RUNNING HEAD: PROPOSITIONAL LEARNING

Why a propositional single-process model of associative learning deserves to be defended

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During the past 40 years or so, research on associative learning has been dominated by cognitive association formation theories. These models postulate that the effect of relations between events in the world on behavior is mediated by the formation of associations between the mental representations of those events (see Bouton, 2007, and Pearce & Bouton, 2001, for reviews). Recently, however, it has been proposed that associative learning might be mediated by the formation and truth evaluation of propositions about relations in the world (e.g., De Houwer, 2009; Mitchell, De Houwer, & Lovibond, 2009a; Waldmann, 2000). Although most learning researchers now accept that associative learning can reflect the operation of propositional processes (e.g., Shanks, 2007; Mitchell, De Houwer, & Lovibond, 2009b), many believe that at least some instances of associative learning are mediated by the formation of associations (e.g., Mclaren, Green, & Mackintosh, 1994; Sternberg & McClelland, 2012). As such, most learning researches endorse a dual-process model of associative learning (see Mitchell et al., 2009b, p. 230).

In this chapter, I argue that there is merit in defending the position that all instances of associative learning are due to the formation and truth evaluation of propositions about relations in the environment. I first provide a functional definition of associative learning that is neutral with regard to the mediating processes and thus allows for both associative and propositional accounts of associative learning. After explaining the core assumptions of these accounts, I consider and dismiss several arguments for postulating the existence of an association formation mechanism in addition to a propositional learning mechanism. I then offer several reasons for why it is actually better to avoid a dual-process account of associative learning. Finally, I discuss what the debate on the mechanisms of associative learning teaches us about the merits of dual-process models in general.

What is Associative Learning?

I define associative learning as an effect, that is, as the impact of relations between events in the environment on behavior (De Houwer, 2007; De Houwer, Barnes-Holmes, & Moors, submitted). Whereas some relations involve two stimuli (e.g., a bell and food), others involve a stimulus and a behavior (e.g., pressing a lever and food). Labeling a change in behavior as an instance of associative learning thus implies a hypothesis about the environmental causes of the behavior. In other words, the learned behavior is considered to be an effect of a particular relation in the environment. Importantly, this functional definition of learning does not contain any assumptions about the mental mechanisms by which the relation in the environment causes the change in behavior. Hence, associative learning is an effect that could in principle be due to different types of mental processes. Distinguishing between associative learning as an effect, on the one hand, and associative learning as a mental mechanism, on the other hand, not only maximizes theoretical freedom but also allows one to verify the presence of associative learning without having to verify the presence of a particular mental mechanism (De Houwer, 2007, 2011). To determine whether associative learning has taken place, it suffices to test whether an observed change in behavior is caused by a particular relation in the environment. In laboratory settings, this can be achieved by manipulating the presence of the relation while controlling for other environmental differences. If the manipulation affects the target behavior, one can infer that the behavior was caused by the relation and thus that associative learning has taken place.

Models of Associative Learning

Association Formation Models

All cognitive association formation models postulate that, under certain conditions, relations in the world result in the formation and adaptation of associations in memory which in their turn influence behavior under certain conditions. Different association formation models differ with regard to their assumptions about the conditions under which associations are formed and adjusted, the nature of the representations that are linked via associations (e.g., stimulus or response representations), and the conditions under which associations in memory influence behavior (see Bouton, 2007, and Pearce & Bouton, 2001, for reviews). Although association formation and the impact of associations on behavior is assumed to occur only under certain conditions (e.g., when the presence of stimuli is unexpected; e.g., Rescorla & Wagner, 1972), these mechanisms are often conceived of as being relatively automatic and stimulus-driven (see Mitchell et al., 2009b, p. 231, for a discussion). For instance, it is often assumed that association formation is automatic in that it can occur even when participants are unaware of the relations in the world that drive the formation of those associations or when they have the goal to prevent the formation of associations. Moreover, association formation is stimulus-driven in that it is determined by the objective events as they occur in environment. Most models do assign an active role to the organism, but this active role is explained also in terms of objective events that the organism recently experienced. For instance, several models postulate that the effect of a single pairing of two stimuli on the strength of the association between the representations of those stimuli depends on the extent to which the organism pays attention to the stimuli. However, attention is assumed to be a function of the way in which stimuli have co-occurred in the past (e.g., Mackintosh, 1975; Pearce & Hall, 1980; Rescorla & Wagner, 1972). In sum, although there are important differences between different association formation models, it is safe to say that these models tend to view learning as fairly automatic and stimulus-driven.

Propositional Models

Propositional models of associative learning postulate that the impact of relations in the environment on behavior is mediated by the formation and truth evaluation of propositions about those relations. A proposition is a belief about a state of affairs in the world. Hence, a proposition about a relation between events in the world is a belief about the relation between those events. As such, propositions have an objective truth value, that is, they can correspond in different degrees to the actual state of the environment. Associations between mental representations, on the other hand, do not imply a claim about events in the world and therefore do not have truth value (also see Moors, this volume).

A second difference between propositions and associations is that only propositions can contain information about the type of relation between events (see Lagnado, Waldmann, Hagmayer, & Sloman, 2007, for an excellent discussion of this issue). Events in the world can be related in many different ways. For instance, a substance in the blood of a patient can be either a cause of a disease or an effect of the disease. Knowing the type of relation between events is vital for our understanding and control of the world. For instance, knowing whether a substance in the blood is a cause or effect of a disease determines how useful it is to try to remove the substance from the blood of the patient (Lagnado et al., 2007). This crucial information can be contained within propositions (e.g., “the substance causes the disease”) but not associations. The fact that propositions have a truth value and specify the way in which events are related, opens the possibility to generate and truth evaluate novel propositions based on existing propositions, that is, to make inferences.

Current propositional models incorporate the assumption that the formation and truth evaluation of propositions is a non-automatic process (De Houwer, 2009; Mitchell et al., 2009a). It is thought to involve active problem solving that organisms undertake in order to discover the structure of the world in which they live. Like problem solving, learning can make use of all the mental capacities that organisms have at their disposal. Given that problem solving is typically an intentional, time-consuming and effortful process, one can envisage that associative learning is facilitated when organisms have the goal, the time, and the resources to engage in the formation and truth evaluation of propositions about relations in the world. However, just like problem solving can become more automatic in certain situations as a result of practice, associative learning might also be unintentional, fast, and efficient in certain situations. Nevertheless, current propositional models postulate that it always depends on awareness. More specifically, it is assumed that a relation in the world can influence behavior only after a proposition about that relation has been consciously entertained as being true. Although this assumption is not a logical implication of the idea that associative learning is mediated by the formation of propositions, it does seem reasonable to assume that a belief about the world can only be considered to be a belief once it has been entertained consciously. The processes by which the proposition arises into consciousness or the processes by which it is evaluated as true might well be unconscious, but the proposition itself at some point in time needs to be entertained consciously. The emphasis on consciousness also strengthens the constructive nature of propositional models, that is, their emphasis on the active role of the organism. According to these models, (learned) behavior is determined not by the objective (co-)occurrence of events but by whether and how the (co-)occurrences are constructed and interpreted by the organism. Whereas it is generally accepted that perception and memory involve constructive processes

(Bruner, 1992), propositional models emphasize the idea that associative learning is also based on constructive processes. A contingency between events in the world is psychologically inert until the contingency is consciously appraised as some type of relation between the events (see Hayes, Barnes-Holmes, & Roche, 2001, for related ideas).

Do We Need a Second Mechanism for Associative Learning?

Although propositional models have not (yet) been formalized, they are able to explain a wide range of empirical findings and have generated many new predictions that were verified empirically (see De Houwer, 2009, and Mitchell et al., 2009, for reviews). As a result, most learning researchers now accept the idea that at least some instances of associative learning are mediated by propositional processes (e.g., Mitchell et al., 2009b, p. 230; Shanks, 2007, p. 297). However, very few researchers seem to believe that associative learning always involves the formation and truth evaluation of propositions (see Mitchell et al., 2009b). In this section, I discuss three types of associative learning that are alleged to fall outside of the scope of propositional models: automatic associative learning, irrational associative learning, and associative learning in (certain) non-human organisms. Before I evaluate these proposals, I would like to point out that their validity does not necessarily inform us about the validity of association formation models. Associative learning effects that cannot be explained by propositional models are not necessarily due to association formation processes. The only conclusion would be that a second, non-propositional process needs to be assumed in order to provide a full account of associative learning. In principle, this can be a mechanism other than the formation of associations (see Jamieson, Crump, & Hannah, 2012, for an example).

Association Formation Mechanisms are Needed to Explain Automatic Associative Learning Effects

Automaticity is an umbrella term that refers to the conditions under which an effect or process can occur (De Houwer & Moors, in press; Moors & De Houwer, 2006a). For instance, associative learning could be described as automatic if it occurs independently of certain goals of the organism that learns, even when the organism is not aware of what is learned or that learning takes place, even when the organism is engaged in other tasks or when it has little time. It is reasonable to assume that associative learning can have features of automaticity. For instance, a light that is paired with a painful electric shock is likely to evoke an involuntary galvanic skin conductance response that is by definition hard to control consciously.

Some have argued that automatic instances of associative learning cannot be due to propositional processes simply because these processes are assumed to operate in a non-automatic manner. There are two reasons why this argument is incorrect. First, behavior is always the product of multiple underlying processes. Associative learning, for instance, requires not only the formation of representations but also processes by which these representations influence behavior. Although propositional models do specify that the formation of propositions has certain features of non-automaticity, they do not stipulate that the impact of propositions on behavior is non-automatic. In fact, there are good reasons to assume that propositional knowledge can have uncontrolled effects on behavior. Imagine, for instance, that someone tells you that a tiger is lurking behind your back. If you evaluate this proposition as being true, you are bound to experience all kinds of uncontrolled changes in behavior (e.g., increased heart rate, sweating). Likewise, entertaining the belief that a light will be followed by an electric shock is likely to cause uncontrolled changes in behavior. In fact, providing verbal instructions about the relation between a light and an electric shock has been shown to produce conditioned galvanic skin responses even when light and shock never co-occurred (Cook & Harris, 1937). The effects of consciously entertained propositions on behavior can be automatic also in the sense of fast and efficient. Hence, unlike to what is sometimes assumed, also learning effects that arise in speeded response tasks (e.g., priming tasks) or tasks in which responding occurs under considerable mental load (e.g., when engaging in difficult secondary task) could be due to propositional processes (see De Houwer & Vandorpe, 2010, and Peters & Gawronski, 2010, for evidence supporting this argument).

Also propositions that are no longer consciously entertained might influence behavior in an automatic manner. Once a proposition has been formed, it can be stored in memory. Memory research has shown that information can be retrieved from memory automatically, that is, without intention or consciousness (e.g., Richardson-Klavehn, Lee, Joubran, & Bjork, 1994). Hence, a proposition about the relation between events in the world (e.g., that a light is followed by an electric shock) could be retrieved from memory automatically and thus influence behavior in a fast, efficient, and uncontrolled manner (see Moors, this volume, for an insightful discussion about the conceptual implications of this assumption). An automatically activated proposition might influence behavior even when the proposition can no longer be consciously recalled or when a conflicting proposition is consciously entertained (e.g., that the light will no longer be followed by an electric shock). Hence, propositional models are compatible with instances of associative learning that seem to go beyond or even contradict currently held beliefs. Note, however, that these models are currently silent about when automatically retrieved propositions can overrule currently held beliefs. Without specific assumptions about this issue, propositional models can become impossible to falsify.

There is also a second reason why the existence of automatic associative learning effects does not invalidate propositional models: Very few processes, if any, are fully automatic. It is now generally accepted that different features of (non-)automaticity do not always co-occur (Bargh, 1992; Moors & De Houwer, 2006a). Instead, all processes are likely to possess both features of automaticity and features of non-automaticity. Propositional models emphasize the fact that a relation between events in the world can have an impact on behavior only after a proposition about those events has been entertained consciously, but it is less clear whether the formation of propositions also requires other features of automaticity. Just like problems can sometimes be solved in a non-intentional, efficient, and fast manner, propositions about relations in the world sometimes appear to pop up in our conscious minds when we do not have the intention to detect a relation, very quickly, and without much effort. Although in most cases, the formation of propositions, just like problem solving, is hampered by the absence of motivation, time, and mental resources, it seems reasonable to assume that propositions can sometimes be formed in an unintentional, fast, and efficient manner. Hence, evidence for unintentional, fast, or efficient associative learning effects does not necessarily contradict propositional models.

Because proponents of propositional models emphasize the assumption that the formation of propositions requires consciousness, much of the debate about the validity of propositional models has focused on whether there are instances of unconscious associative learning. Although there have been repeated reports of the impact of relations between events on behavior in the absence of awareness of these relations, many of these reports have been criticized because (1) the reported effects cannot be replicated, (2) the observed changes in behavior were not instances of associative learning (i.e., were not due to relations between events), or (3) consciousness of the relations was not assessed properly (see Lovibond &

Shanks, 2002, and Mitchell et al., 2009a, 2009b, for reviews). It is beyond the scope of this chapter to revisit this debate in detail. However, it might be possible to draw two conclusions on the basis of the existing literature. First, it is striking that there is so little undisputed evidence for unconscious learning in the literature. In contrast, there is clear evidence showing that awareness of relations does strengthen learning (e.g., Dawson & Biferno, 1973; Hoffman & Sebald, 2004; Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010). This suggests that if a non-propositional learning mechanism does underlie associative learning, it does so only under very limited conditions. Second, there are some striking demonstrations of unconscious learning that do appear to challenge propositional models (see Custers & Aarts, 2011, for recent intriguing findings). If it can be verified that these demonstrations involve genuine instances of unconscious associative learning, there are only two ways that propositional models can deal with this challenge: (1) concede that a second non-propositional mechanism produces certain instances of associative learning or (2) drop the assumption that propositions must be entertained consciously before they can influence behavior. Although the latter option would require a post-hoc assumption and further reduce the falsifiability of propositional models, it could lead to interesting new predictions. For instance, if unconscious propositions mediate unconscious associative learning, then even unconscious associative learning effects might depend on the way in which events are related (e.g., A causes B or A is an effect of B). To the best of my knowledge, this hypothesis has not yet been considered in the literature. Finally, we would like to point out that the current emphasis of propositional models on consciousness relates only to the formation of propositions. Once a proposition has been stored in memory, it can be retrieved from memory and influence behavior even if the organism is not aware of the proposition itself, the origins of the proposition, or the impact of the proposition on behavior (also see Gast, De Houwer, & De Schryver, 2012; Gawronski & Walther, 2012).

Association Formation Mechanisms are Needed to Explain Irrational Associative Learning Effects

It has been proposed that associative learning effects can be irrational in at least one of two ways: (1) The changes in behavior are not in line with the actual relations in the world. (2) The changes in behavior are not in line with the conscious propositions that people report. Several distinguished researchers have documented such irrational associative learning effects and argued that they invalidate a propositional account of associative learning (e.g., Karazinov & Boakes, 2007; Sternberg & McClelland, 2012; see Mitchell et al., 2009a, pp. 192-193, for a discussion). It is, however, difficult to see why so-called irrational learning effects would pose a serious problem for propositional models. One might perhaps argue that propositional models are "rational" in that the formation and transformation of propositions is probably involved in rational thinking and behavior. However, this does not imply that the propositional processes themselves or their effects are always rational.

First, people can make errors in forming propositions about the world. If they make errors in their propositions about relations in the world (e.g., they see relations where there are none), this would produce irrational associative learning effects. Second, as we pointed out in the previous section, propositional processes can result in automatic associative learning effects. Some of these effects could be described as being irrational, for instance, when the change in behavior cannot be controlled or when automatic retrieval of old propositions from memory leads to effects that run counter to currently held propositions. Third, retrieval of propositions from memory might be incomplete. For instance, after forming and memorizing the proposition "A is opposite to B", subsequent presentations of A might result in the recollection that A is somehow related to B without retrieving the information that A is the opposite of B. Such partial retrieval of propositions is functionally very similar to the operation of associations in memory and thus allows propositional models to mimic the operation of association formation models, including irrational learning effects.

A propositional single-process model of associative learning is also compatible with the existence of dissociations between different effects of a single relation in the world. For instance, Sternberg and McClelland (2012) recently showed that information about the nature of relations between events (i.e., whether some stimuli are causes of other stimuli) influences learning as indexed by predictions about presence of a stimulus but not learning as indexed by the speed of responding to the presence of a stimulus. Such dissociations are often interpreted as strong evidence for the operation of multiple learning mechanisms. Assuming that there is only one rational way in which a particular relation in the world influences behavior, dissociations can also be seen as evidence for irrational learning. However, dissociations might result also from the operation of a single propositional learning mechanism. For instance, they might arise because different types of behavior depend on different propositions about the same relation (e.g., see De Houwer, 2009, pp. 6-7). It is also possible that some types of behavior (e.g., fast responses in a reaction time task) are more likely to be influenced by the partial retrieval of propositions from memory than other types of behavior (e.g., predictions that are made without time pressure).

Although irrational learning effects are not by definition incompatible with propositional learning models, it is true that these models need auxiliary post-hoc assumptions in order to explain them (see Mitchell et al., 2009a, pp. 192-193, for examples). Adding post-hoc assumptions to a model is often regarded as undesirable. However, extending models with post-hoc assumptions is scientifically valuable if it generates new predictions that can be verified or disconfirmed in subsequent studies. Therefore, if proponents of propositional models want to maintain that irrational learning effects do not challenge their models, they need to specify the auxiliary assumptions that need to be made and to test new predictions that can be derived from these adapted models. If new predictions cannot be derived or verified, one should concede that the observed learning effect is beyond the scope of propositional models and thus accept that a second, non-propositional learning mechanism drives associative learning.

Association Formation Mechanisms are Needed to Explain Associative Learning Effects in Non-Human Animals

Propositional models focus on the role of complex cognitive processes in associative learning. Assuming that (some of) these cognitive processes are uniquely human, one has to conclude that propositional models cannot account for associative learning as it is observed in non-human animals. One should, however, not underestimate the cognitive capabilities of certain non-human animals. There are good reasons to believe that many species of non-human animals do form propositions about relations in the world using complex cognitive processes akin to those used during problem solving. More and more empirical studies reveal that non-human animals possess a wide range of complex cognitive capabilities, including reasoning and problem solving (e.g., Clayton & Dickinson, 1998; Wass et al., in press). Some studies strongly suggest that they use these capacities when learning about relations between events in the world (e.g., Beckers et al., 2006; Blaisdell, Sawa, Leising, & Waldmann, 2006). It does indeed make sense to assume that cognitive capabilities developed gradually throughout the evolution of animal life rather than that they arose out of thin air with the dawn of humankind. Moreover, differences that are observed between associative learning in human and in non-human animals could be related to quantitative differences (e.g., in working memory capacity) rather than to qualitative differences in the nature of the representations and processes involved.

One could argue that the formation and truth evaluation of propositions does depend on one cognitive capacity that is uniquely human: the use of language. This assumption can, however, be contested. Propositions are in essence beliefs about the state of the world. Such beliefs might well be nonverbal and could involve embodied, grounded representations (Barsalou, 2008). In fact, tool use such as seen in many non-human species seems to require propositional beliefs, that is, beliefs about how events in the world are related.

Even if one would concede that some non-human animals are capable of associative learning by forming and testing propositions about relations in the world, it still seems highly unlikely that all animals possess such capabilities. Nevertheless, very simple organisms such as honeybees and snails also show associative learning effects that are functionally quite similar to learning that is observed in more complex organisms such as humans (e.g., Deisig, Sandoz, Giurfa, & Lachnit, 2007). It is highly improbable that learning in these simple organisms is based on the formation and testing of propositions, which leads to the conclusion that these organisms rely on a non-propositional learning mechanism. This does not mean, however, that one should accept the existence of a non-propositional learning mechanism in humans.

First, even if association formation as a mental mechanism would have evolved first during the evolution of life on our planet, it is not necessarily the case that this mechanism would have remained active when a second, propositional mechanism came into being. Instead, the association formation mechanism might have been transformed into a propositional mechanism rather than that a propositional mechanism was suddenly added to the association formation mechanism (Mitchell et al., 2009b).

Second, learning in very simple organisms probably tells us little about how mental processes mediate learning in humans. Whereas the formation of propositions and the formation of associations both belong to the non-physical realm of mental representations and information processing (Gardner, 1987), learning that occurs in simple organisms or man-made cell assemblies is most likely not mediated by mental processes. It could be argued that learning in simple organism and cell assemblies tell us something about how neural links are formed in the human brain. However, this does not mean that it also informs us about the mental processes that mediate learning in humans. To understand this point, it is important to realize that there is a many-to-many relation between the physical neural level and the non-physical mental level of scientific inquiry. That is, one physical (neural) system could in principle implement many non-physical mental processes whereas one non-physical mental process can in principle be implemented in many physical (neural) systems (Gardner, 1987). Although knowledge about the neural level certainly constraints theories at the mental level, one cannot simply confound the two levels of inquiry.

Third, Mitchell et al. (2009b) pointed out that there is little to be gained by having a second, association-based learning mechanism. One might argue that the principle of spreading of activation that is incorporated into association formation models is highly adaptive because it allows for quick responses to stimuli in the environment via the process of spreading of activation through associations once they have been formed. The formation of propositions, on the other hand, is assumed to be a slow and effortful mechanism. However, this argument is flawed because it compares properties of the *activation* of associations with properties of the *formation* of propositions. It is indeed true that the formation of propositions is typically a slow and effortful process. But the formation of associations is typically assumed to also require many pairings of events before activation can spread automatically between the representations of those events (e.g., Fazio, Sanbonmatsu, Powell, & Kardes, 1986). If anything, the formation of propositions is more flexible and fast because it can be based on all the knowledge and cognitive capacities of an organism. Therefore, even a single experience could be enough to form a proposition about relations between events. In fact, relations might be discovered purely on the basis of inferences even before experiencing the relevant events. From this perspective, learning via the formation of propositions has huge evolutionary benefits. Moreover, once a proposition has been formed and stored in memory, it can be retrieved from memory very quickly and thus allow for fast and efficient responses to objects in the environment. In sum, there are few if any compelling evolutionary reasons for accepting the existence of a non-propositional learning mechanism in humans.

Arguments for Resisting Dual-process Models of Associative Learning

Until now, I argued that there is little to be gained by postulating the existence of a non-propositional learning mechanism in addition to the existence of a propositional learning mechanism. Now I will point out that there are also costs attached to proposing a dual-process account of associative learning.

First, dual-process models tend to be less parsimonious than single-process models. Although parsimony is perhaps not the primary criterion on which to evaluate mental process theories, the most parsimonious model should be preferred until it is absolutely clear that it has less heuristic and predictive value than more complex models. This provides a first justification to defend the idea that all associative learning is mediated by propositional processes. One should note, however, that single-process might become less parsimonious than dual-process models if the former need to be supplemented with more auxiliary assumptions in order to account for the properties of the to-be-explained effects.

Second, dual-process theories tend to be more difficult to falsify than single-process theories. As a class, both propositional and association formation models of associative learning are already virtually impossible to falsify. Whereas propositional models are not yet formalized and therefore to a large extent unconstrained in their predictions, association formation models can vary on such wide range of parameters that they can be made to predict almost any pattern of results (e.g., De Houwer, 2009; Miller & Escobar, 2001). When these levels of freedom are combined in a dual process model that allows for the operation of both classes of mechanisms, there is even less hope of ever falsifying such a model. Without further constraints, it would often be difficult to derive a single, clear prediction about learning in a particular situation. Because of this loss in falsifiability and predictive value, there is little scientific merit in simply claiming that associative learning can be due to both propositional and association formation processes.

Dual-process models can contribute to our understanding of associative learning only if they specify (1) the nature of the association formation mechanism, (2) the nature of the propositional mechanism, (3) the conditions under which each process operates, and (4) the way in which both mechanisms interact. With regard to (1), researchers have to decide which kind of association formation mechanism they actually want to include in their dual-process model. Whereas some seem to favor a very simple mechanism that forms Stimulus-Response associations in a highly automatic, almost unconditional manner, others favor a complex mechanism that forms Stimulus-Stimulus associations in a complex, somewhat non-automatic manner (see Mitchell et al., 2009b, p. 237). Accepting more than one association formation mechanism is possible but further decreases parsimony and requires additional assumptions about how each association formation mechanism interacts with the other association formation mechanism(s) and with the propositional mechanism. Specifying these interactions implies assumptions not only about when which mechanism controls behavior but also about how the operation of one mechanism influences the operation of the other mechanism(s). Although it might be feasible to construct dual-process models that possess this level of detail (see Gawronski & Bodenhausen, 2011, for an example), until now most researchers who argued in favor of dual-process models of associative learning have remained silent about these essential assumptions (Mitchell et al., 2009a, 2009b). Until dual-process models are proposed that provide a full-fledged alternative for a propositional single-process model of associative learning, it remains sensible to adhere to the latter type of model.

Lessons for Dual-Process Models in General

As is evidenced by the mere existence of this book, a call for dual- or multiple-process models has been launched in many areas of psychological inquiry. In this section, I discuss how the debate between proponents of propositional and dual-process models of associative learning might be relevant for the debate between single- and dual-process models in general. In my opinion, the arguments for upholding a propositional single-model of associative learning reveal some reasons for why single-models in general should not be dismissed too easily.

First, any mental process theory of behavior needs to specify not only the nature of the representations that mediate the impact of the environment on behavior but also the processes by which those representations are formed or activated and the processes by which they influence behavior. When researchers focus on one step in the chain of mental processes that mediate behavior, they might be inclined to explain all the complexity of behavior at that step in the chain of mental events. For instance, in order to explain both automatic and non-automatic instances of associative learning, one might postulate both an automatic (associative) and a non-automatic (propositional) mechanism for forming representations. However, the existence of both automatic and non-automatic associative learning effects could result from the operation of one (non-automatic propositional) mechanism for forming representations if those representations can influence behavior in different (automatic and non-automatic) ways. More generally, before doubling the number of processes that perform a single mental function (e.g., the formation of representations) or before doubling the number of representations, one should consider whether similar explanatory power can be achieved by mental processes that perform another mental function (e.g., the retrieval of information) within the chain of processes that is assumed to determine behavior. Note that from this perspective, the expressions “single-process model” and “dual-process models” are misleading because there cannot be any behavior that depends on just one or two processes. Instead, these expressions make sense only when applied to one step in a chain of multiple processes that mediate the impact of environment on behavior.

Second, the proposal of dual-process theories is often motivated by the observation of instances of behavior that seem to fall beyond the scope of existing single-process models. This typically leads to the proposal of a criterion for differentiating the behaviors that can and cannot be accounted for on the basis of a single process. In learning research, for instance, we have seen that instances of associative learning were dichotomized in terms of automaticity, rationality, or the type of organism that is involved. The merit of this approach, however, depends on the extent to which (1) the criterion can be actually used to differentiate between the two types of behavior and (2) the two types of behavior actually overlap with the two types of processes in the dual-process account. With regard to the first point, few criteria for distinguishing between types of behavior are unambiguous (also see Moors, this issue). Most importantly, the automaticity criterion that is often central in dual-process accounts does not allow one to dichotomize behavioral effects. As we noted before, all effects probably have both features of automaticity and features of non-automaticity (Bargh, 1992; Moors & De Houwer, 2006a). Moreover, several automaticity features are continuous and therefore do not allow for a straightforward dichotomization. Likewise, the distinction between rational and irrational behavior or complex and simple organisms is not always easy to make. With regard to the second point, it is unlikely that any behavioral dichotomy (if one can be found) overlaps perfectly with a dichotomy between two types of processes (e.g., Keren & Schul, 2009; Moors & De Houwer, 2006b). All behavioral effects are determined by multiple processes. Hence, the features of behavior (e.g., whether learned behavior is irrational) are unlikely to provide a perfect index of whether a particular process determined that behavior (e.g., the formation of associations; De Houwer, 2011).

Third, competing single- and dual-process models should be formulated and compared at the same level of explanation. Deviations from this principle could bias the scientific debate. For instance, evidence for learning in organisms that are unlikely to possess mental capacities (e.g., worms or man-made cell assemblies) or evidence for plasticity in the physical brain (i.e., dendrites that form between neurons) is often seen as providing unique support for association formation models. This point of view is incorrect because neural and mental processes are not related in a one-to-one manner. Although information about neural processes and structures does constrain mental process theories, one should avoid a conflation of the two levels of analysis (Poldrack, 2006).

Finally, the scientific merit of dual-process models depends on the extent to which they incorporate specific assumptions about the nature of the two types of processes and the way in which they interact. Although a model with two processes can probably explain more effects than a model with just one of those processes, this potential benefit in heuristic value can be offset by a decrease in parsimony, falsifiability, and predictive validity. Dual-process models therefore have merit only if the nature of the processes and their interactions are specified in sufficient detail.

Conclusion

Although it is now generally accepted that associative learning can be due to propositional processes, many researchers still believe that at least some instances of associative learning are due to the formation of associations. The idea that all associative learning is propositionally mediated should, however, not be dismissed too easily. I have argue that many of the arguments against a propositional uni-model are misguided. Moreover, there are also downsides to accepting a dual-process account of associative learning. In addition to evaluating the merits of a propositional single-process model of associative learning, I hope to have revealed the implications of this particular debate for the more general debate on the usefulness of dual-process models in general.

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