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Pavlovian Conditioning: It's not what you think it is - Part II

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INFORMACIÓN ART.

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ABSTRACT

In a highly cited paper, Rescorla (1988) argued that conditioning can be thought of as involving active information seeking and causal reasoning. In this paper, I argue that the full implications of this perspective are yet to be explored. The idea of causal reasoning (a) does not fit well with the association formation models that currently dominate conditioning research and (b) goes beyond the notion of prediction error as the dominant source of learning. As such, Rescorla's (1988) perspective is bound to remain a source of inspiration for future research.

El condicionamiento pavloviano: no es lo que tú crees. Segunda parte

Palabras clave
condicionamiento,
formación de la asociación,
cognición

RESUMEN

En un artículo muy citado, Rescorla (1988) argumentó que se puede pensar que el condicionamiento involucra la búsqueda activa de información y el razonamiento causal. En este artículo, sostengo que las implicaciones completas de esta perspectiva están todavía por explorar. La idea de razonamiento causal (a) no encaja bien con los modelos de formación de asociaciones que actualmente dominan la investigación del condicionamiento y (b) va más allá de la noción de error de predicción como origen fundamental del aprendizaje. Como tal, la perspectiva de Rescorla (1988) está destinada a seguir siendo una fuente de inspiración para futuras investigaciones.

In 2006, I had the privilege of being the promotor of the honorary doctorate that Bob Rescorla received from Ghent University. At the time, I did not know Bob personally (even in my laudation, I referred to him as Robert) but I was (and still am) a great admirer of his work. I am particularly fond of his 1988 paper "Pavlovian conditioning: It's not what you think it is" that was published in American Psychologist. In retrospect, my fondness of this paper was in part due to the fact that the views expressed in this paper were very similar to those I

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was brought up with by my mentor Paul Eelen. Paul's views can be found in a chapter that was originally written in Dutch (Eelen, 1980) and later translated into English (Eelen, 2018). Although the chapter was written some years before Rescorla's famous 1988 paper, it drew heavily on Rescorla's work in the 1960s and 1970s and thus foresaw the message of the 1988 paper. Moreover, Paul Eelen's views on conditioning were in part shaped during a two-year visit in 1976-1977 to Penn State where he worked together with Martin Seligman and Richard Solomon, the latter of whom was the supervisor of the PhD of Bob Rescorla.

A modern view on conditioning

Rescorla's 1988 paper and Eelen's 1980 chapter had a profound impact on my work. In these papers, they argued against a stimulus-response account of conditioning which holds that when a conditional stimulus (CS) is paired with an unconditional stimulus (US) that evokes an unconditional response (UR), the CS will also come to evoke the UR (which is now called a conditional response; CR). From this S-R perspective, Pavlovian conditioning is restricted to stimulus substitution, that is, to documenting when and how a response (UR) that is evoked by one stimulus (US) can also be evoked by another stimulus (CS) provided that the two stimuli are presented together. Rescorla (1988) and Eelen (1980) highlighted many problems with this view.

More importantly for the purposes of this paper, Rescorla (1988) and Eelen (1980) also put forward an alternative, explicitly cognitive way of thinking about conditioning that directly shaped much of my future research. More specifically, they presented a "modern" perspective on conditioning as an intriguing phenomenon for studying how human and non-human animals acquire complex knowledge about their environment. Rescorla (1988, p. 154) put it like this:

> "Rather, the organism is better seen as an information seeker using logical and perceptual relations among events, along with its own preconceptions, to form a sophisticated representation of its world. Indeed, in teaching undergraduates, I favor an analogy between animals showing Pavlovian conditioning and scientists identifying the cause of a phenomenon. If one thinks of Pavlovian conditioning as developing between a CS and a US under just those circumstances that would lead a scientist to conclude that the CS causes the US, one has a surprisingly successful heuristic for remembering the facts of what it takes to produce Pavlovian associative learning (see Dickinson, 1980; Mackintosh, 1983)."

Likewise, inspired by the ideas of Rescorla (e.g., Rescorla & Holland, 1976) but also by the work of Revusky and Garcia (1970) and Testa (1974), Eelen (2018) wrote "Instead of an automatic process that plays out in a passive organism, the organism emerges as an active information-processing system" (p. 200) and "To put it in more trivial terms, when a rat is administered a shock by the experimenter, it might ask itself: What is this shock due to (asks after the cause)?" (p. 204). He devoted several pages discussing the similarities between conditioning, on the one hand, and causal attribution, on the other hand, to conclude with the rhetorical question "Does, after this discussion, it still seems absurd that an animal responds "as if" it were making an attribution?" (p. 207).

Current views on conditioning

Despite the fact that Rescorla's 1988 paper has been cited widely, it seems fair to say that the idea of conditioning as involving active information seeking and causal reasoning has not become mainstream. Quite disappointingly, even today certain textbooks refer to conditioning as simple stimulus-response (S-R) learning (e.g., Purves et al., 2008, p. 686). Many other textbooks do present a more cognitive view on conditioning but, in my opinion, this view does not fully capture the picture that Rescorla painted in his 1988 paper. I will first briefly discuss the way in which current views on conditioning can be considered cognitive. Afterwards, I address the limitations of mainstream cognitive views on conditioning.

There are several ways in which current mainstream thinking about conditioning is cognitive (De Houwer, 2018a, p. 99). First, conditioning is commonly thought of in terms of cognitive representations, more specifically the formation of associations between those representations. After an association has been formed between the representations of the CS and the US, the presentation of the CS can lead to the activation of the US representation which then gives rise to conditioned responding (see Bouton, 2016, for a review). Second, the formation of associations between cognitive representations is thought to occur only when the cognitive conditions are right. Most importantly, association formation is typically thought to depend on attention to CS and/or the US (e.g., Mackintosh, 1975, 1983). Third, spreading of activation between associations in memory is assumed to give rise to cognitive states such as the expectancy that an event will occur in the near future. It is assumed not only that these cognitive states determine (anticipatory) conditioned responding but also that they play a crucial role in creating the cognitive conditions that influence association formation. Especially the idea of prediction error as put forward in the Rescorla-Wagner model (Rescorla & Wagner, 1972) has proven highly influential: the bigger the discrepancy between the expectancy of the US and the actual presence or absence of the US, the more learning occur (i.e., associative strength will be updated). In the literature of reinforcement learning, prediction error has become a core idea that has grown beyond the prediction of the presence of a US to the prediction of cognitive states (e.g., the extent to which there is a discrepancy between experienced task-conflict or and the expected conflict in that task; e.g., Verguts & Notebaert, 2008).

Limitations of current views on conditioning

Although cognitive in nature, these mainstream ideas about conditioning do not fully capture Rescorla's (1988) idea of conditioning

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as involving active information seeking and causal reasoning. Most importantly, the very idea of association formation is ill-suited to encode causal knowledge and causal reasoning (Hummel, 2010). Eelen (2018, p. 206) already hinted at this problem when he wrote that the term association "does not permit a distinction between the propositions "event X reminds me of event Y" and "I ascribe event X to event Y"". An association is simply a link between two representations via which the activation of one representation can result in the activation of the other representation (e.g., Haselgrove, 2016, p. 228). Causal knowledge, on the other hand, is relational: it specifies how things are related (e.g., X is a cause of Y) and the role that each element plays in that relation (e.g., X is that which causes; Y is that which is being caused). Put differently: causal knowledge is by definition propositional in nature.

One could argue that causal or other propositional knowledge might somehow be captured in complex associative networks (e.g., Gawronski & Bodenhausen, 2006; Kollias & McClelland, 2013). What is crucial within the context of this paper, however, is that the models of conditioning and association formation that have until now dominated research on conditioning and related topics such as reinforcement learning are poorly equipped to encode causal knowledge and other propositions (De Houwer, 2018b; Hummel, 2010).

Whereas mainstream views on conditioning are largely silent about the causal nature of conditioning, they have emphasized the notion of prediction. Causation allows for prediction but not all predictors are causes. Nevertheless, also predictive knowledge is propositional in nature and thus difficult to capture in terms of associations. For instance, the belief that X predicts Y specifies that the relation between X and Y is a predictive one (rather than a causal relation or a relation of equivalence), as well as the role of each element in that relation (that X is that which predict Y rather than the other way around). One could argue that the cognitive state of "expecting" is not necessarily propositional and might reflect the extent to which a representation is activated via an associated representation (i.e., the higher the level of activation of a representation, the more that the presence of the represented stimulus is expected). But it is unclear when and why activation of representations would lead to a state of "expecting" rather than other states such as "thinking of" (Zenses et al., 2021) or "being reminded of" (Eelen, 1980; Jozefowiez, 2018). Hence, in contrast to common belief, the idea of association formation is also ill-suited to fully capture the notions of prediction and expectancy (see Jozefowiez, 2018, for more details).

A propositional view on conditioning

Together with colleagues such as Peter Lovibond and Chris Mitchell, I have fully embraced the idea that conditioning effects involve active information seeking and causal attribution (e.g., De Houwer, 2009, 2018b; Mitchell et al., 2009; also see Waldmann & Holyoak, 1992). We put forward a propositional perspective on associative learning according to which conditioning can occur only after a propositional representation is constructed about the nature of the relation between the CS and the US. Hence, this perspective encompasses the idea that conditioning involves the acquisition of causal knowledge, which is one kind of propositional knowledge. From a propositional perspective, organisms must actively seek information because mere spatio-temporal contiguity or contingency is insufficient to determine the nature of a relation (see Lagnado et al., 2007).

For me personally, adopting the propositional perspective was liberating. It allowed me to fully embrace the idea that conditioning involves active information seeking and causal reasoning without having to worry about whether this is compatible with the idea of association formation as the driving force of conditioning. Throughout my career, this approach has provided inspiration for research on a variety of topics on learning and behavior, including fear conditioning in humans (e.g., Mertens & De Houwer, 2016) and rats (Beckers et al., 2006), human contingency learning and causal learning (e.g., De Houwer et al., 2002), evaluative conditioning (De Houwer, 2018b), habitual behavior (De Houwer et al., 2018), and implicit cognition (e.g., De Houwer et al., 2020).

It must be said, however, that the propositional perspective did not contribute much to popularizing the idea that conditioning involves active information seeking and causal attribution. In fact, although I never discussed it with them in depth (adoration can hinder scientific discussion), neither Bob Rescorla nor Paul Eelen seemed to be quite fond of the propositional approach to conditioning. Like many of their peers, they were strongly committed to associationism and the elegance of association formation models. Both of them also emphasized the "as if" nature of their proposal, making very clear that they did not want to make the ontological claim that (non-human) animals "actually" engage in active information seeking and causal reasoning.

Perhaps the debate between proponents of propositional and association formation models (see McLaren et al., 2014; Mitchell et al., 2009) focused too much on ontological issues, more specifically on the nature of the representations that "actually" mediate conditioning. In hindsight, this discussion was bound to lead to a stalemate given that it is notoriously difficult to reach conclusions about the nature of mental representations. As pointed out already by Barsalou (1990) in the context of category learning, inferences about mental representations necessarily depend on assumptions about how these representations are formed and how they influence behavior. Because these auxiliary assumptions can vary while assumptions about the nature of representations are kept constant, a debate about the nature of representations actually entails a debate between broad classes of models in which each class of models can account for virtually any set of findings (also see Miller & Escobar, 2001). When also taking into account that association formation models focus on the acquisition of representational structures whereas propositional models focus on the content of propositions (and that propositions could thus in principle be encoded in associative structures), it becomes even more pointless to try to decide between associative and propositional models as classes of models (De Houwer et al., 2020).

In recent years, I have therefore started to think and write in terms of a propositional perspective rather than in terms of propositional models (e.g., De Houwer, 2018b; De Houwer et al., 2020). This

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phrasing is meant to communicate that it involves a way of looking at phenomena that is meant to have heuristic and generative value (i.e., to help organize existing knowledge and make new predictions) rather than to make ontological claims about the "true" content or structure of the mental world. Even when no conclusions can be reached about the nature of mental representations, a propositional perspective can still be useful because it highlights other phenomena and questions than a more mainstream association formation perspective. In some way, this shift has brought me closer to the views of Rescorla (1988) and Eelen (1980) who also emphasized the "as if" nature of information seeking and causal reasoning. Rather than falling into the ontological trap of whether organisms are "really" active information seekers and causal reasoners, there remains merit in using this perspective as a tool to learn more about the variables that moderate conditioning effects.

Beyond prediction error

Until now I have focused on Rescorla's idea of conditioning as involving active information seeking and causal reasoning, as well as how this idea goes beyond current association formation models but fits well with a propositional perspective on conditioning. In the final section of this paper, I discuss how Rescorla's idea also goes beyond the notion of prediction error. This is worth highlighting because the notion of prediction error is often seen as the core of Rescorla's legacy (but see Gallistel, this issue) and as the core of learning in general. Let's start with the question of why organisms would engage in active information seeking and causal reasoning. An obvious answer seems to be that identifying causes allows them to predict and perhaps influence future events. If information seeking and causal reasoning are indeed goal-directed activities, then one could argue that organisms have some pre-existing conception of what causes or predictors are and what they are good for. Why else would they actively seek to identify them? From this perspective, conditioning involves not only knowledge about the CS and the US but also knowledge about the class of causal stimuli. Active information seeking and causal reasoning have the aim of establishing whether the CS is equivalent to other causes, that is, whether it has the functions of a causal stimulus (e.g., whether it allows to predict and influence future events). Establishing that a CS is a cause (of a particular stimulus) requires information, such as information about stimulus contingencies or the presence of other potential causes. Hence, I believe that Rescorla's ideas about causal reasoning in conditioning imply that conditioning is not just about prediction error but also about equivalence: conditioning is as much about learning that the CS is a cause (i.e., is a member of the class of causal stimuli) as it is about learning that the CS reliably precedes the US (also see Boddez & De Houwer, 2020). One could even argue that the latter is in service of the former: when learning about causes, prediction error is important but only because it is one possible argument for the conclusion that the CS is equivalence to other causes.

Unlike many of my contemporaries, I was made aware of the limits of prediction error as the main principle of learning already very early on in my career. When I started my PhD at the lab of Paul Eelen in 1991, Frank Baeyens was completing his PhD with Paul on the topic of evaluative conditioning (e.g., Baeyens et al., 1992; see De Houwer et al., 2001, for a review of the early work on this topic and Hofmann et al., 2010, for a more recent review). Evaluative conditioning can be thought of an effect, that is, the impact of CS-US pairings on the liking of the CS. For instance, a product name (CS) will be evaluated as being more positive after being paired with a picture of smiling faces than after being paired with a picture of frowning faces (US). Hence, as an effect, the only unique thing about evaluative conditioning is that it involves changes in liking rather than in other types of responses (e.g., anticipatory responses such as salivation). Interestingly, there seem to be marked differences between the moderators of evaluative conditioning and more traditional types of (anticipatory) conditioning. For instance, extinction procedures (i.e., CS-only presentations after CS-US pairings) or contingency manipulations (i.e., CS-only or US-only presentations intermixed with CS-US pairings) seem to have little effect on the strength of evaluative conditioning effects (e.g., De Houwer et al., 2001, 2020; Hofmann et al., 2010). Extinction and contingency effects are typically explained in terms of prediction error. Hence, the fact that those manipulations had little effect on evaluative conditioning led to the proposal that evaluative conditioning is not about prediction error. Whereas early on Frank Baeyens and colleagues (e.g., Baeyens et al., 1992) referred to evaluative conditioning as "referential learning" (i.e., learning that the CS refers to or makes you think of the US) which he contrasted with "expectancy learning" (i.e., learning that the CS predicts the US), more recently I argued that evaluative conditioning involves learning about the equivalence of the CS and US (De Houwer & Hughes, 2016, 2020). In this case, CS-US co-occurrence (i.e., a similarity in the spatio-temporal properties of the CS and US) seems to function as a cue for the equivalence of the CS and US (i.e., a similarity with regard to other properties of the CS and US, such as their valence).

When combined, these ideas paint a rich picture of conditioning that goes far beyond the notion of prediction error. Prediction error is important as one possible cue for one possible meaning of the CS (i.e., as a cue for the causal nature of the CS). But there are many other things that organisms can learn about a CS using many other types of cues. For instance, similarity of CS and US in terms of spatio-temporal features (i.e., the fact that CS and US occur together in space and time) can function as a cue for the equivalence of CS and US (De Houwer & Hughes, 2016, 2020). Other types of similarity between CS and US can function as a cue for the equivalence of CS and US as well. For instance, in a recent set of studies (Hughes et al., 2020) we demonstrated that when a CS (e.g., a neutral brand name) and a US (e.g., a positive word) are presented in the same color, the CS will be evaluated in line with the valence of the US (e.g., the CS becomes positive). From this perspective, evaluative conditioning effects are just one possible demonstration of a more general shared-features principle: when stimuli share one feature, people will respond as if they also share other features (for a detailed discussion see De Houwer & Hughes, 2020, Chapter 4). It has to be noted that many of the findings that I discussed in this section originated from studies in humans. Hence, it is not clear to which extent the ideas discussed in this section also apply to non-human animals (see De Houwer et al., 2016, for a

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discussion). The main point I want to make in the context of this paper is that there is more to conditioning than prediction error, a point that is implicit within Rescorla's view on conditioning as involving active information seeking and causal reasoning and that is explicit within some areas of conditioning research, such as research on evaluative conditioning.

Conclusion

I hope that this paper reveals the richness that I see in Rescorla's causal view on conditioning. As Bob wrote in the first paragraph of his 1988 paper, "many think of Pavlovian conditioning as an obsolete technical field that is intellectually stagnant". Anyone who learns about the astounding contributions that Bob made throughout his career will realize how fascinating Pavlovian conditioning is. I am convinced that his views can continue to provide inspiration, especially if one is willing to move beyond the confines of association formation and prediction error.

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