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The magic mirror of Robert Rescorla's methodological behaviorism

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ABSTRACT

Learning research assumes that the underlying learning processes are mirrored in behavior. However, learning may or may not show as a change in behavior, and a behavioral change may or may not be the result of learning. Thus, behavior turns to be a distorted mirror of what the organism has in its head, and learning researchers put a great effort in designing control conditions to ensure that what the mirror reflects is the learning process responsible. Here I present my tribute to Robert Rescorla and his uncanny ability to use clever designs to allow behavior to separate among different underlying learning processes. I will use the research about the contents of learning as the guiding thread, connecting the results of Rescorla's research in nonhuman animals with recent research on the same issue in human associative learning.

El espejo mágico del conductismo metodológico de Robert Rescorla

RESUMEN

La investigación en aprendizaje asume que los procesos de aprendizaje que subyacen a la conducta se reflejan en esta. Sin embargo, el aprendizaje puede que no se muestre como un cambio conductual, y los cambios conductuales podrían no ser consecuencia del aprendizaje. Así, la conducta se convierte en un espejo distorsionado de lo que el organismo tiene en su cabeza, y los investigadores en aprendizaje ponen un gran esfuerzo en diseñar las condiciones de control que aseguren que lo que refleja el espejo es el proceso de aprendizaje y no otra cosa. Presento aquí mi tributo a Robert Rescorla y su habilidad única para utilizar diseños ingeniosos que permiten diferenciar entre distintos procesos de aprendizaje a través de la conducta. Como hilo conductor utilizaré la investigación acerca de los contenidos del aprendizaje, conectando los resultados de la investigación de Rescorla con animales no humanos con resultados recientes en los mismos asuntos en el campo del aprendizaje asociativo humano.

One of the classical studies that I regularly discuss with the students of my introductory learning course is one conducted by Tolman and Honkiz (1930). The study mixed groups from different experiments and surely would not be easily published nowadays. Nevertheless, the

results, and the ideas they support, still stand up as correct. The study factorially combined four different treatments involving hungry rats exposed to a complex maze. Rats in group R were rewarded with food when they reached the goal box of the maze. These rats showed a gradual decrease in the number of errors (enters in blind aisles) and in the latency to reach the end of the maze as training progressed. Rats in group NR did not receive food when they reached the end of the maze, and their performance remained roughly stable and slow throughout training. Group R-NR received the same training given to group R during the first 10 days of training, and then were no longer reinforced from day 11 on. Performance in this group rapidly reached a similar level to the one showed by rats in group NR from day 12 on, in what may be interpreted as rapid extinction. Group NR-R was the most interesting group. Rats in this group received no reinforcement during the first 10 days of training, and the same treatment received by group R from day 11 on. Thus, rats in this group found food at the end of the maze in day 11, and they showed basically the same performance as group R from day 12 on. That finding suggests that, first, reinforcement may be necessary for performance, but not for learning; and second, that learning is not always reflected as a behavioral change (Tolman & Honzik, 1930).

Similarly, not every behavioral change is due to learning, not even in those situations specifically designed to evaluate learning. Allow me to use here an example that Robert Rescorla used in his undergraduate learning class at the University of Pennsylvania. One of the interesting questions in the analysis of the conditions that produce associative learning concerns the most effective way to present the stimuli for associations to develop. As the basic laws of association were already formulated by Aristotle, including the law of contiguity, one might expect little discussion about this issue two millennia later. However, it is a well-known fact that to observe conditioned responding (CR), some asynchrony is needed between the conditioned stimulus (CS) and the unconditioned stimulus (US). In other words, even though the law of contiguity is, perhaps, better fulfilled when the CS and the US are simultaneously presented, better performance is reported when the CS starts slightly before the beginning of the US, in what is referred to as delayed conditioning. Note that I have avoided the use of the term "learning" when comparing simultaneous and delayed conditions. Even today, ninety years after the study of Tolman and Honzik (1930), confounding learning and performance is not unusual.

Let's go back to Rescorla's undergraduate class. While discussing these two conditions thought to produce learning, he confronted his students with a simple comparison. Animals received either simultaneous or delayed/successive conditioning training followed by a common test in which the CS is presented alone. The science of the process was clean and fulfilled the fundamental requirements of the experimental study of learning phenomena: The results of the different treatments were compared under the same testing conditions. The question his students had to solve was whether presenting the CS alone at testing in the simultaneous and delayed groups was actually testing the animals in these groups under the same conditions.

Using his Socratic approach to teaching, he would lead his students to search for a reason that could explain the poorer performance of the simultaneous group relative to delayed group even if it was the

case that simultaneous training could lead to stronger learning than successive training. There was, of course, an answer. The simultaneous procedure involves simultaneous presentations of the CS and the US such that when the CS is presented by itself during the test, the organism immediately has the opportunity to detect that the testing situation has changed with respect to the training conditions. This change by itself could lead to a reduction in responding. The situation in the delayed group is different. The US is not presented at the same time as the CS during training, but after the CS has been on for a while. When the CS is presented by itself during the test, the organism is less able to detect that the situation has changed, and its responding should be similar to training at least during the initial part of the CS. In summary, what seemed apparent as a common test for the two different training procedures was unveiled as an unfair comparison that confounded learning with performance. I should confess that even as a postdoc, those undergraduate classes with Bob were enjoyable and informative, and 25 years later they are still part of what I try to share with my students as a way to develop their critical thinking.

These studies, that I simply use as a general example of the existing gap between learning and performance, give an idea of one of the main difficulties on studying learning: Inferring the underlying learning processes from behavioral changes that may or may not occur. Metaphorically speaking, the study of learning consists of looking at learning through the distorted mirror of the reality of behavior. The behavior sometimes reflects different processes with the same image, or as in the case with Tolman's N group, reflect nothing at all. That is the situation that learning researchers and theorists deal with daily. They must develop complex experiments with a myriad of control conditions to correct for distortions in the mirror so that the reflection shines through that glass darkly and reveals the correct learning process. Dealing with this complex situation is where the genius of Robert Rescorla is revealed to its fullest. All his work reflects a mastery of this process.

An example of his almost unnatural ability to create mirror-smoothing designs can be found in the experiments he conducted to evaluate the learning in simultaneous and delayed conditioning mentioned above. Finding the same testing conditions to compare the learning in simultaneous and delayed conditioning is not an easy task. It seems that that kind of comparison would have to wait until science evolves to the point where associative learning can be evaluated without having to depend on behavior. And that might be true in the end, but meanwhile, Rescorla (1980) found a smart design that allowed that comparison.

He conducted 4 experiments using two different procedures (conditioned taste aversion, and conditioned suppression) and 3 neutral stimuli in a sensory-preconditioning design. The design allowed for the change between training and testing conditions for both simultaneous and successive conditioning to be the same. Here is how it worked. All rats received training with an AB->C combination of stimuli. That is, A and B occurred together at the same time, while C followed them in time. The training was designed to allow associations to form between A and B by way of simultaneous conditioning, and form between A and C by way of successive/delayed conditioning. Associations might also form between B and C, but this

was not important. Stimulus A had a simultaneous relationship with B, and a successive relationship with C. Testing was with A alone. As A had always been paired with B, the test with A alone reflects the same change from training to testing regardless of whether it is for evaluating a simultaneous AB association, or a successive AB->C association.

Following the phase of AB->C pairings, the rats were divided into two groups. One group received conditioning with stimulus B paired with the US (e.g., illness in the taste-aversion studies, footshock in the conditioned suppression studies), while the other received delayed conditioning with stimulus C. The idea here is that both B and C are now capable of producing a strong CR. Finally, all groups were tested with A. Conditioning B, with which A had a simultaneous relationship led to stronger responding than did conditioning C, with which it had a successive relationship. In both cases, A was presented alone and the degree of change between training and testing was identical for both groups. Simultaneous associations appeared to be stronger than sequential ones.

The experimental design used to compare the effectiveness of simultaneous and successive associations is just one of the many examples of the ability of Rescorla to find the proper design to disentangle alternative explanations of the same phenomenon. The following sections will present a brief overview of the work conducted by Robert Rescorla and his colleagues as a way to illustrate the use of smart experimental designs to infer the associative contents of learning through behavioral changes (see also Rosas et al., 2017).

The study of the contents of associative learning

The study of the contents of associative learning often tries to determine what relationships between elements of the situation may be learned by the organism, such as the stimuli and the responses that are involved in a given associative learning experiment. Taking Pavlovian conditioning as an example, a prevalent discussion has been whether experiencing CS-US pairings establishes an association between the conditioned stimulus and the conditioned response (S-R association) or between the conditioned stimulus and the unconditioned stimulus (S-S association). These two approaches represent two different theoretical views of learning: S-R theories, that emphasize the concepts of habits and S-R associations, and S-S theories, that propose associations between representation of different stimuli. S-R theories provide rules that regulate the relationship between the stimulus and the response (e.g., Guthrie, 1935; Hull, 1943; Spence, 1936; Thorndike, 1898). The more cognitive S-S theories describe learning as part of a larger problem of perceptual reorganization with experience (e.g., Kohler, 1940; Tolman, 1932). Although these theories have been traditionally seen as incompatible, using Rescorla's words, the main difference between these two theoretical perspectives lies in what they put their focus, with cognitive theorist focusing on the contents of learning, while S-R theorists focus more so on the conditions under which learning occurs (see Holland, 2008). I am going to focus here in the cognitive analysis of learning, and in how Rescorla's studies have contributed to the understanding of what the organism learns in different situations.

The study of the contents of learning in Pavlovian conditioning

Rescorla (1988) briefly summarizes the complexity of the potential associative structures of Pavlovian conditioning situation. As he points out, associations may be formed between the CS and the US, between each of those events and the context (e.g., Balsam & Tomie, 1985), between elements within each of those events (e.g., Rescorla & Durlach, 1981), as well as hierarchical associations among the different events that are present in the learning situation (Holland, 1983; Rescorla, 1986).
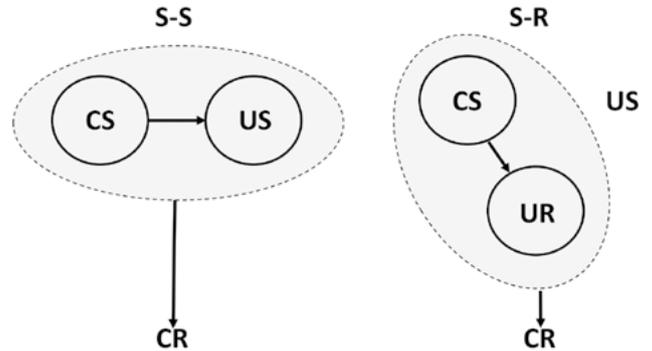
Figure 1. *Schematic representation of simple binary S-S and S-R associations in Pavlovian conditioning. Representations of the CS, US and UR is presented with bubbles. In S-S associations the CR is the outcome of an underlying CS-US association. In S-R associations, the CR is the outcome of a direct link between the CS and the CR.*

When the CS is repeatedly paired with the US, the CS is also paired with all components of the unconditioned response (UR) that the US elicits. Later, the presentation of the CS alone elicits a conditioned response. As can be seen in Figure 1, according to S-R theories the association that leads to the appearance of that response is an association between the CS and some component(s) of the UR with which it had been paired. In this view, the CS directly elicits the response, and the US is only a catalyst that facilitates the formation of the S-R association (e.g., Hull, 1943). Alternatively, S-S theories assume that Pavlovian conditioning produces a CS-US association, so that the presentation of the CS evokes a representation of the US, that leads to the conditioned response (e.g., Pavlov, 1927; Tolman, 1932; Wagner, 1981; Wagner & Brandon, 1989).

The analysis of the distinction between S-S and S-R learning in Pavlovian conditioning began by searching for the possibility of establishing CS-UR associations in the absence of the US. Loucks (1935) paired the sound of a buzzer with flexion of a foreleg induced by electrical stimulation, rather than by administering a shock US. This arrangement was assumed to permit the establishing of an S-R association, while preventing the establishment of S-S associations as the US was not presented. In those conditions, the UR they were searching for not appear to develop, suggesting that simple S-R pairings were not enough to establish learning. However, a null result is not a good base to reach a conclusion. In fact, when the arrangement included the presentation of food at the end, leg flexion was acquired. But that situation was of little help as it could be equally explained by S-S and S-R approaches. The S-R approach only needed to assume

that the reward produced by pain reduction or food was needed for the habit to be established (Spence, 1950). Thus, this approach to distinguishing S-S and S-R learning in classical conditioning seemed to lead to a dead end.

Applying similar logic, studies have tested whether conditioning could be established in the absence of responding. For instance, Finch (1938) found that conducting conditioning in a situation that prevented the salivary response (administering atropine sulphate), salivary CRs were observed when the effects of atropine disappeared. Conditioning was established in a situation that prevented the formation of S-R associations, though that conclusion is based on the arguable idea that S-R associations would be established at the neuromuscular level, rather than in the brain.

More convincing results were obtained in sensory preconditioning designs (Brodgen, 1947). There, two neutral stimuli (neutral in the sense that they not produce the target response) are paired (e.g., S1S2), presumably establishing of an association between the two. When S2 is then paired with a US the alternative stimulus ends showing the same conditioned response as the one that was actually paired with the US by way of the S1-S2 association. However, S-R theorists suggested alternative explanations for this situation, based in orienting responses, an explanation as difficult to prove as it is difficult to refute (see Cousins & Lorne, 1971; Holland, 2008). You may recognize that this is the same type of design as used in the first part of Rescorla's simultaneous/delayed conditioning experiment described above, though it involved pairing 3 stimuli

Rescorla (1973, 1974) approached the problem of S-S vs S-R learning using elegant designs that relied on changes in the value of the US after training (Rozeboom, 1958), which produced clear conclusions that are difficult to refute. Changing the value of the US changes how the animal responds to the US. According to S-R associations, the CR should not be affected by post-training changes in the value of the US, as the US is not part of the associative structure, only the CS and the original UR components. However, conditioned responding based on S-S associations would depend on the current value of the US and would be reduced by post-training devaluation of the US, and increased by post-training inflation of the US.

Rescorla found that paring a light with a loud noise would lead the light to produce a strong CR in rats. Post-training habituation to the noise used as the US attenuated responding to the light. However, it did not affect responding to a different stimulus that signaled the light. That is, first order conditioning was affected by changes in US value, but not second order conditioning. Those findings suggest that first-order conditioning led to S-S associations that are not as likely to form in second-order conditioning (Rescorla, 1973; see also Holland & Rescorla, 1975). Similar results were found when a CS was paired with a moderate shock, and post-training revaluation involved presenting a strong shock in the absence of the CS. The "inflation" of the US produced an increase in the CR after first-order conditioning, but not after second-order conditioning (Rescorla, 1974). Similarly, responding to quinine associated with a salty flavor is augmented by a post-training injection of formalin that increases the organisms need for salt (Rescorla & Freberg, 1978). All of these results suggest that organisms form associations between detailed representations of the stimuli involved.

A complementary approach to exploring the type of associations involved in a learning situation has been the use of transfer techniques, a procedure that was routinely used in Rescorla's lab to explore the contents of both, Pavlovian and instrumental learning (Rescorla, 1988). In a typical transfer (Pavlovian-to-Instrumental Transfer, PIT) experiment the organism is trained with two different instrumental responses (i.e., chain pulling and lever pressing) each followed by a different outcome (i.e., food or sucrose). During Pavlovian training, two different CSs are followed by either food or sucrose. In the final test, the animal has the opportunity to choose between the two instrumental responses in the presence or in the absence of each stimulus. The typical result is that instrumental responding is increased by the presentation of the CS. The organism choses the instrumental response that leads to the same outcome with which the CS was paired showing the role of CS-US associations in Pavlovian conditioning (e.g., Colwill & Rescorla, 1986; 1988; Rescorla, 1984).

At the University of Jaén we have extended the analyses of the contents of associative learning to human predictive learning, using procedures based on same logic and ideas as ones Rescorla developed with animals. Gámez et al. (2013), trained participants to expect that certain battlefield cues led to different outcomes such as the destruction of different targets (ships, planes) in a video game. Devaluation was accomplished by simply informing the participant that one of the outcomes was now indestructible. That devaluation led to an immediate decrease in the participants expecting the devalued outcome to be destroyed in the presence of the cue that predicted it. Rescorla's techniques applied to predictive learning suggest that cue-outcome associations play a role in human predictive learning similar to the one they play in standard classical conditioning.

The above result was also confirmed using the PIT procedure with designs based on the ones used with animals, described above. Paredes-Olay et al. (2002) used a simple video-game with a war setting. Participants learned to use two different responses to destroy two different attackers (R1-O1destruction, R2-O2destruction). They also learned, in the absence of being able to make the response, that the two different attackers are predicted by two different cues/stimuli (A-O1 and B-O2). The cue-outcome (S-S) associations were evaluated by giving participants the opportunity to perform the two different responses in the presence and in the absence of the two predictive cues. Similar to what it has been reported with rats, the cue enhanced the response that had been trained with the same outcome, further suggesting that predictive learning establishes cue-outcome (S-S) associations in humans (See Colwill, 1993; Rescorla & Solomon, 1967; Trapold & Overmier, 1972). Interestingly, Gámez et al. (2013), also using transfer techniques, found that participants also formed judgement-outcome (R-O) associations during predictive training.

Experiments such as these show that S-S associations play a role in Pavlovian conditioning and human predictive learning. Bob emphasized in his learning course that the demonstration of the involvement of the S-S association in classical conditioning is very important. However, he also made clear that fact that devaluation of the outcome does not usually fully eliminate the CR. That result suggests that S-R habits also play a role, albeit a smaller one, in classical conditioning (see also Spence, 1950). As Rescorla (1988) suggests,

Pavlovian conditioning may be based in simple associations, but where they form and their combinations allows a rich representation of the world.

The study of the contents of learning in instrumental conditioning

As was the case in Pavlovian conditioning, many effective approaches to the study of what it is learned in instrumental conditioning come from post-training assessments of the nature of learning. The studies explore the associations among the three elements of the basic instrumental conditioning situation, the instrumental response (R), the reinforcer (O) and the discriminative stimulus (S). Evidence for each of the possible associations has been found using methods championed by Rescorla.

Rescorla and his colleagues, once again, applied a devaluation procedure to show the role of R-O associations in instrumental conditioning (e.g., Colwill & Rescorla, 1985). Specifically, when two responses led to two different respective outcomes, post-training devaluation of one outcome led to a preference bias for the other response, the one that was not paired with the devalued outcome. This result has been reported in human instrumental conditioning using techniques based on the same principles (Gámez & Rosas, 2007). Indirect evidence of S-R associations is also reported by Colwill (1994; see also Gámez et al., 2017) using transfer procedures.

Colwill and Rescorla (1986, 1988) also used transfer tests to uncover the role of S-O associations in instrumental conditioning. For instance, Colwill and Rescorla (1988) trained two instrumental responses with two different outcomes in the presence of two different discriminative stimuli (A:R1-O1 and B:R2-O2). They then trained two new responses each followed by one of the previous reinforcers (R3-O1 and R4-O2). During the test, rats had the choice of performing R3 and R4 in the presence and in the absence of discriminative stimuli A and B. Each discriminative stimulus selectively increased the response with which it shared the reinforcer, showing stimulus control of the instrumental responses based in S-O associations (see also Gámez & Rosas, 2007).

In addition to the binary associations mentioned above, Colwill and Rescorla (1990) reported data suggesting that hierarchical S:R-O associations are also developed in instrumental conditioning (Skinner, 1938). They trained rats in a conditional discrimination in which the outcomes of two responses were reversed depending on the stimulus present (A:R1-O1, R2-O2 and B:R1-O2, R2-O1). Subsequent devaluation of one of the outcomes led rats to choose the other response selectively depending on the S presented. That is, if the devalued outcome was O1, rats chose R2 in the presence of A, and R1 in the presence of B, a result that only seems to be explained if the animal established S:R-O hierarchical associations. Gámez and Rosas (2007) found similar results using an analogous design in human instrumental conditioning.

Recent reports suggest that the range of associations that can be established in an instrumental situation is even larger than the ones discussed so far. Thrailkill and Bouton (2015), and Gámez et al. (2017) studies of the role of context in instrumental conditioning suggest a more complex picture of the contents of instrumental learning that the one depicted. Entering into discussion of the role played by contexts in instrumental conditioning falls outside the scope of this manuscript. For the current purpose, it would be enough to say that those studies use the tools developed and refined by Rescorla and his colleagues to determine the full set of associations established within the instrumental conditioning situation.

The study of the contents of learning after extinction

The use of the transfer technique within Rescorla's laboratory has also provided important insights about the contents of extinction learning. Presentation of the CS without the US or the instrumental response without the outcome leads to a decrease in the respective response (Pavlov, 1927; Skinner, 1938). The simplest approach to explain this phenomenon assumes that the extinction treatment eliminates the associations established during the acquisition training. Although this assumption is implicitly or explicitly included within influential models of associative learning such as Rescorla and Wagner (1972; Wagner & Rescorla, 1972), from the early studies of Pavlov (1927) it is known that such an assumption is incorrect. Both, Pavlovian and instrumental conditioned responses recover when a retention interval is interposed between the extinction training and the test (i.e., spontaneous recovery; e.g., Rescorla, 1997; Robbins, 1990; Rosas & Bouton, 1996), when the test is conducted in a context different from the extinction context (i.e., renewal; e.g., Bouton & Bolles, 1979; for a review see Bouton, 1993), and when the organism is exposed to the outcome in the context where the CS will be tested (i.e., reinstatement; e.g., Rescorla & Heth, 1975). Post-extinction recovery of responding in the absence of new learning would not be possible if extinction had erased the original acquisition learning. Accordingly, extinction has been suggested to involve some kind of new learning of an inhibitory nature (e.g., Bouton, 1993; Konorski, 1948; Wagner & Brandon, 1989).

Once again, the tools used to explore the contents of learning developed by Rescorla and his colleagues have been essential in determining the type of association that is developed during the extinction training. Within the cognitive tradition, extinction is assumed to lead to inhibitory associations between the CS or the instrumental response and the outcome. These associations interfere with the excitatory association developed during the initial training, and are modulated by the context where the new learning (extinction) takes place (e.g., Bouton, 1993). That kind of approach, with minor assumptions, allows for all the retrieval-from-extinction-phenomena listed above to be explained as the result of contextual change. Changes in temporal or associative contexts where extinction occurred would make S-NoO or R-NoO inhibitory associations hard to recover.

Studies conducted with rats (Delamater, 1996) and humans (e.g., Rosas et al., 2010) found that Pavlovian to instrumental transfer survives across a variety of extinction manipulations, a finding that is not compatible with the idea that the US representation is suppressed. Similar results have been found in instrumental conditioning by Rescorla (e.g., Rescorla, 1991, 1993a, 1993b). For instance, Rescorla (1993b) explored the state of the R-O association after extinction of instrumental responding by devaluing the outcome. He found that responses that had been associated with the devalued outcome were depressed, even when the specific R-O association had undergone extinction. Using the PIT technique, Rescorla (1992) observed transfer regardless of whether the

response had been extinguished or not, so that both the R-O and the S-O associations seem to survive instrumental extinction. Those findings suggesting that instrumental extinction in nonhuman animals is not based in the formation of S-NoO or R-NoO inhibitory associations, leaving the inhibitory S-NoR association as the most likely candidate to explain the contents of learning during instrumental and classical conditioning extinction (Rescorla, 1993a; see also Bouton & Todd, 2014).

Contrary to the general trend in comparative studies regarding nonhuman and human associative learning contents, results in human instrumental conditioning point towards the idea that extinction affects different associative structures in human and nonhuman animals. Gámez and Rosas (2005) used PIT and found that extinction of an instrumental response eliminated the transfer effect, suggesting that human instrumental extinction may be solved by establishing S-NoO associations, rather than by establishing S-No R associations (see also Gámez et al., 2020).

At any rate, differences in the contents of extinction learning in humans and other animals is an open question. Nevertheless, thanks to Rescorla we have the necessary tools and ideas to explore these mechanisms in both animals and humans, elucidating the similarities and differences in human and non-human associative learning.

A personal note of conclusion

In the previous paragraphs I have tried to give a brief, but general, overview of how the study of the contents of learning has developed in the last century. I am aware that the selective review is far from being comprehensive; it was not intended to be so. I have consciously skipped enormous amounts of content only to provide an example. Likewise, the manuscript cannot provide a comprehensive review of all the many contributions of Robert Rescorla to the study of associative learning, and to psychology itself. Any of those goals would have been of great interest, for sure, but my goal with this manuscript was a much modest, and personal one.

I was hired as a postdoc by Bob at the University of Pennsylvania, and spent a year in his laboratory between 1996 and 1997. During that time, I had the opportunity to learn from both the genius and the person. The goal I had with this manuscript was to give my personal view of what I consider to be one of the most important contributions of Rescorla to the study of learning: His uncanny capacity to ask the right questions and to pinpoint the exact design that allows behavior to be used to enter into the organism's thoughts. He had direct participation in many of the studies cited above, of course, but his contribution goes much further. Most of the studies that did not include his name were conducted by people that, as it was my case, learned from him, and are part of his legacy.

What I learned during my stay with Bob at UPenn was that the critical thinking and awareness of the skeptical nature of science was even more important than the specific results obtained. To be fair, I was already trained in that way of thinking by my previous mentors, Gumersinda Alonso, at the University of the Basque Country, and Mark Bouton, at the University of Vermont. It was what I learned with them what allowed me to take true advantage of the short year

I spent with Bob. But this story is not about me, but about him. His ability to use behavior to look inside the minds of organisms was complemented by his ability to formalize how thoes minds operate, such as in the Rescorla and Wagner model (Rescorla & Wagner, 1972; Wagner & Rescorla, 1972). His skills in design confirmed many counterintuitive predictions that such formalization made about how learning operates. For instance, conditioning of a compound after separately training its elements leads to a decrease in the conditioned response elicited by each element (e.g., Rescorla, 1970), a phenomenon that is usually named as overexpectation (see for instance, Lattal & Nakajima, 1998), and that it was later shown that it may share the underlying mechanism with nonreinforcement effects such as extinction (Rescorla, 2007). The workings of his own mind not only allowed him to cleanly answer important questions, but also to define what questions were important for our understanding of learning.

There was a sense of magic in the clarity with which his experiments answered important questions. His work was a magic mirror that would allow him to use behavior to see inside the thoughts of the organisms. I knew him as an extraordinary mentor and friend. He naturally mixed the critical analysis of any idea with a fine sense of humor, creating a work environment where you felt challenged and protected at the same time. It is this admiration that gave rise to this modest contribution to honor the memory of one of the greatest psychologists of the twentieth century. I cannot think of a better way to honor his memory that imitating his kindness, his teaching ability, his concern for a job well done, and his determination while doing it, and passing it on to my students.

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