RESEARCH HIGHLIGHT

Clarifying punishment

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I watched as my young daughter took her first sips of a vanilla milkshake. Slow at first, then she began to quickly slurp up the delicious treat. And then, suddenly, she stopped... BRAIN FREEZE! Her actions of rapidly consuming the cold beverage were *punished* with the adverse consequence of a brief headache. Understandably, she took more caution when she returned to her dessert. Punishment is when an instrumental action causes an aversive event. When effective, this negative consequence reduces the probability that action will occur again in the future, hence my daughter no longer hastily consumes cold drinks. Rapid behavioral adjustment to aversive consequences is crucial to our survival, health, and happiness. Dysfunction in punishment is characteristic of the symptoms underlying myriad neuropsychiatric diseases. Understanding the psychological processes and neural mechanisms of punishment is, therefore, a top priority. But, although seemingly simple, punishment is theoretically quite complex. It is also challenging to model in the laboratory, owing to the many confounding processes that can occur when aversive events are presented. In this issue, Jean-Richard-Dit-Bressel et al. [1] provide a review of punishment, the content of its learning, considerations for its study, its neural mechanisms, and how its dysfunction might contribute to pathological states. The review, therefore, has something for everyone.

For anyone interested in punishment, the review outlines what punishment is and, crucially, what it is not. Punishment is not active avoidance/escape. Although rare in Los Angeles, this week it is raining. I use an umbrella to avoid getting wet. In this case, performance of the action prevents or stops an aversive event. In contrast, punishment is passive avoidance, withholding an action prevents the aversive event. Punishment is also not aversive Pavlovian conditioning. In punishment, the aversive event is *contingent* on the subject's behavior—a brain freeze is contingent upon hasty ice cream consumption. In aversive Pavlovian conditioning, the aversive event is signaled by associated stimuli and occurs *independent* of the subject's behavior—a gray cloud in the sky predicts rain, regardless of my behavior. Punishers come in three broad flavors, as follows: (1) positive punishers, actual aversive events; (2) negative punishers, omission of a pleasant event; (3) conditional punishers, stimuli predictive of an aversive event. For clarity, the authors provide glossary that will be appreciated by novices and aficionados alike.

For the learning theorists, the review discusses the psychological processes that underlie punishment. While early views suggested that punishment might cause unlearning of the original instrumental association [2], later evidence suggested that punishment can result in formation of an action–outcome association [3]. But, many processes confound our ability

to attribute detected behavioral suppression to response–contingent punishment itself. My daughter's trepidation to return to her milkshake, for example, might have been a Pavlovian conditional response to the milkshake as a stimulus predicting the aversive brain freeze, rather than resulting any learned association between her hurried consumption and the adverse consequence. With further training, I suspect, she will learn the true cause of her brain freeze. It is critical to dissociate response suppression due to Pavlovian fear from that due to punishment.

The theorists will also enjoy discussion of potential overlap in the psychological processes of punishment and extinction. Indeed, new evidence indicates that, similar to extinction, suppression of responding due to punishment, is context specific, i.e., action performance will return when tested outside the punishment context [4, 5]. This indicates that punishment is regulated by contextual stimuli. Among other possibilities, this could be achieved by a hierarchical context–action–outcome association or by a direct stimulus–response inhibitory association. More research is needed.

To facilitate future investigation, the review is also a handy guide for the experimentalists. Due to the complexity of potential associations learned during a punishment experiment, there are many potential pitfalls in experimental design that could be punished with uninterpretable data. Not to fear, however, the authors lay out 5 lessons learned from decades of punishment research that will aid in the design of elegant punishment experiments. For example, inclusion of a non-contingent aversive event control group, usually with administrative of aversive events yoked to a response–contingent subject, will help assess and overcome the interpretational confound created by potential simultaneous aversive Pavlovian conditioning.

For the neuroscientists, the review delineates the brain mechanisms of punishment. The contributions of corticolimbic-striatal and midbrain dopamine circuits are discussed. Neuropsychopharmacologists will appreciate the discussion of the contribution of serotonin and norepinephrine and the anti-punishment effect of anxiolytics. Appetitive behavioral neuroscientists may notice overlap between the circuitry proposed to contribute to punishment and that known to function in appetitive instrumental conditioning, providing insights into potential appetitive–aversive interactions and common learning mechanisms. Though, relative to positive reinforcement, our understanding of punishment mechanisms is more limited.

Those studying or treating patients with mental illness will know that altered sensitivity to punishment can be a core symptom of diseases marked by maladaptive motivation and/or decision making. Decreased sensitivity to adverse

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consequences, for example, is characteristic of addictions and impulse control disorders. Increased sensitivity to punishment has been associated with depression. The more we know about punishment, the better we will be able to model, understand, and treat these conditions. In this regard, an important question is the extent to which models of punishment, in which negative consequences are often administered with short delay, relate to real-life. A brain freeze immediately follows hasty milkshake consumption, but in many cases the negative consequences of our behavior may not manifest until long in the future. It may be hours before a hangover sets in, or even years until the ill effects of unhealthy eating habits emerge. Altered discounting of future punishment undoubtedly occurs in neuropsychiatric conditions and, therefore, such discounting should be considered, where relevant and possible, in the laboratory.

In summary, this review by Jean-Richard-Dit-Bressel et al. clarifies punishment, delineates its currently known processes and mechanisms, and, perhaps most importantly, exposes vital new questions ripe for exploration.

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ADDITIONAL INFORMATION

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