**Learning from different types of punishment across various learning contexts**

Ran Aaron Cohen (aharon.cohen2@mail.huji.ac.il)

Department of cognitive science, The Hebrew University of Jerusalem,

Mount scopus, Jerusalem, Israel

# Abstract

**Background:**We learn the value of states and actions in a specific structured environment throw rewards and punishments. Different kinds of punishment were used in behavioral research but not yet probed by themselves in a long, phone-home based, longitudinal study.

**Methods:**Here we examine two essentially different punishments: Monetary Loss and Loud White Noise. To distinguish between them subjects performed regularly, morning and evening, a trial-and-error choice task and their psychological and behavioral responses were collected for 12 days. Subjects were assigned randomly to one of the two types of punishment and played the tasks in a novel mobile-phone platform that was installed in their own devise and therefor was conducted in their own familiar environment and not in the lab.

**Results:** We found a high accuracy rates in training and in testing for both groups. Additionally, subjects maintained a good recall of stimuli value for a long time after they learned them. A heartrate analysis showed a ….

**Conclusions:**Subjects learned and remembered well stimuli values throughout the 12 days of the study in both types of punishment. The mobile platform we used is valid for studying the mechanisms of aversive learning in a longitudinal experiment.

**Keywords:** Punishment, White Noise, Learning rates, Contexts, Ranking, Generalization.

* Operant vs Classical conditioning
* Punishers & Rewards
* Methods – avoidance
* Punishment implications on clinical disorders
* Punishment definitions
* Punishment noise
* Punishment money
* nRPE vs negative punishment
* context experiment

# Introduction

Operant instrumental learning is used for a deeper understanding of states and actions in the environment. In classical conditioning (i.e. Pavlovian), when an appetitive or aversive stimulus (unconditioned) is repeatedly paired together with a neutral stimulus, the agent format an associative link between them. Now the agent assumes there is a connection between those stimuli and therefore elicits a response to the neutral stimulus that corresponds to the unconditioned stimulus. For a more interactive/operative understanding of our environment we use operant instrumental conditioning to establish a state-action-outcome connection. As a result, we can have better choices and more rewarding interactions in the future. A well-established way to describe this process is reinforcement learning. We act (or observe actions) in different states, evaluate the outcomes obtained by those actions and reevaluate our prior conditioned beliefs (posteriors). Over time, we get a reasonably effective knowledge of our surroundings, therefor we can adapt, habituate, and thrive.

Appetitive or aversive outcomes are used to encourage or inhibit, respectively, a state-action behavior. They are essential components in operant instrumental learning. The interaction between the agent's actions (approach or withdrawal) or inaction (inhibition, ignorance) in a specific state and the outcome obtained molds the value of that state-action over time. [The dynamics of the reinforcement value function is having an expected value (prediction) of the potential gain/loss from a state-action, receiving the outcome, forming a prediction error, and updating the expected value. Following sufficient steps, a steady and "good enough" evaluation of the state-action is expected. ]

In a way, punishment and reward are "two sides of the same coin" in the process of operant learning. Nevertheless it is well known that they differ in some important characteristics (*Jean-Richard-Dit-Bressel et al 2018*). The activation and nonactivation of dopaminergic neurons in the ventral striatum in the brain are classically attributed to reward mechanisms of positive reward prediction error and negative reward prediction error, respectively (*Schultz 2007*), whereas in aversive learning mechanisms the amygdala is more widely implicated (*Toshikazu et al. 2018; Jean-Richard-Dit-Bressel et al 2018*; *Costafreda et al 2008*). For example, Michely et al show that subregions in the basolateral amygdala encodes a punishment prediction error (Michely et al 2020). Furthermore, with respect to neurotransmitters, Dopamine is associated with reward prediction errors whereas Serotonin is implicated in punishment prediction errors (Cools et al 2008).   
Moreover, there is evidence that punishment has a different influence on learning and behavior than reward. Steel et al found that punishment had greater effect on learning in both sequencing skill task (SRTT) and motor skill task (FTT), although the effect on the SRTT task was positive whereas the effect of punishment on the FTT task was negative (Steel et al 2016). Galea et al. found that punishment produced faster learning for motor adaptation whereas reward caused greater retention (Galea et al 2015)**.** Moreover, people are more inclined to choose the no punishment than the matching reward option. This is the view of the canonical prospect theory of *Kahneman & Tversky* named as loss aversion and loss bias (*Kahneman & Tversky 1979)*. In animal research of punishment, Marchant et al found individual differences in the susceptibility to constant shock intensity in alcohol preferring Pack rats. The data showed a bimodal distribution in the response to punishment (*Marchant et al 2018*). However, other studies did not find a significant difference in classical conditioning through reward and punishment (**Delgado et al**).

In the clinical psychiatric perspective, disfunctions in reward or in punishment, result in different kinds of clinical disorders. For example, a dysfunctional reward system (e.g. unstable learning rate) has been linked to depression and bipolar disorder (*Eldar 2016*). I contrast, a dysfunctional punishment system, was linked to anxiety (more precisely, cognitive anxiety; see *Wise & Dolan 2020*). For example, Aylward et al found that anxious participants learned faster from negative outcomes, i.e.- had higher learning rate (*Duits et al 2015; Aylward et al 2019*; although see *Wise & Dolan 2020*). On the other hand, a lower sensitivity to punishment is implicated in addiction and psychopathy (*Jean-Richard-Dit-Bressel et al 2018*).

research in operant conditioning predominantly focused on the processes of appetitive reinforcement. Reward incentivization and its traits, mechanisms and implications are widely probed, and great progress has already been made. Unfortunately, this is not the case for punishment. Although punishment has an important role in learning processes and its great potential implications for psychiatric disorders (*Jean-Richard-Dit-Bressel et al. 2018; Wise & Dolan 2020*), we are still in ignorance with respect to some of its traits, neuronal and computational mechanisms, and its precise influence on human behavior (*Jean-Richard-Dit-Bressel et al. 2018; Wise & Dolan 2020*). Thus, the investigation of punishment is crucial and has a promising, fruitful prospect.

Based on Azrin and Holtz we can define punishment as the delivery of a stimulus that is contingent\* to some behavior and causes a reduction in the likelihood of that behavior occurring again (*Azrin and Holtz 1966*). This famous *Azrin and Holtz* definition emphasizes two important points, the punisher is not necessarily an aversive stimulus and that an aversive stimulus is not always punishment. The main feature a punisher must have is the reduction in the probability of a behavior to occur. If, for example, aversive US is paired with another CS but there is no reduction in the occurrences of the CS, the aversive US is not a punisher. We must see a learning process (e.g. the rat is not eating the cheese anymore to avoid a repugnant taste). The other feature is the contingency of the punisher with a behavior. In other words, the punisher's temporal association with the stimulus drives a reduction in the stimulus attraction and hence reducing its probability to get happen in the future. [There are other phenomena that although look like punishment but are in fact very different, therefor we must not confuse between them (see *Jean-Richard-Dit-Bressel et al 2018 for heuristic* differences between them and punishment).]

Two theories offered to describe the **effect** of punishment on choices. The additive theory and the subtractive theory. The **additive** theory claims that punishment reinforce another stimulus that avoids the punishment, therefor reducing the occurrences of punished stimulus, whereas the **subtractive** theory claims that punishment suppresses the appetitive attraction of a stimulus and thus causing a reduction in the probability of choosing that punished stimulus (Toshikazu et al, 2018). Furthermore, in the subtractive school there is a long dispute about the symmetrical nature of reward and punishment (*Rasmussen and Newland 2008*). *Rasmussen and Newland* concluded that punishment has a greater effect on choices than reward and therefor they are not symmetrical. Interestingly, Palminteri et al show, that over time, in a punishing context, punishment shifts to a reward system of reinforcement. The agent starts associating the non-punishing response with reward and the punishing response with no-reward (Palminteri et al 2015).

## The psychological literature a few types of punishers. One distinction is between positive and negative punishment. A positive punisher is the appearance of an undesirable or aversive stimulus contingently after an operant response. Some examples in research of positive punishers will be the delivery of an air puff, electric shock, and loud noise. Conversely, a negative punisher is the removal of an appetitive stimulus (a reward). Examples in research for negative punishers will be the removal of food and monetary loss (*Jean-Richard-Dit-Bressel et al 2018*). In this context, an interesting question is whether the loss of an existing reward (a negative punisher) is equal to the loss of a potential future reward (Negative RPE)].

## Another distinction in the punishment literature is of primary and secondary aversive stimulus. The primary punisher is one that the agent instantaneously perceives as aversive and unpleasant without the need for learning or conditioning. Examples of this type are the delivery of an air puff, electric shock, and loud noise that create an immediate repulsion when encountered. Conversely, a secondary punisher is one that needs to be conditioned and learned. For example, a parking ticket, an increase of product price and social punishments like an angry or disapproving face.

*Delgado et al* conducted experiments to probe the effects of monetary loss as a secondary reinforcer and to examine the differences between a primary and secondary punisher in a fear conditioning paradigm. They found that the striatum has an important role in monetary loss punisher (secondary) as in mild shock punisher (primary). Interestingly, the amygdala was activated only in the mild shock condition. They concluded that learning from monetary losses may depend on reinforcement learning mechanisms whereas primary punishers rely more on biological mechanisms. Importantly, they did not find a significant difference between primary and secondary punishment in the acquisition of conditioned responses (*Delgado et al 2011*; *Delgado et al* 2006). In a different study, *Delgado et al* show punishment prediction error signals in the striatum both in primary and secondary punishers. (*Delgado et al* 2008).  
In a different study, *Delgado et al* observed similaritiesin the NRPE signal and monetary loss signal(*Delgado et al 2000*).

Like Electric Shock, Loud White Noise is a common unconditioned stimulus (US) used in punishment conditioning research (Sperl et al 2016). For experiments with many conditioning trials, Sperl et al tried to which of the two US will cause a long and strong Conditioned Stimulus, that will satisfy an EEG and MRI test, and will be strong enough to avoid extinction. They designed a comparison study between them and concluded that Loud White Noise had greater valence of unpleasantness, less extinction of Conditioned Response (CR), and a better recall of the CR after 24h (Sperl 2016). Following Sperl et al we used a Loud White Noise of between 92 DB to 95 DB and considered reducing the volume if the noise was too aversive for participants. It is worth mentioning that other studies, like Muller et al, delivered different volumes and durations of white noise (Muller et al 2014, Moses et al 2007, Dolan et al 2006).

As mentioned above, punishment is considered a complementary side to appetitive reinforcement (*Jean-Richard-Dit-Bressel et al 2018*). ***Conceptually***, they differ in the direction of the probability of choices. While Reward ***increases*** the likelihood of a behavior to occur punishment ***decrease*s** it (*Johnston, J. M. 1972*). This may explain the fact that research of punishment in humans mainly focused on the ways in which punishment suppress appetitive behavior in a monetary context (*Wise & Dolan 2020*). Money is one of the only contexts that punishment can easily and plainly be manipulated and quantitively measured. On each stimulus the potential outcomes are gain or loss (and sometimes also a neutral outcome – no loss/gain). In many studies, punishment was not a single reinforcer but working simultaneously with reward (Steel et al 2016). Another reason for this common paradigm is that experiments want to simulate the frequent environment of learning, an environment that includes punishment vs reward, withdrawal vs approach and repulsion vs attraction. In this kind of design each stimulus has the prospect of delivering reward, punishment and sometimes a neutral feedback. Each stimulus also has different probabilities for each feedback (e.g. Palminteri et al 2015; O'Doherty et al 2001). Another within group paradigm is to designate one session to each reinforcer (Delgado et al). In a between group paradigm researchers designated a group for reward, punishment and added a control group (e.g. Galea et al 2015).

This study differs from those designs as it is testing punishment exclusively in a punishing environment. The only possible outcomes are punishment and the absence of punishment. Hence, there is only punishment prediction error. Importantly, the subject's choice is to avoid the stimulus that has the worse potential outcome by a withdraw action and as a result, the other (supposedly better) stimulus, is chosen. This design is implementing a scenario in which the agent can only lose, there is nothing to gain by avoiding the bad stimulus. It simulates a situation of running away from a threat and therefor all the attention is going to the punisher. As a result of this excluding environment, we wanted to capture more precisely the effect of punishment and its unique features and see more clearly how punishment affect learning and decision-making. Furthermore, we can test the effects of different kinds of punishments and compare between them (*Delgado et al 2011*).

Moreover, our experiment has a novel methodology in four manners. **First**, it is a longitudinal experiment conducted for about 12 days. **Second**, it is a between subject design which gives a cleaner effect to the US punisher, as we avoid the noise caused by switching the settings. **Third**, we used a different primary punisher (Loud White Noise) than *Delgado et al 2011* (Mild shock) that showed more efficacy in the Sperl et al study (2018). **Forth**, the experiment is running throw a novel mobile platform design and conducted at the natural environment of the subject. This is a new realistic approach for human studies that hopefully will give us also more realistic data collection.

Delgado et al design is different from the one we use in our experiment in a few ways. (1) their design is of a fear conditioning task when the subjects simply observe the CS and the US attached to it. (2) their experiment is a within-subject design, meaning each subject had two sessions – one of each punisher.

This study has two main goals. The first is to validate the differences between a positive-primary punisher and a negative-secondary punisher. We wanted to examine the learning process and performance in each punishment type, some physiological (Heart rate) and psychological (e.g. mood self-reports) measurements. The second goal is comparing these aversive instrumental learning results with a parallel experiment on reward instrumental learning.

For the monetary-loss group, we conducted a preliminary task beforehand to create an experiment bank from which the subject can lose money. This task is somewhat similar to other monetary loss studies (such as *Delgado et al 2011*; Steel et al 2016; Steel et al 2020) although our task was unique. The task included spinning a Wheel of fortune with different amounts of gains (400-1000 shekels). Unknown to the participants, the amount of money they won was fixed on 600 shekels (eq to ~182 dollars). For magnifying the effect of money loss on subjects, we created a sense of endowment to make the subject value more the initial sum of money. We also wanted to create a sense of agency, to increase the engagement and interest of subjects (Taub et al. 2020). The reason for doing that is our fear that since the amount being reduced in each loss of a coin is meager (0.2 shekels, ~ 0.06 dollars) we might lose the loss aversion effect and the motivation to avoid punishments might be sparse too. Although we have many trials along the experiment, and therefor the potential amount of loss is great, still, participant might not look on the big picture and therefor disregard the micro loss in a single trial. The sense of endowment and agency over the money increases the aversiveness of the monetary loss, therefor magnifying the effect on the subject (*Delgado et al 2011*; *Tricomi et al., 2004; Zink et al., 2004;* *De Martino et al., 2009*).

The aim of this study is to validate that our design is working, and subjects do learn through punishments the values of the stimuli throughout the 12 days of the experiment. Additionally, this experiment will give us preliminary results that would help in developing similar studies in the future.

## 

# Materials and Methods

This is the “HOW”-section and has the purpose of describing in detail exactly how the research was conducted. The ideal aim should be that another researcher based on the information given in this section should be able to replicate the study. The materials and methods section is normally divided into a number of subsections:

## (Participants)

If your study involves a survey or experiment, often the first section contains some minimal demographic information about the participants. How many? Gender distribution? Mean age and standard deviations? Any particular inclusion/exclusion criteria (e.g. only participants speaking languages relying on SVO were included or participants with prior knowledge of Japanese were excluded). If relevant something on informed consent and payment?

## (Materials/Stimuli)

Specify also the test/survey materials and maybe give an example of one or more stimulus items in a figure (if the stimuli was of a visual kind).

## Procedure

How was the investigation carried out? Outline the procedure you followed in detail. What were the participants supposed to do and when? Outline the full experimental procedure (e.g. “first participants were instructed and given the opportunity to familiarize themselves with the test materials. Then they were engaged in a session consisting of x trials ...” etc.). Also specify which equipment/software/ programming language and packages were used to record responses/mine data/build your model (e.g. “Survey was administered with Surveymonkey and results were transferred to .csv files.” …. “; “Using the facebook graph API, we tracked user comments to 40 public posts over a period of two weeks…”; “I used Python and nltk to analyze the rate of X among A versus B by…”. )

## Analysis

Outline procedures for any type of preprocessing of the data such as transcriptions or coding (what was the coding scheme? Was any data excluded and if so on what grounds? Were any means taken in order to secure reliability?). Optionally, here you can also specify which statistical test you used and the software tools. If your study did not involve a lot of data processing (if you recorded data that can be more or less directly fed into statistical analysis) this section can be collapsed with the result section rather than constitute a separate section.

# Results

WHAT did you find? Here you present the output of your statistical analyses. This is often a pretty short section with mostly numbers (means, standard deviations and optionally inferential stats such as e.g. t-values and p-values). The results should preferably be accompanied with figures presenting tables or possibly graphs such as scatter plots or bar diagrams illustrating the results visually. Notice that this section is not the place for lengthy descriptions and interpretations of your results – that should go to the Discussion-section.

Table 1: Interesting results.

| Condition | Means/sd |
| --- | --- |
| xxxx | 63% ± 12% |
| yyyy | 96% ± 23% |
| zzzz | 70% ± 8% |
| wwww | 22% ± 9% |

fig4_StructIconExp2

Figure 1: This is a figure.

# Discussion

The discussion will often start with a brief summary of the results but in prose (no numbers). Then follows an interpretation connecting the findings to the hypotheses (were they confirmed or rejected? Why/why not?) and the relevant literature. In some sense the discussion often makes the opposite movement than the introduction: i.e. it starts with the local, concrete observations and then relate that to the literature and eventually to the overall theoretical field of inquiry. Also, often the discussion will comment on limitations and/or possible confounding factors in the experiment and might touch upon prospects for further research.

Again the discussion can be one continuous, uninterrupted section, but it is also often divided into shorter sections with subheadings.

# Conclusions

Implications and applications (as well as limitations) of your work. It can also contain subsections.

# Acknowledgments

If you need to acknowledge someone, place such acknowledgments in a section at the end of the paper just before the references.

# References

Follow the APA Publication Manual for citation format, both within the text and in the reference list.

Alphabetize references by the surnames of the authors, with single-author entries preceding multiple-author entries. Order references by the same authors by the year of publication, with the earliest reference first.

Example:

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# Footnotes

\**Azrin and Holtz* uses the phrase ***immediate***. we used the word ***contingent*** because, though weaker, a punisher may also be delayed and still reduce the likelihood of the preceding behavior. Additionally if we explain the delay to the subject there is an increase in probability reduction (*Trenholme & Baron, 1975*)