue for the nature of the relation between the paired stimuli (De Houwer & Hughes, 2015). In sum, from the perspective of RFT, "simple" associative learning is not necessarily as simple as it may seem (see Leader, Barnes, & Smeets, 1996, for relevant empirical and conceptual analyses of this basic argument).[2]

Second, the learning history that is assumed to be crucial for AARR is so extensive and complex that it is probably experienced only by humans. This could explain why, despite

[2] Complexity at a functional level refers to the number and nature of the moderators of behavioral effects, as well as the way in which these moderators interact. From the perspective of AARR, associative learning is more complex than is often assumed in that it can be moderated by factors that are typically not considered to be moderators of associative learning (e.g., the learning history that leads to AARR, specific contextual cues). Complexity at the level of cognitive mechanisms depends on the number and nature of the processing steps involved in the mechanism, as well as the interactions between different steps in the mechanism (e.g., feedback loops). Propositional models are more complex than association formation models in that they postulate representations that can contain more information than typical associations (i.e., relational information). There is not necessarily a one-to-one relation between complexity at the functional and mechanistic level. In principle, complex functional relations can be due to simple mechanisms. Nevertheless, complexity at the functional level often requires complexity at the mechanistic level simply because the mechanism needs to produce a larger set of more complex functional relations. Hence, we believe that complexity at the two levels does tend to be correlated.

extensive efforts, evidence for AARR in nonhuman animals is extremely limited (see Lionello-DeNolf, 2009, for a review). Some have argued that aspects of AARR have been found in nonhuman animals and that failures to find AARR in nonhuman animals might be related to procedural factors (e.g., Zentall et al., 2014). Others, however, pointed out that the flexibility and complexity of AARR as observed in humans by far exceeds that seen in nonhuman animals (Hughes & Barnes-Holmes, 2014). Interestingly, the postulate that language and thinking are instances of AARR fits well with evidence suggesting that the evolutionary divide between human and nonhuman animals entails all kind of instances of AARR, including language and abstract thinking (Hayes et al., 2001). Note, however, that RFT allows for the possibility that this divide may be bridged by providing nonhuman animals with a learning history that is modeled on the behavioral history that is assumed to be necessary for AARR to arise in humans (Hughes & Barnes-Holmes, 2014). Whether this potential can be realized is an empirical question.

Summary

After Skinner's (1957) failure to account for higher-order cognition in terms of functional principles such as reinforcement, some functional psychologists moved on to propose novel accounts of language and thinking, such as RFT. At the core of RFT is the idea that language and thinking are in essence instances of AARR, that is, context-specific ways of acting as if events are related in a certain manner. From the perspective of RFT, even seemingly simple instances of associative learning could qualify as instance of AARR. However, (complex) instances of AARR seem to occur only in humans.

On the relation between propositional theories and RFT

In order to understand the relation between propositional theories and RFT, it is vital to realize that both are formulated at different levels of analysis. Whereas RFT is a functional theory that aims to explain behavior in terms of environmental events, propositional theories are cognitive theories that explain the impact of the environment on behavior in terms of mental processes (De Houwer, 2011). Again, consider the example of classical (evaluative) conditioning in which person A is liked more than person B because A co-occurs with a friend and B co-occurs with an enemy. Functional accounts explain the change in liking in terms of the environmental events. For instance, a functional account in terms of “simple” conditioning might argue that the changes in liking are due to the contingent and contiguous pairing of the stimuli. A functional account in terms of RFT might also explain the changes in liking in terms of the stimulus pairings but in a way that is moderated by specific contextual cues and the learning history that gives rise to AARR (Hughes et al., in press; Leader, et al., 1996; Smyth et al., 2006). Both functional accounts, however, are neutral with regard to the mental mechanism by which events in the environment lead to the changes in liking. Propositional theories of classical (evaluative) conditioning, on the other hand, do specify such a mechanism. More specifically, they postulate that stimulus pairings exert an impact on liking because of the formation of propositions in memory (e.g., De Houwer, 2009; Mitchell et al., 2009).

Because propositional theories and RFT are situated at different levels of analysis, they are not necessarily in conflict with one another (De Houwer, 2011; Hughes et al., in press). For instance, propositional theories seem to fit very well with the central idea of RFT that seemingly simple instances of associative learning depend on much more than the mere pairing of stimuli. As we pointed out earlier, mere pairings often provide insufficient information to determine how the paired stimuli are related (e.g., whether substances in the blood are causes or effects of cancer). The contextual stimuli and learning history that RFT highlights as moderators of AARR might well be the environmental events that are crucial for the formation of propositions about how stimuli are related. Vice versa, instances of AARR could well be mediated by the formation of propositions. In contrast, the association formation models that are currently available in the literature cannot account for the properties of AARR. Although we do not exclude the possibility that, at some point in the future, AARR may be explained in terms of a mechanistically simple association formation model, it seems more likely to us that a successful mental account of AARR will need to postulate the formation of representations that encode information about how events are related.

There are, however, also points at which propositional theories and RFT seem to diverge. One limitation of propositional theories of associative learning as they are currently formulated (e.g., De Houwer, 2009; Mitchell et al., 2009) is that they have little to say about the difference between NAARR and AARR. In both cases, responding is relational and thus seems to necessitate some kind of mental representation that contains information about the type of relation between stimuli (e.g., “identical to”, “larger than”, …). According to RFT, on the other hand, NAARR and AARR are fundamentally different phenomena that are determined by different aspects in the environment (i.e., NAARR is controlled largely by the physical properties of the related stimuli, and/or other physical parameters, whereas AARR depends on contextual cues and a highly elaborated learning history). Moreover, whereas NAARR can be observed in nonhuman animals, complex instances of AARR seem to occur only in humans. In the next section, we point out that both the commonalities and the differences between propositional theories and RFT, as well as the theories as such, have important implications for the debate on higher-order cognition in nonhuman animals.

Implications

A new perspective on the question of whether evidence for higher-order cognition can be explained in terms of associative learning

Until now, the debate between higher-order cognitive accounts and associative learning accounts was conceptualized most often in terms of competing mental mechanisms. Whenever a piece of evidence for higher-order mental mechanisms in animals was put forward, the question was raised about whether this evidence could also be accounted for in terms of some type of association formation mechanism. This conceptualization is problematic in that it does not distinguish between associative learning as an *effect* and association formation as a *mechanism*. As result of this conceptual confound, arguments against higher-order mental process accounts were framed most often in terms of a possible impact of stimulus pairings on behavior. That is, whenever an observed change in behavior could somehow be attributed to the pairing of events, this was taken as an argument against an account in terms of higher-order mental processes. The logic underpinning this conclusion seems flawed because effects of paired events (i.e., associative learning effects) are not necessarily due to association formation but could themselves be mediated by higher-order mental processes such as the nonautomatic formation of propositions. Before evidence for the impact of stimulus pairings on a specific behavior (i.e., evidence for associative learning) can be used to argue against an explanation of this behavior in terms of higher-order mental processes, one has to demonstrate that the impact of stimulus pairings on the to-be-explained behavior is not mediated by higher-order mental processes. We believe that this important additional requirement has never before been acknowledged in the longstanding debate about higher-order cognition in nonhuman animals.

Consider the example that Heyes (2012) uses to illustrate the debate on higher-order cognition in nonhuman animals, in which she refers to the study by Horner, Carter, Suchak, and de Waal (2011), who tested chimpanzees on the Prosocial Choice Test (PCT). The crucial result of this study was that chimpanzees selected more often a token that resulted in food for themselves and for another chimpanzee than a token that resulted only in food for themselves. Based on these findings, Horner et al. concluded that chimpanzees are sensitive to the needs of others, that is, they spontaneously act in a prosocial manner. Heyes, however, put forward an alternative account of the findings in terms of associative learning. She pointed out that each piece of food was packaged in a wrapping. Hence, the sound of unwrapping systematically preceded the pleasant taste of food. This sound-food pairing could thus have resulted in a liking of the unwrapping sound. Chimpanzees might thus have selected the "prosocial" token because a choice for this token was followed by two unwrapping sounds (one produced by the chimpanzee that made the choice and one produced by the other chimpanzee) whereas a choice for the "selfish" token was followed by only one unwrapping sound (produced by the chimpanzee that made the choice).

The first thing that we want to note about this clever alternative explanation is that it is formulated in terms of associative learning as an effect, that is, it refers only to the impact of paired events on behavior. Nevertheless, Heyes (2012) seems to conceive of "associative learning" as a mechanism rather than an effect, more specifically as some kind of association formation mechanism. This is, for instance, indicated by the fact that she contrasts associative learning with inferential, propositional processes:

> *"the majority of even the most enthusiastic contemporary supporters of associative learning would not deny that inferential processes play crucial roles in human cognition. They are subscribers to some kind of 'dual-process' theory … assuming*

that humans use both associative learning and inference processes to find out about the world. Furthermore, the majority would readily agree that, at least in humans under some circumstances, conditioning phenomena can be produced by inferential rather than associative processes. However, along with the brain imaging data discussed earlier, carefully designed experiments on human causality judgements have shown that, in many cases, complex human decision-making is controlled by associative learning." (see Heyes, 2012, p. 2698)

A second point to note is that the alternative explanation put forward by Heyes (2012) does shed important new light on Horner et al. (2011) findings. First, it raises the *possibility* that the observed phenomenon can be explained in terms of a simple association formation mechanism. If the so-called pro-social behavior of the chimpanzees is an instance of associative learning and if some instances of associative learning are due to a simple association formation mechanism, then it is possible that the phenomenon is one of those instances that depends on association formation. Second, Heyes' arguments point to the potential role of general purpose mechanisms (i.e., whatever mechanism that underlies associative learning, be it associative or propositional) rather than specific cognitive abilities (e.g., empathy).

It is crucial to realize, however, that Heyes' (2012) alternative explanation does not rule out a contribution of higher-order processes. As we pointed out earlier, arguments in terms of associative learning as an effect do not exclude the possibility that behavior is driven by any possible type of higher-order mental process. For instance, even if the choice for the so-called prosocial token was a function of the contingencies between the unwrapping sound and food and between the token and the number of unwrapping sounds, it could still be the case that these contingencies influenced choice only because the chimpanzee formed certain propositional representations in memory about the relationship between a specific token and the sound of multiple wrappers. Based on the argument that we have developed in this paper, this possibility should be taken seriously. One cannot simply dismiss a phenomenon as evidence for higher-order mental processes in nonhuman animals because it is an instance of associative learning. Knowledge about the contribution of associative learning effects can, however, help constrain theories about the environmental determinants of the observed change in behavior and the mental processes that underlie the observed behavior. In our opinion, this type of contribution from associative learning research is more constructive and productive than the narrow debate about whether all higher-order cognition can be reduced to association formation processes.

The need to develop more fine-grained ideas about different types of higher-order cognition

So far, many contributions to the debate on higher-order cognition in nonhuman animals were built on the premise that there are two types of mental processes that can drive behavior: higher-order mental processes and low-level associative processes. As Heyes (2012) correctly pointed out, this premise ignores the fact that there are at least two types of associative processes; the formation of S-R associations and the formation of S-S associations. Whereas the former could indeed qualify as "low-level", it is typically assumed that the formation of S-S associations qualifies as cognitive in that it depends on mental faculties such as attention and memory. Heyes therefore put forward the idea that one should consider three types of processes that could underlie (human and nonhuman) behavior: low-level processes (i.e., formation of S-R associations), cognitive processes (including the formation of S-S associations), and super-cognitive processes (e.g., rational inferences). In Heyes' terms, the question then becomes whether evidence for super-cognitive processes in nonhuman animals can be explained on the basis of low-level processes *or* cognitive processes.

Although we agree with Heyes (2012) that association formation processes are not necessarily non-cognitive, we also believe that the debate on higher-order cognition in nonhuman animals could benefit also from a more fine-grained analysis of what higher-order cognition actually entails. Consider the observation that nonhuman animals show evidence for NAARR but not (or only in a very limited way) for AARR. As we pointed out above, from a propositional point of view, both types of responding are relational and would thus fit with the idea of propositional representations that encode relational information. On the other hand, at least some association formation theories have difficulties accounting for the properties of relational responding (see Lazareva, 2012). However, propositional theories say little about when and why human and nonhuman animals differ in their capacity to NAARR or AARR, simply because they do not refer to those terms. In hindsight, one could argue that these theories do allow for AARR. For instance, proponents of propositional theories (e.g., Mitchell et al., 2009) embraced findings suggesting that nonhuman animals can reason in counterfactual ways (e.g., Beckers et al., 2006; Blaisdell et al., 2006). Assuming that counterfactual reasoning is an instance of AARR, one could thus argue that propositional theories do allow for AARR in nonhuman animals.

In this context, RFT and functional psychology in general could facilitate the development of propositional theories by drawing attention to the distinction between NAARR and AARR (see Stewart & McElwee, 2009) and to the differential role of contextual cues and learning history in these phenomena. For instance, RFT postulates that although the capacity to NAARR is a prerequisite for the capacity to AARR, specific additional learning experiences are required before AARR will arise (Hayes et al., 2001). Input from RFT research could be integrated with existing ideas and theories about propositional reasoning in humans. For instance, there might be different ways of encoding relational information in mental representations. As noted by Penn, Cheng, Holyoak, Hummel, and Povinelli (2009, p. 222), in addition to the fact that propositions encode relational information,

> *"there are many other critical features of propositions … such as the capacity to systematically represent types, variables, roles, and higher-order relations, and to perform rule-governed operations over these representations in an inferentially coherent fashion (Hummel & Holyoak 1997). Crucially, these propositional features do not form a package by nomological necessity (cf. Fodor & Pylyshyn 1988). In our view, nonhuman animals approximate certain features of propositions and not others."*

It would thus be interesting to see how ideas about the different properties of propositions relate to the role of contextual cues and learning history in NAARR and AARR as specified by RFT. Such theoretical work could shed important new light on the differences and commonalities in NAARR and AARR between human and nonhuman animals.

Conclusion

The question of how humans relate to other living organisms is fascinating. In (comparative) psychology, this question has often centered on whether nonhuman animals have higher-order cognitive abilities or whether the evidence for such abilities can be explained also on the basis of associative learning. As is often the case in long-standing and heated debates, at least some of the disagreement can be reduced to conceptual issues. An important conceptual issue concerns the status of associative learning as either an effect or a mental mechanism. When conceived of as an effect, it becomes clear that associative learning might depend on much more than the simple pairing of stimuli and might well be based on higher-order mental processes. This point of view reveals the need for a reconceptualization of the debate on higher-order cognition in nonhuman animals and further developments in our understanding of higher-order mental processes. We hope that our paper will help set the stage for these important new developments.

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Figure Legends

Figure 1. Set up for studying non-arbitrarily applicable relational responding (NAARR).

Figure 2. Set up for studying arbitrarily applicable relational responding (AARR).

Figure 1.

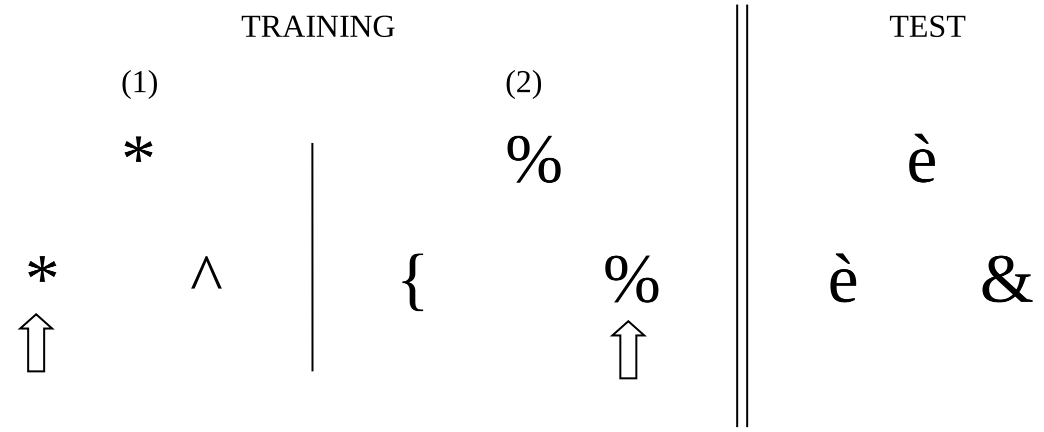

Figure 2.