# Introduction

Conceptually, punishment differs from reinforcement in the direction of change in the probability of choosing a behavior. While Reward increases the likelihood of a behavior to occur, punishment decreases it (Azrin and Holtz 1966; Johnston, J. M. 1972). Naively, we might say that punishment is the negative equivalent of reward, therefore they should behave the same, only in different dimensions.

Nevertheless, it seems like aversive reinforcement is unique in its traits, as we can observe in the famous phenomenon referred to as loss-aversion bias in which people prefer to avoid punishment over gaining an equivalent reward, (*Kahneman & Tversky 1979)*. In other words, the absolute value of a coin lost is perceived greater than a coin gained (Rasmussen & Neweland, 2008).

Many studies have demonstrated the differences between reward and punishment (*Jean-Richard-Dit-Bressel et al 2018*). These differences involve many aspects such as the neuronal systems, effects on learning, and clinical psychiatric disorders (*Schultz 2007*; Cools et al 2008; *Costafreda et al 2008; Galea et al 2015; Eldar et al. 2016a; Steel et al 2016; Toshikazu et al. 2018; Jean-Richard-Dit-Bressel et al 2018*; *Aylward et al 2019*; Michely et al 2020).

Although punishment learning mechanism has an important role in learning processes and its extensive potential implications for psychiatric disorders (*Jean-Richard-Dit-Bressel et al. 2018; Wise & Dolan 2020*), we still know little about some of its neuronal and computational processing, and its precise influence on human behavior (*Jean-Richard-Dit-Bressel et al. 2018; Wise & Dolan 2020*). Thus, the investigation of punishment effects and implications is crucial and has a promising, fruitful prospect.

The most fundamental form of punishment for humans and animals alike is primary aversive stimulus. It is naturally perceived as to have negative value without any conditioning. An example which is frequently used in research is the delivery of an electric shock. The recipient is immediately repelled even if it is the first time it ever encountered this stimulus. In contrast, a secondary punishment is aversive only after having been conditioned with a primary aversive stimulus. Monetary loss is a widespread example of a secondary punishment frequently used in human experiments (*Franzoi, S. L. 2015; Jean-Richard-Dit-Bressel et al 2018*).

Although studies with primary punishments are common, there are not many longitudinal experiments probing their effects over time. Moreover, although monetary loss can be highly aversive to humans as electric shock, it is still related to reward mechanisms *(Delgado et al 2006*; *Delgado et al* *2011*; *Palminteri et al 2015*). Thus we thought it was important to probe both types of punishments and in order to extract the conditioned response for each one of them separately (*Delgado et al* *2011*), we chose a between group experiment.

Individuals often differ in their perception of reward and punishment (Carver and White 1994). Studies suggest that this receptivity to affective outcomes is implicated in different forms of psychopathology (Johnson et al 2003).

Eldar et al (2018) divides this receptivity into two parts: sensitivity and responsivity. They define Sensitivity to punishment as the transformation from objective value into subjective utility and responsivity as how much attention is given to the dimension of punishment. They found that responsivity to reward prediction errors changes from day to day and these changes involves in mood fluctuations. Although responsivity to punishment may also fluctuate over days, we do not currently know how its dynamics resemble or differ from responsivity to reward. Moreover, studies have also suggested that we learn differently in multiple timescales (ligaya K. 2016; Wimmer & Poldrack 2017; Eldar et al 2018).

## In order to explore these dynamics we sought to develop a platform that enables to investigate how punishment sensitivity and responsivity varies by day as a function of the degree to which subjects tried to avoid images associated with punishments and their heartrate responses to the aversive stimulus, respectively.

Although using electric shock as punishment is common in regular studies, using it in a remote longitudinal experiment has two downsides: the first is the lack of experimental control (Reips 2000), meaning that it is hard to operate it at the home of the subject and we have no good way to ensure that the procedure of delivering the electric shock would not be compromised. The second concern is that subjects will habituate to the stimulus with time (Mcsweeney & Roll 1998). In order to address these issues, we used a different kind of primary aversive stimulus, loud white noise.

Sperl et al (2016) presented a comparison between electric shock and loud white noise as an unconditioned stimulus and concluded that the latter had greater valence of unpleasantness, less extinction of conditioned response, and a better recall of the conditioned response after 24h. To make sure that the delivery of the aversive noise was not compromised we made sure the subjects wore the earphones during the learning game and that they heard the aversive noise through it (the sound volume was set at the beginning of the experiment and coerced on the phone's system), we added randomly between trials a task that tests whether they are listening and attentive to sounds delivered through the earphones.

## To carry out a longitudinal experiment on learning from primary aversive punishment we applied a novel mobile platform that can be used by subjects outside of the laboratory. This kind of online design has proven reliable for aversive conditioning studies (Seow & Hauser 2021) and has many advantages but also a few challenges (Reips 2000).

To make sure the data we collect is indeed reliable, subjects' data was uploaded and stored in a secured location every few hours. This data was reviewed by the experimenter regularly and a few reliability tests were made such as checking the reaction time was standard, side bias, performance, and tasks time schedules. We will elaborate on these measurements in the methods section.

The aim of this study is to validate that the design we developed is reliable to investigate learning from punishment for multiple days, meaning that subjects do learn the values of the stimuli throughout the 12 days of the experiment. To do that, we tracked the daily performance and heartrate responses of subjects to evaluate the effects of the aversive stimulus. These results will also give us a first glimpse about the differences between a positive-primary punisher and a negative-secondary punisher, and between them to reward. Nonetheless, unfortunately, due to time limitations, our sample size is too small to draw conclusions about group differences from it. This novel experiment will hopefully give us good basic design for future studies that will get meaningful results on the variability of sensitivity and responsivity to punishment over multiple days, and its involvement in behavior, mood fluctuations and psychiatric disorders such as depression and anxiety.