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TIME PERCEPTION AS A FUNCTION OF REINFORCEMENT AND PUNISHMENT: AN EXPLORATORY STUDY

PERCEPÇÃO DE TEMPO COMO FUNÇÃO DE REFORÇAMENTO E PUNIÇÃO: UM ESTUDO EXPLORATÓRIO

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ABSTRACT

In this paper, time perception as a function of reinforcement and punishment is investigated within a retrospective paradigm. The experiment used a computer game simulating a maze, where the participants controlled an avatar and had to make path choices between left and right to progress. Under punishment (P-), "wrong" choices resulted in the loss of points; under reinforcement (R+), "right" choices produced points. In the control condition (C), there was no presentation of points. The data of 49 participants (n=49) were analyzed in this study. At the end of the task, the participants were asked to estimate the playing time and to evaluate how much fun the game was. The results show that Group R+ presented overestimation in relation to real time, while Group P- did not distort temporal perception. In addition, the real time spent finishing the task differed from the control condition for both experimental groups (P- higher and R+ lower than C). Game appreciation was slightly more positive for condition P-, but this difference was not statistically significant. These results suggest the influence of operant contingencies on temporal perception and the independence between these contingencies and reported fun.

Keywords: time perception; verbal estimation; reinforcement; punishment; video games.

RESUMO

A percepção de tempo, no paradigma retrospectivo, foi investigada em função de reforçamento e punição. Foi utilizado um jogo de computador, simulando um labirinto, em que os participantes controlavam um avatar e tinham que fazer escolhas de caminho entre esquerda e direita para progredir. Sob punição (P-), as escolhas "erradas" produziam perda de pontos; em Reforçamento (R +), as escolhas "certas" produziram o ganho de pontos. Na condição Controle (C) não houve apresentação de pontos. Os dados de 49 participantes (n = 49) foram analisados neste estudo. Ao final da tarefa, os participantes foram solicitados a estimar o tempo de jogo e avaliar o quanto era divertido. Os resultados mostram que o Grupo R + apresentou superestimação em relação ao tempo real, enquanto o Grupo P- não apresentou distorção temporal. Além disso, o grupo P- precisou de mais tempo para concluir a tarefa. A apreciação do jogo foi geralmente mais positiva para a condição P-, mas a análise estatística não pode verificar significância nessa diferença. Esses resultados sugerem a influência das contingências operantes na percepção temporal e a independência entre essas contingências e a diversão relatada.

Palavras-chave: percepção de tempo; estimativa verbal; reforçamento; punição; videogames.

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Human time perception is one of the oldest topics in experimental psychology. Lejeune and Wearden (2009) pointed out that since 1868, when Vierordt published the first known paper on this matter, correlations between the precision of time perception and several variations in physiological conditions have been analyzed. Studies have shown, for example, that a higher body temperature might be correlated with a faster subjective time (Wearden & Penton-Voak, 1995), that women's time perception might be less accurate than men's when estimating an interval that has already elapsed (Block, Hancock, & Zakay, 2000), that children and elderly people might evaluate the durations of an interval differently (Wearden, 2005), that the use of caffeine might be associated with a faster subjective time (Gruber & Block, 2003) and that individuals who are dependent on stimulant substances, such as cocaine and methamphetamines, overestimate some durations (faster subjective time) when compared to non-stimulant-dependent individuals (Wittmann, Leland, Churan, & Paulus, 2007).

Psychological variables, such as being aware that one will have to estimate the duration of a given episode, are also important. People who know they will have to estimate an event duration before it happens usually produce more precise estimations, with a lower variance, than people who are only informed about the estimation task after the time to be estimated has already elapsed (Block & Zackay, 1997; Ades, 2002). To account for this difference, time estimation studies are usually divided into studies of prospective timing (where the participant knows in advance that he or she will have to estimate duration) or retrospective timing (where the participant is questioned about interval duration just after the time has elapsed). Regarding the influence of the quality of the task over timing skills, data suggest that tasks with a higher complexity level are associated with a reduction in the perceived time duration (Smith, 1969; Block & Gellersen, 2010).

However, questions on many other aspects of this relationship remain unanswered. For example, common sense frequently tells us that our time perception can be dependent on how fun or boring the activity that we are involved in is. It is common to assert that a nice activity ends quickly, but a boring activity passes slowly. "A watched pot never boils" goes the saying. However, what could "having fun" or "being bored" mean from a scientific perspective? This lay observation is frequent among different cultures and times (Assis, 1894; Gaskell, 1848), and efforts to scientifically evaluate this hypothesis have been conducted from different psychological perspectives (Kellaris & Kent, 1992; Sackett, Meyvis, Nelson, Converse, & Sackett, 2010).

According to the common sense, the notions of fun and boring activities could serve as an experiential lay description of being under positive reinforcement or aversive contingencies (Skinner, 1986). It is well known that reinforcement and punishment have opposite effects on the probability of response: the former increases this probability, and the latter reduces it (Catania, 2013). Opposite emotions and feelings, although not inherent in the scientific definitions of reinforcement and punishment, are frequently associated with these terms (Skinner, 1953; 1986). Therefore, while this operationalization by no means captures the literal experiences of boredom and fun, it is possible to speculate that these opposite feelings may be affected by opposite operant contingencies, such as punishment and reinforcement, respectively.

To our knowledge, no study has investigated the specific influence of reinforcement and punishment contingencies on the perceived duration of a given task. The present investigation aimed to fill this gap, verifying whether positive reinforcement and negative punishment contingent on a task may differentially affect the perception of the time taken to perform it. In parallel, we verified how fun or boring the participants considered our experimental situations to be, and we analyzed whether these feelings were correlated with the contingencies and the contingencies with the real time spent on the task.

METHOD

Participants

A total of 60 people volunteered for this study. They were informed about the study through posters affixed at bus stops and in public places on the main campus of the University of São Paulo. The poster specified that candidates should be male and within the age range of 18 to 35 years to participate in this study.

From this initial number, 11 participants were eliminated due to factors that are known to affect time perception, such as the use of substances, body temperature above normal level (>37 Celsius) or technical issues. Body temperature was verified utilizing a simple thermometer under the arm during the initial briefing on the experiment, and the other body issues were reported by participants on a questionnaire. The participants were not informed that these were exclusion criteria and performed the experimental tasks as normal to avoid highly motivated participants giving false answers to the questionnaire or sharing this information with other participants. We had a total of 49 valid participants (n=49) for this experiment.

The project was submitted to the research ethics board of the Institute of Psychology of the University of São Paulo, and its approval is registered on the report numbered 285,718. Informed consent was obtained prior to the first session for all participants.

Equipment

A total of 4 virtual mazes were generated through the Neverwinter Nights 2 toolset software specifically for this research. All mazes were identical in size and shape, differing from one another only in cosmetic features such as the color of the floor and walls. These cosmetic differences were applied to help participants note that they had moved from one maze to another.

Each maze presented a total of 3 choice situations where participants had to choose between left or right. The choice was made by moving the avatar through one of the two doors (left and right) found at each junction. After the avatar was moved, the door locked behind it, and it was impossible to go backward in the maze. After finishing a maze, the participant was automatically transported to the next. To complete an experimental session, each participant had to run through all mazes 3 times (3 cycles), totaling 36 choice situations (3 choices per maze, through a total of 4 mazes and going through the whole cycle 3 times). At the beginning of each cycle, all doors were unlocked. Figure 1 shows a schematic map of a single maze. Door locations are marked in red.

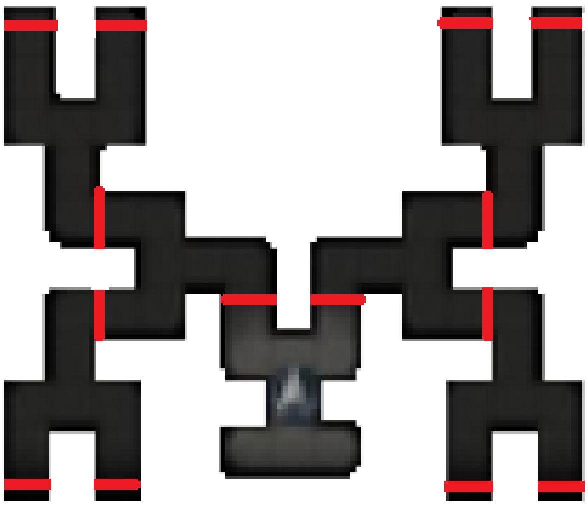

Figure 1. Schematic map of a maze.

All experimental sessions were run on the same notebook, an LG 410A model equipped with an Intel I3 dual core processor (2365 MHz), 512 mb of RAM and an NVidia 310 M video board that provided optimal software performance. An optic mouse was also provided.

The sessions were carried out in a lab room without clocks or any specific time measurement devices. During the session, the researcher stood in a room next to the lab and would come in only when requested orally by a participant.

Procedure

Participants were received in the experimental room by the experimenter. A quick briefing followed, where the experimenter would read the terms of informed consent along with the participant, answer any questions regarding the terms, explain that the experimental session would last for a maximum of 40 minutes and tell the participant that further questions regarding the experiment would only be answered after the end of the experimental session.

At this point, the participants were requested to turn off their cell phones and remove any items such as watches and MP3 players and store them in their backpacks.

The software was initiated, and the experimenter left the room. If the participant requested that the experimenter return before the end of the experimental task, the researcher would answer the participant's call, but that participant's data would be considered invalid given that this disruption artificially increased the time needed to finish the task.

Participants were randomly assigned to one of 3 experimental conditions: control group (C) (n=16), negative punishment (P-) (n=15) and positive reinforcement (R+) (n=18). Initially, the groups had the same "n", but as mentioned, some participants' data had to be discarded.

Groups differed in the quantity of initial life points and programmed consequences for the desired behavior. The instructions for the control group were also slightly different, to create a situation where participants were not influenced by gain or loss of life points.

Regarding the quantity of life points, group C had no life points whatsoever, while groups P- and R+ could both achieve a maximum of 138 life points and a minimum of 30 life points but differed in the fact that P- started the game with the maximum possible amount and R+ with the minimum amount of life points.

Regarding the programmed consequences, there were no life point consequences for group C. Group P- would lose 3 life points for each incorrect choice and receive no bonus for correct choices. Group R+ would receive 3 life points for each correct choice and lose no life points due to incorrect choices.

The choice situations occurred whenever the participant's avatar reached a bifurcation in the maze, whereupon the participant had to choose between left and right. There was a predetermined sequence of left and right choices that was considered correct for each maze (Table 1), but as the maze had a symmetrical pattern design, at each bifurcation, the participant had the chance to be exposed to consequences. To confirm his choice, the participant had to go through a door at the end of the chosen path, which would lock behind the participant's avatar and prevent his return. The correct choice patterns were the same for the R+ and P- groups. When the participant finished a maze, he would be transported to a new maze, which was signaled by different colors and textures of the walls and floor.

Table 1
Choices that led to consequences (reinforcement or punishment) at each junction of each maze

	1st Bifurcation	2nd Bifurcation	3rd Bifurcation
Maze 1	Left	Left	Left
Maze 2	Right	Right	Right
Maze 3	Left	Right	Left
Maze 4	Right	Left	Right

For all groups, the instructions and performance results were themed in a medieval style as a way to increase engagement with the task. Both the instructions and the performance results were delivered by a virtual character in the game. The instructions for groups R+ and P- were exactly the same. The instructions for group C had to be adapted given the absence of life points for this group. The instructions were as follows:

Groups R+ and P-

> *"The king demands that his vassals show their valor by going through each of the four castle mazes three times. The higher your life points are at the end of the task, the higher will be the title of nobility that the king will bestow upon you. Those who finish the mazes with at least 57 life points will be called squires. Those who finish with at least 84 will be called knights. The brave who make it to the end of the mazes with at least 111 points will be called champions of the kingdom!*
> *To move through the mazes, you must click with the left mouse button on the spot where you want to go. To open doors, click on them. On your character's portrait, you will find the current and maximum quantity of life points. If you have any questions, go through instructions again. Let's get to work!"*

Group C

> *"The king demands that his vassals show their valor by going through each of the four castle mazes three times. At the end of the mazes, you will have the honor of meeting your king. (click the left mouse button to proceed)*
> *To move through the mazes, you must click with the left mouse button on the spot where you want to go. To open doors, click on them.*
> *If you have any questions, go through instructions again. Let's get to work!"*

Life points were displayed to participants in groups R+ and P- in a volumetric and numeric panel with the current and maximum possible amounts. For group C, there was no numeric display, and the volumetric display was kept full and unchanged throughout the experiment. Whenever a participant received life points (only for group R+) or lost life points (only for group P-), a message appeared over the participant's avatar announcing the change in life points, and a quantity of 3 life points was either added or subtracted from the current number of life points that the participant's avatar had. Figure 2 shows a sample choice situation in a maze, with the life points displayed in the upper right corner.

In all conditions, participants had to complete a full course through the 4 mazes three times in a row to finish the task. This repetition was designed to increase the number of choice responses emitted (to a total of 36).

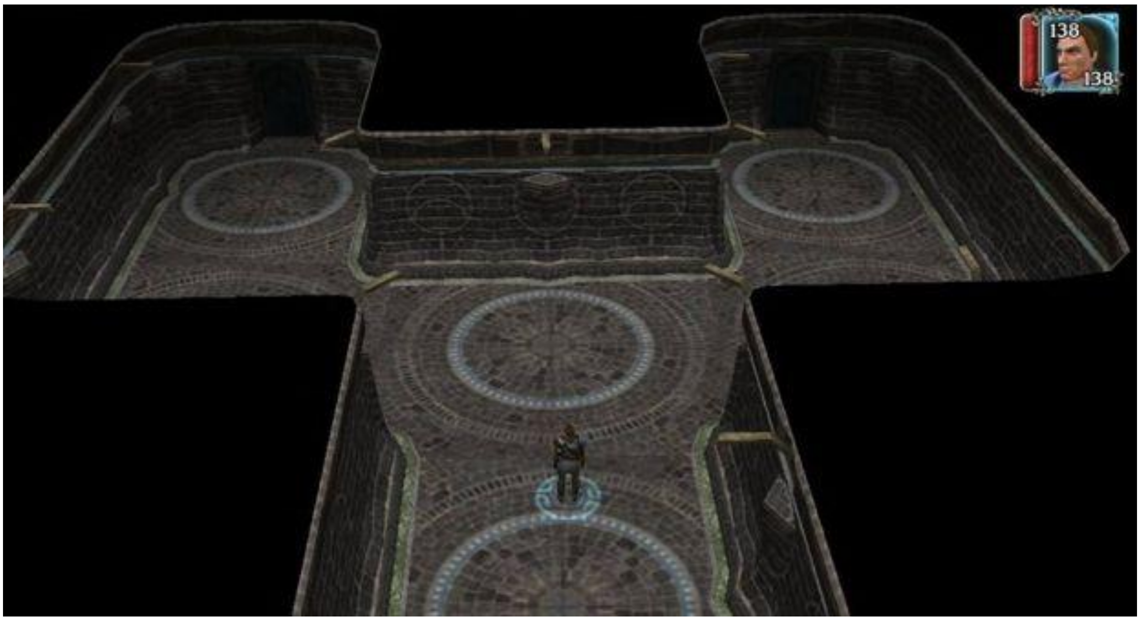

Figure 2. Participant's view of the maze.

After finishing the tasks, participants were prompted by the software to answer a survey with questions regarding their experience with the game. The questions asked in the survey are displayed in Table 2.

After completing the survey, the participant had to return to the software and click on "proceed". A confirmation then popped up that asked the participant to make sure he had finished the survey before moving forward, and then the participant's avatar was transported to a last room where he met the king and his court. There, a short-automated sequence occurred in which the king congratulated the participant and gave him his title of nobility in accordance with his score and then the court celebrated him. The final feedback was stated as follows:

> *"May the kingdom look upon the man who stands before me, because he is the one who has beaten the royal challenge, the castle's maze. May the bards sing his glory, and the court know that before me stands the newest _(title)_ of the kingdom. (Please contact the researcher)*."

If the participant did not achieve the minimum score to receive a title (57 life points), the second paragraph was substituted with the following:

> *"You have beaten the castle's maze. Congratulations. (Please contact the researcher)"*

The maze software automatically recorded all path choices made by the participant throughout the experiment and the time taken by each participant to complete the maze. It recorded the time from the moment participant opened the first door in the first-choice situation in the maze until the last click in the game, just before the participant was prompted to answer a survey on a paper inside an envelope near the computer. The participant had no idea before that moment that the envelope would be of any relevance to him.

Table 2
Questions asked after participants finished the game.

1	For how long do you think you have been playing since the message appeared indicating game start? For _ _ minutes and _ _ seconds.
2	On a scale of 1 to 5, where 1 represents no fun whatsoever and 5 represents a lot of fun, how would you score this game? What could be changed to make it more fun?
3	What do you believe you had to do to get to the end of the maze with maximum life points?
4	Do you usually play video games? What games have you been playing lately (maximum of 3)? What's your favorite video game style?
5	Did you drink any beverage containing caffeine in the last 5 hours (i.e., coffee, black tea, mate tea, Coke)? If so, which drink and how long ago?
6	Have you drunk any alcoholic beverages in the last hour (beer, wine, etc.)? It's not necessary to specify which one.
7	Do you make regular use of any medication? If it's acceptable to you, please specify (all information you give us here is confidential, under the informed consent terms).
8	Have you used any medicines or drugs in the last hour? If you do not wish to go into detail, there is no need to specify which ones. If you do not wish to answer this question at all, you are free to leave it blank (all information you give us here is confidential, under the informed consent terms).

Data Analysis

We compared group averages for different indexes: time perception, real time spent to conclude the task and enjoyment of the experimental task (fun).

The time perception index was created by the ratio (perceived time/real time) x 100: the precise time perception corresponds to the ratio = 100%; values above indicate overestimation, and values below indicate underestimation.

To compare group averages, when pertinent, a test of normality (Kolmogorov-Smirnov) and of equality of variance (Levene) were utilized. When these tests indicated data normality and homoscedasticity, we utilized a variance analysis (one-way ANOVA) followed by a Tukey post hoc test. When homoscedasticity was not found, we applied a Brown-Forsythe test followed by Dunnett's 3T post hoc test.

Spearman correlations between fun and real time & and fun and time perception were also assessed. Finally, to check for differences in the fun score averages among groups, the Kruskal-Wallis test was utilized.

For all tests, results showing $p<0.05$ were considered significant.

RESULTS

The Levene and Kolmogorov-Smirnov tests showed that the group data compositions were homogeneous ($p= 0.206$) and that the homogeneity of each group's data distribution was normal ($p = 0.200$, 0.191 and 0.200 for groups C, P- and R+, respectively).

A one-way between-subjects ANOVA, conducted to compare the effect of contingencies of reinforcement over time perception in R+, P- and C conditions, identified a significant effect of the experimental condition over time perception ($p=0.001$). Post hoc comparisons using the Tukey HSD test indicated that the mean score for R+ was significantly different from the C condition ($p = 0.011$) and from the P- condition ($p = 0.001$). The differences between the P- and C conditions were not significant.

Taken together, these results show that time perception might be influenced by the functional relation between the organism and the environment, with the effect of positive reinforcement being stronger.

Figure 3 shows that the most precise average was obtained for group P-, while group C displayed a slight overestimation of the interval duration, even though the differences between C and P- were not statistically significant. The effect size, according to Cohen's d analysis, was considered large when groups R+ and C were compared (d = 0.995; delta = 1.235) and when groups R+ and P- were compared (d = 1.365, delta = 1.806).

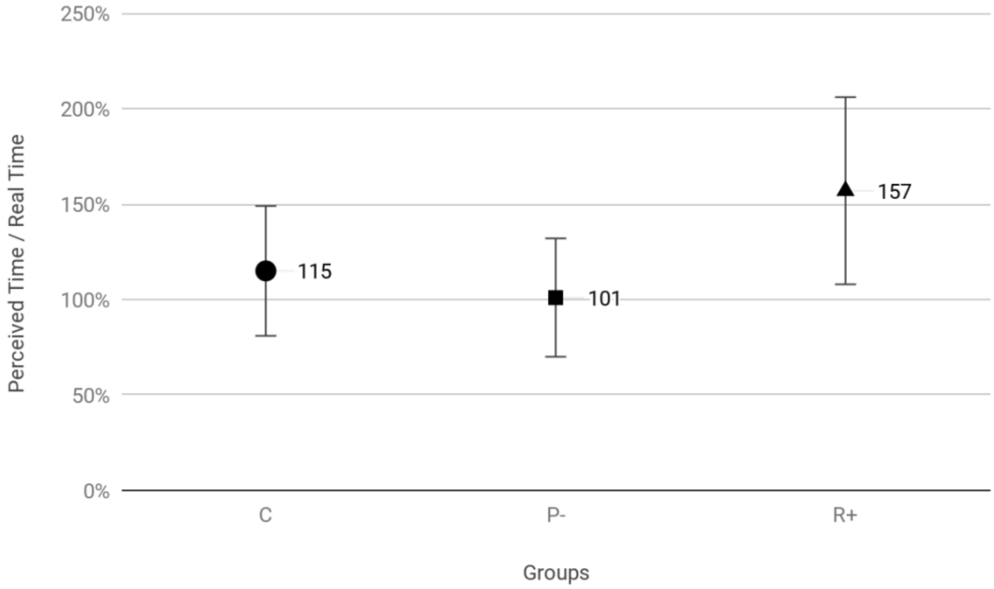

Figure 3. Time perception averages (and respective standard deviations) for each group.

Figure 4 shows the average time to finish the task (real time). The data distribution was found to be normal in the Kolmogorov-Smirnov test (p> 0.200 for all groups) but not homogeneous in Levene's test (p = 0.001). Given this violation of ANOVA's assumption of sample homogeneity, we switched to a Brown-Forsythe F test followed by Dunnett's 3T post hoc test. The one-way between-subjects Brown-Forsythe test identified a significant effect of the experimental condition on the real time to finish the maze (p <0.001). Post hoc comparisons using Dunnett's 3T test indicated that the mean time for P- was significantly higher different from the C condition (p = 0.006) and from the R+ condition (p = 0.001); the R+ was significantly lower them the C condition (p = 0.031). These data show that the experimental situation had an impact on the real time needed to finish the task in both the P- and R+ conditions. The effect size, according to Cohen's d analysis, was considered large when groups P- and C (d = 0.913; delta = 0,813), P- and R+ (d = 1.754, delta = 1.367) and R+ and C (d = 0.970, delta = 0.962) were compared.

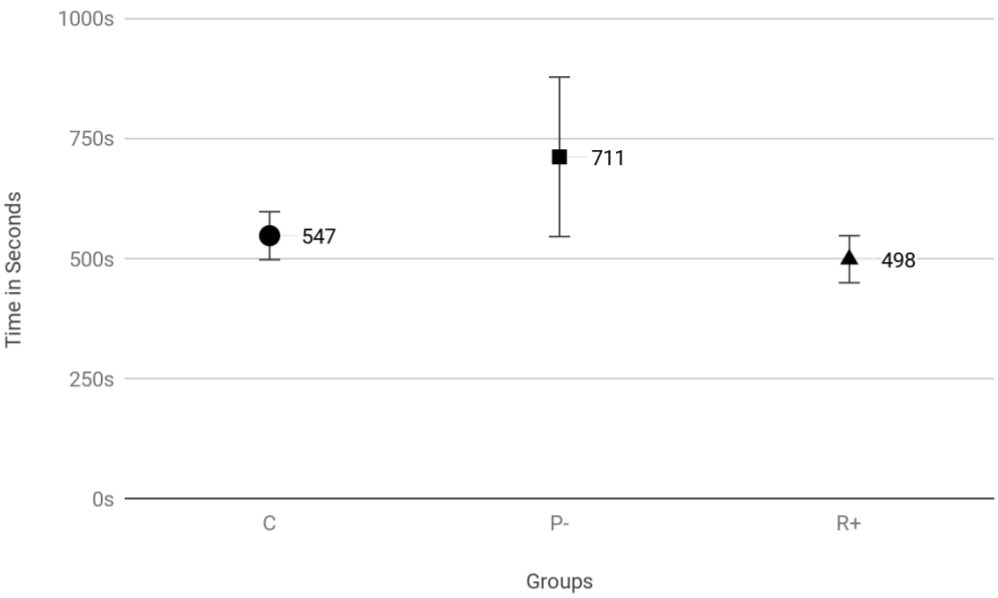

Figure 4. Average time taken to finish the task (and respective standard deviations) for each group.

We analyzed the correlations between the fun score average for each group and the experimental condition through a Kruskal-Wallis independent sample test. Because not all participants answered the question regarding fun, the n for this analysis was slightly reduced: n = 14 for group C, n = 14 for group P- and n = 17 for group R+. The differences in the fun averages reported in the different experimental conditions, as well as the correlations between fun and time perception and fun and real time, all resulted in no significant differences (Figure 5).

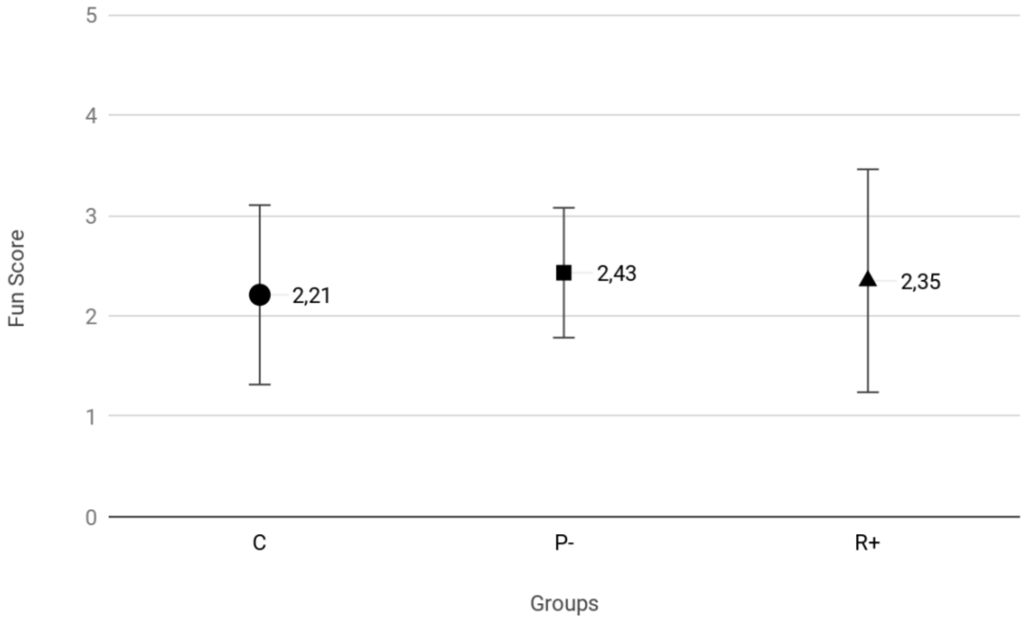

Figure 5. Average fun scores (and respective standard deviations) for each group.

DISCUSSION

The main question proposed to be investigated in the present research was whether the time taken to perform a task is perceived differently depending on positive reinforcement or negative punishment contingencies based on the participants' responses. In parallel, two other questions can be complementarily asked: first, whether the levels of fun were correlated with these contingencies and, finally, whether the reported degrees of fun were correlated with the perception of the time taken to perform the task.

Regarding the first question, our results showed that both contingencies differentially affected time perception: positive reinforcement produced overestimation of the time taken to conclude the task, while negative punishment did not distort temporal perception. These results suggest that the nature of the contingencies (aversive or not) can be an intervening variable that may influence time perception, and it must be controlled for if we want to make sure that experimental situations across different studies are comparable.

It is important to mention that, given that our objective was not to evaluate a learning process, the terms positive reinforcement and negative punishment are used here to designate, respectively, winning and losing points that are contingent on the participant's choices at the intersections of the mazes. This use is supported by many studies showing that winning and losing points (such as money or other conditioned reinforcers) have the aforementioned functions under different experimental conditions. For example, using gain or loss of money in an experimental situation, Rasmussen and Newland (2008) demonstrated that reinforcement and punishment have asymmetric effects: a penny lost is valued more than a penny earned, suggesting an asymmetry in the law of effect; in other studies with humans or pigeons, it was identified that reinforcement and punishment have different costs in a choice condition (Fox & Pietras, 2013; Pietras & Hackenberg, 2005). Therefore, our data are compatible with this literature showing that time perception is, possibly, one more behavioral dimension that is differentially affected by these opposite contingencies.

What is special about positive reinforcement, such that it generates the alteration in perception? Is it intrinsic to the reinforcement contingency, or is it a byproduct of the strategies developed under the different contingencies, such as the constant use of a single response to solve the problem (since the response works)?

Parallel data recorded during the experiment raise the possibility that different strategies were developed under both contingencies. We identified that groups exposed to different contingencies differed in the real time taken to finish the task: the punishment group spent more time finishing the task than the control group, while the reinforcement group spent slightly less time finishing the task than the control group. Contrary to some suggestions that punishment reduces behavioral variability (Sidman, 1989), we suggest that the longer average time to finish the task by participants of the punishment group could be a consequence of the increase in response topography variance that occurred when the participants were exposed to the punishment contingency, possibly trying new responses at the next choice situation to avoid or escape punishment. This hypothesis is corroborated by reports of the participants during post-session debriefing, when they explained what they did to succeed at the experimental task. Additionally, participants in the punishment group were the ones who found most of the bugs in the software (which led to invalidation of these participants' data and collection of new participants for this experimental group after debugging the software). Following this interpretation, participants in the reinforcement conditions could be driven to finish the task faster because the reinforcing stimuli promote the repeated use of the same single response that led to reinforcement previously, reducing the response variability.

Of course, it is only a hypothesis that the longer average time taken to finish the task by these participants is a consequence of an increase in the response variability. This suggestion needs to be directly investigated in future studies. This would account for the increased standard deviation exhibited in the real-time index for the punishment group (given that different participants would try different strategies, with different levels of complexity).

The time overestimation found for the positive reinforcement group is apparently in opposition to the original lay hypothesis that "time flies when you are having fun". However, this opposition could only be suggested if positive reinforcement was effectively associated with more fun than negative punishment, a hypothesis that our data do not support. Although both contingencies generated relatively low reports of fun, the punishment contingency was considered slightly more amusing by our participants.

The behavioral analytical literature has already pointed out that the distinction between reinforcement or punishment is a function that is established by several interconnected factors (Luiz & Hunziker, 2018): even aversive stimuli such as shocks can sometimes act as a reinforcer, and positive reinforcement can involve aversive contingencies (Perone, 2003). It is also possible, given the binary nature of our task and the symmetric nature of the reinforcement and punishment definitions, to make the interpretation that, in some measure in the R+ condition, the choice of the "wrong" path could act as a negative punishment, while on the P- condition, the choice of the "right" path could act as a negative reinforcement. The dichotomous conceptualization of punishment and reinforcement has been considered unsatisfactory by several authors (Michael, 1975; Hunziker, 2018), and the relativity of the aversive or reinforcing function of contingencies has been highlighted (Perone, 2003). In the present study, what can be pointed out is that the differences in the conditions of loss and gain of points had only a small effect on the fun perception (the loss condition being perceived as slightly more fun) but differentially affected the real time taken to play the game as well as the perception of the time spent in this game activity. These results seem compatible with the possible asymmetry of the law of effect suggested by Ramussen and Newland (2008).

No significant relation could be found between the reported fun averages and the differences in time perception. Nevertheless, this does not mean that fun has no influence over time perception. The fun averages we found were relatively low for both groups, and there was no significant difference between them; thus, we cannot make any strong assertions about the influence of fun on time perception. For the moment, we can only say that simple differences in the nature of the contingency (R+ or P-) were not enough to create a significant alteration in the amount of fun that our game could produce.

Distortions in time perception and high levels of enjoyment are considered constitutive elements for the experience of "flow", a concept related to a highly focused and task-immersed state of consciousness. The research around flow has been highly relevant to the development of video games, both in the sense of creating more enjoyable games (Cowley, Charles, Black, & Hickey, 2008) and avoiding the development of unhealthy video game playing behavior (Nuyens, Kuss, Lopez-Fernandez, & Griffiths, 2019; Xiao & Henderson, 2019). No equivalent studies based on behavioral analysis principles were found. The research about the effects of operant contingencies over time perception and levels of enjoyment could help to comprehend better what underlies the phenomenon described as flow.

In short, our data suggest that time perception might be affected by the nature (reinforcement or punishment) of the contingency. This information has direct implications for studies on time perception. Our data also question the assumption that reinforcement and punishment are procedures that are necessarily correlated with internal states characterized by positive or negative emotions, respectively. Although the methodological rigor of the experimental analysis of behavior does not allow for this kind of direct assumption, it is not uncommon to find it underlying some analyses or prescriptions of contingencies, especially in the applied context (Skinner, 1986). As we have seen in this study, the experimental data discredited this inference, and this is a good example of the need for experimentation as a strategy to understand behavior. We understand that, as an exploratory study, this paper raises more questions than it provides answers to, but we believe that it has the merit of being a first exploration that will be followed by more detailed investigations over the relations between operant contingencies and time perception.

DECLARATION OF CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

CONTRIBUTION OF EACH AUTHOR

Both the authors are equally responsible for the article contents.

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