Relationship between Delay Discounting and Risk Preference in Chimpanzees (*Pan troglodytes*) and Humans

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Abstract

Adaptive decisions require that decision makers factor in the subjective values of different possible outcomes, and the probability of these outcomes occurring. Subjective values depend, among other things, on how far an outcome is away in time. This can be captured by assessing an individual's delay discounting of different options. An individual's risk preference also affects how attractive particular choice options appear to them. In humans, probability discounting and delay discounting are often related. People who show more risky behaviors also tend to be more impulsive and less patient. Based on such findings, single-process models of delay discounting and probability discounting have been suggested. In the current study, we tested if this relationship is equally present in chimpanzees, one of human's closest extant evolutionary relatives. We presented 23 chimpanzees with a patience task and a risky-choice task. The patience task was designed to explicitly distinguish between delay preference and self-control (i.e., the ability to wait a given delay). Still, we found no strong correlations between risk and delay preferences. As this task has not been used with humans before, we implemented a computerized version and tested it in a sample of twenty adult participants. Initial results indicate that the task is well suited to capture patience, and it makes a promising candidate to be used in behavioral delay discounting experiments in humans.

Keywords: Delay Discounting; Hybrid-delay Task; Decision-making; Risky Choice; Implicit Risk Theory; Chimpanzees

Introduction

Most animals, including humans, are regularly confronted with situations where they have to decide between outcomes that occur at different times. The value of rewards is often discounted over time; this means the subjective value of a reward decreases the longer one has to wait for it. Adaptive choice of reward options requires weighing reward features such as size, desirability, or perishableness against delayed pay-out time.

Implicit risk theory suggests that delay discounting can be explained by delayed rewards affording more risk and uncertainty as compared to immediate rewards. As a result, perceived risk and an individual's risk preference are directly related to an individual's delay discounting and resulting decisions. Empirical evidence from humans lends support to this possibility and suggests that delay discounting and probability discounting might build on a single underlying process or at least share substantial variance components (for example, Benzion et al., 1989; Bixter & Luhmann, 2015; Mishra & Lalumière, 2017; see Johnson et al., 2020, for a meta-analytic overview and discussion of mixed evidence for single-process models).

Delay discounting has also been studied in other animals, including chimpanzees, one of humans' two closest, living primate relatives (for example, Beran et al., 2014; Beran & Hopkins, 2018; Paglieri et al., 2013; Rosati et al., 2007; Stevens et al., 2011; Stevens & Stephens, 2010). Chimpanzees can wait several minutes for a 'larger-later' reward option. Given this general ability to delay immediate gratification, the question arises whether delay discounting and risk preference are similarly related in chimpanzees. If we were to find similar correlations as seen for humans, this might indicate that delay discounting and probability discounting co-evolved and have brought about certain "types of decision-makers" already in the last common ancestor of human and chimpanzees. If delay discounting and risk preference are independent processes in chimpanzees but related in humans, this might indicate fundamental differences in cognitive decision-making architecture between the species.

The goal of the current study was to investigate whether the relationship of delay discounting and probability discounting is a human-specific effect, or is shared with a closely related primate species, the chimpanzee. To do so, we tested a group of chimpanzees in a risky-choice experiment and a patience experiment. Furthermore, we implemented a computerized human version of the chimpanzee patience task, known as the Hybrid Delay Task (HDT; Beran et al., 2014; Beran & Hopkins, 2018; Paglieri et al., 2013). The HDT is a two-step task, with step 1 using a binary choice to assess delay preferences and step 2 constituting a waiting task to assess delay abilities. This task has not been used in humans before but given its power to dissociate a preference for 'larger-later' rewards from the ability to maintain delays, we think it makes a good candidate to provide additional insights into human inter-temporal choices.

Methods - Chimpanzees

Subjects

We tested 23 chimpanzees (11 males, 12 females, age range 12–35 years) from Ngamba Island Chimpanzee Sanctuary, Uganda (https://ngambaisland.org/). The chimpanzees were tested individually in a familiar room of the holding facility. The chimpanzees were never food deprived for this study and could stop participating at any time. Usually, they signalled this by leaving the testing area, climbing up into their hammocks, or approaching the closed door to the forest. Water was always available ad libitum. The current research was approved by the University of Warwick research ethics committee and the Chimpanzee Sanctuary and Wildlife Conservation Trust (CSWCT) as well as the Uganda Wildlife Authority and the Uganda National Council for Science and Technology (UWA/COD/96/05).

Procedure

All chimpanzees participated in a patience experiment and a risky-choice experiment. We used established methodologies to test both behaviors. Before each experiment, we conducted numerical discrimination tests and familiarization trials to ensure that the chimpanzees could discriminate the quantities involved and understood the respective experimental procedure.

Presentation order of tasks and conditions wasn't counterbalanced across chimpanzees because this experiment assessed the correlations between individual differences in risky choice and delay discounting, making it important to provide all individuals with the same stimuli and order of conditions and tasks (see Goodhew & Edwards, 2019). As a consequence, all chimpanzees experienced the risk task before the HDT with the break between the tasks ranging from three weeks to six months (dictated by testing opportunities in the sanctuary). Importantly, in neither of the two tasks did the experimenter behave unreliably or deceptively towards the chimpanzees, i.e., she always provided the chosen option and never suddenly aborted the procedure or provided unexpected or random rewards. Hence, we do not expect any carry-over effects that could render the HDT additionally risky and that would bias the chimpanzees to play it safe and choose the immediate option due to a social risk from the experimenter.

Patience Experiment In the patience task, we used the Hybrid Delay Task (HDT) that separately assesses delay preference as well as the ability to maintain the delay during an accumulation procedure. The HDT is well suited to dissociate a preference for larger rewards from patience or self-control.

Figure 1 illustrates the apparatus and test set-up. Before the main task, chimpanzees received two kinds of familiarization sessions. These sessions all consisted of eight trials: on four trials, chimpanzees received the small-immediate reward (4 pieces), and on four trials, chimpanzees received the large-delayed reward (up to 12 pieces). First, every individual received one session where the accumulation platform was out of reach. Only once all items were placed onto the platform did the experimenter push the platform within reach. Second, we presented sessions where the accumulation platform was within reach. Here, the chimpanzees could experience that the experimenter stopped adding items as soon as they pulled the platform or began to eat from it. To ensure the chimpanzees understood this rationale, they had to wait for at least six food items in three of the four large-delayed trials within a session. Two individuals received three such sessions, eight individuals received two sessions, and fourteen individuals only needed one session.

We then introduced the two delay test conditions: 3 s and 10 s. Each experimental session consisted of eight trials, with four experimental sessions per condition. All individuals received the four sessions in the 3s condition first. A session began with two forced-choice trials – one small-immediate trial and one large-delayed trial (order counterbalanced across sessions), with the corresponding transfer speed (3 or 10 s) as per condition. These initial trials served as a reminder of the test procedure and indicated to the chimpanzees which delay condition was in force for that session. The other six trials in each session were test trials (resulting in a total of 24 test trials per condition per chimpanzee).

In both conditions, chimpanzees first chose between a small-immediate reward consisting of four pieces of food and a large-delayed reward consisting of twelve pieces of food. If a subject chose the small option, the experimenter transferred all pieces immediately onto the accumulation platform for the chimpanzee to eat. If a subject chose the large option, the experimenter began to place one piece after another onto the accumulation platform at a rate of one piece every three or every ten seconds depending on condition (see Figure 1). The inter-trial interval was adjusted according to delay condition and was set at 120 s for the 3s condition and 180 s for the 10s condition to ensure that all trials within a condition were of equal length. This means the start of the next trial couldn't be brought about more quickly by choosing the small-immediate option or by accumulating fewer items. For each individual, we assessed: (i) the number of collected food items, (ii) how often they picked the large option, and (iii) how often they accumulated four or fewer items after having picked the large option (later also referred to as 'errors', because four is the number of food items they could have gotten immediately had they picked the smaller option).

Figure 1: HDT chimpanzee test setup during accumulation phase. Here is depicted a trial in which the subject chose the large-delayed option. The experimenter added each piece one by one onto the green accumulation platform. If the subject pulled the green platform, the experimenter stopped adding rewards.

Risky-Choice Experiment In the risky-choice experiment, chimpanzees decided repeatedly (sixty trials) between an option with a constant medium reward outcome and a risky option with a large or zero outcome with a 50/50 chance. We also assessed each individual's indifference point between safe and risky options by applying a titration procedure with choice-dependent adaptation of the size of the safe option: after a risky choice in the previous trial, the safe option of the current trial was increased by 1 piece of food; after a safe choice in the previous trial, the safe option was decreased by 1. Dependent variables in this experiment were the proportion of risky choices and the average size of the safe option resulting from the titration experiment. In this paper, our focus is on the HDT results and the relation between HDT measures and risky choice. More details on the risky-choice procedure can be found in a recent publication by Keupp et al. (2021).

Coding and analysis. The experimenter coded all HDT sessions either live or from video. A second coder, who was blind to the purpose of the study, coded 25% of the videos. Coder agreement was very good for each variable: choice (Cohen's *kappa* =.99) and number of accumulated items (Spearman's *rho* =.99).

We assessed the number of small and large choices and how many items were accumulated per individual and delay condition. All analyses were performed within the R statistical computing environment (version 3.6.2). We ran separate linear mixed models to test for the effect of delay condition on initial choice, number of accumulated items in general, number of accumulated items after choosing the large option, number of errors, and effect of session number within condition on initial choice. Models were fitted using the functions glmer, lmer, and lm of the package lme4 (Bates et al., 2016). The formulated full models included condition as a fixed predictor of interest, subjects as a random effect, and random slope of condition within subject. One model additionally included the interaction of condition and session number in the fixed-effects structure. Session number was z-transformed and included as a random slope within subject. We compared these full models with the respective null models without the fixed-effect predictors (see here for more details on models and analysis: https://osf.io/54qdr/). For all models, we checked model stability by comparing the estimates from the models based on all data with those from models with the levels of the random effects excluded one at a time, and where necessary checked for collinearity by determining the Variance Inflation Factor (VIF, Field, 2009) for a linear model excluding the random effects. There were no obvious deviations from assumptions and no indications for model instability and problematic issues with variance inflation. We calculated conditional R^2 effect sizes using the function r.squaredGLMM of the package MuMIn (Bartón, 2020).

Results - Chimpanzees

Overall, chimpanzees picked the large option 78% (3s) and 72% (10s) of the time. The individual chimpanzees were consistent in their behavior in the HDT, as is apparent from a strong positive correlation between an individual's delay preference and the number of accumulated rewards (3s: r = .913, $p < .001$; 10s: r = .808, $p < .001$). This preference did not reliably differ between delay conditions ($\chi^2 = 1.90$, df = 1, $p < .17$, *conditional* $R^2 = 0.118$).

We also observed group differences, however, between the delay conditions. Figure 2 displays the average number of food items collected and the number of errors for each chimpanzee. The chimpanzees collected more food items in the 3s condition compared to the 10s condition ($\chi^2 = 11.73$, df = 1, $p < .001$, *conditional* $R^2 = 0.437$). After choosing the large option, they accumulated on average more food rewards in the 3s condition (9.5 items) than in the 10s condition (8.1 items) ($\chi^2 = 9.81$, df = 1, $p < .01$, *conditional* $R^2 = 0.423$; see Figure 2A). Moreover, they made more errors (i.e., accumulating only four or fewer rewards after picking the larger option) in the 10s condition than in the 3s condition (χ^2 = 10.78, df = 1, p = .001, *conditional* $R^2 = 0.295$; see Figure 2B).

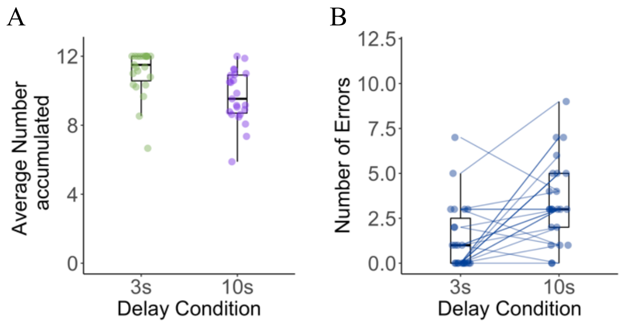

Figure 2: HDT performance chimpanzees. A: Individuals' average number of accumulated rewards after choosing the large option. B: Number of errors per individual. In all boxplots in this paper, horizontal lines represent median (thick line) and 25th & 75th percentiles; Whiskers extend to smallest and largest value within 1.5 * interquartile range

Furthermore, we found a significant interaction of delay condition and session. Each chimpanzee received four sessions of each delay condition. Whereas choice of the large option remained relatively stable in the 3s sessions, the probability of picking the large option decreased across sessions in the 10s condition (χ^2 = 21.22, *df* = 3, $p < .001$, *conditional* R^2 = 0.497). This decrease indicates that with increasing experience, chimpanzees adapted their delay choice to their ability or willingness to wait for the accumulating food.

Finally, we observed no strong correlations between any of the measures in the HDT and the risky-choice experiment in these chimpanzees. The numerically highest observed correlation was found between number of obtained rewards in the 10s condition and size of the safe option in the risky-choice titration paradigm (r = 0.37, p = .083): the more rewards were obtained in the 10s condition the riskier chimpanzees behaved in the risky-choice task.

Discussion - Chimpanzees

We found that chimpanzees preferentially chose the large option in both delay conditions, but were better able to maintain the delay in the 3s condition than the 10s condition. While delay choice and delay maintenance were strongly correlated overall, this difference between delay conditions might nevertheless indicate that delay choice does not always capture an individuals' ability to exert patience or self-control: The longer a delay has to be maintained, the higher the probability that the initial 'larger-later' choice doesn't reflect an individual's self-control ability. Our results also suggest that the chimpanzees seemed to learn from their mistakes and adapted their strategy, as indicated by their decreasing tendency to pick the large option over the course of the 10s delay sessions. After choosing the large option at a relatively stable level in the 3s delay sessions, they first had to experience the new delay condition and then started to adapt their choice strategy.

Our findings complement previous work where chimpanzees were in principle 'successful' in the HDT in that they accumulated more items after choosing the larger delayed option than the amount contained in the small-immediate option (Beran et al., 2014). Like our chimpanzees, the individuals in Beran et al.'s study also showed individual differences in the extent to which they could sustain the delay.

Within the HDT, chimpanzees all experienced the 3s condition first. This consistent ordering means that we cannot exclude the possibility that the difference between 3s and 10s delay conditions is a general effect of repeated participation in the task. To further examine this possibility, we assessed the evolution of individuals' decisions across sessions in each condition and found that the probability to pick the large option was highly stable across the four sessions in the 3s condition, whereas it dropped in the last two sessions of the 10s condition. We interpret this imbalance as a hint that the condition effect was more related to the longer delay than a general effect of test session.

The central finding for the purpose of this paper is that chimpanzees' performance in the HDT did not correlate with their risk preference. This independence indicates that, unlike in humans, risky choice might not be strongly correlated with patience in chimpanzees and that the relationship of delay discounting and probability discounting may be specific to humans. Alternatively, the HDT might be a task that captures patience in a "purer" way, i.e. free of a risk component. This makes the HDT a good candidate to provide additional insights into human inter-temporal preferences. To explore this further, we implemented a computerized human version of the HDT – a task that has not previously been used with human participants.

Methods - Humans

Participants

We tested twenty UK-based participants (mean age = 27.0 years, 11 males, 8 females, 1 non-binary) recruited via the online platform Prolific Academic (prolific.co). Participants were paid £2.50 for the 20-minute experiment and could earn a performance-dependent bonus payment of up to £6.40 (actual range = £0.10-£6.40). All participants provided informed consent, and the experiment was approved by the University of Warwick Humanities and Social Science Research Ethics Committee (HSSREC).

Procedure

We adapted the HDT task used with chimpanzees to be presented to adult human participants via an online experiment using oTree (Chen et al., 2016). Figure 3 shows a task schematic. Participants saw four trials. In each trial, they could first choose between a small-immediate reward of one coin or a large-delayed reward of sixteen coins (each coin was worth £0.10). They knew they would only see four trials, which alleviated the need to hold the intertrial interval constant in this case. If they chose the small option, they received one coin into their bank immediately. If they chose the large option, an accumulation process began, whereby the coins would slowly move across the screen to transfer one-by-one into their bank at a rate of 15 s per transfer (i.e., 240 s maximum trial length for sixteen coins). Participants could stop the process at any time by clicking a stop button (see Figure 3). To prevent participants from spending their time with other activities while waiting for the transfer of the coins to their bank, they had to monitor the browser window at all times to click on a stimulus that appeared seldomly, but unpredictably, to avoid being timed out.

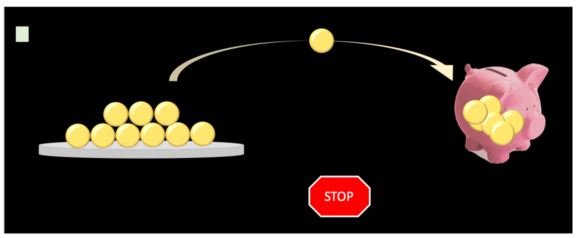

Figure 3: Schematic of the accumulation process in the HDT human version. Coins would slowly move from the pile (on the left) to the piggy bank (on the right), and participant could press the red "Stop" button at any time to collect the money collected thus far. The grey square in the top left corner is the rarely occurring, to-be-clicked stimulus to avoid timing out from the trial.

Results and Discussion - Humans

Participants chose the large option on average 86.3% of the time (SD = 23.6). Figure 4 shows how they accumulated on average 13.9 (SD = 4.1) coins per round in which they chose the large option, and they accumulated on average 47.2 coins across all rounds (SD = 18.6) out of a maximum possible 64. Those participants who chose the large option more often also accumulated on average more coins (r = 0.878, p < .001). Only three errors occurred across all participants and trials, i.e., only three times did a participant choose the large option but then did not wait for more than one coin to accumulate.

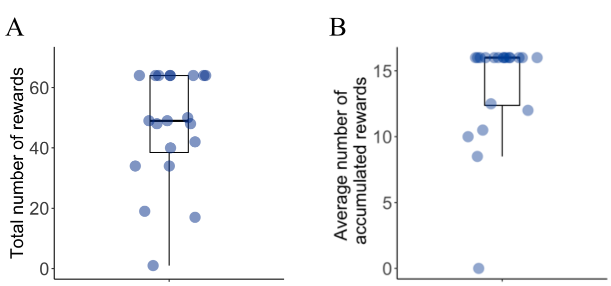

Figure 4: HDT performance humans. A. Total number of coins per participant. B. Average number of accumulated coins per participant after choosing the large option.

These findings indicate that human participants could maintain the delay after choosing the delayed option and thus made rational choices most of the time. They exhibited a consistent pattern of delay choice and delay maintenance. Assessment of participants' comments revealed that the task is likely measuring what we intended: many participants reported they had to force themselves to remain patient about the painfully slowly moving coins, that they sometimes picked the small option because they were tired of waiting, and that they opted for a mixed strategy to trade-off waiting and higher payoff.

General Discussion and Outlook

Based on findings that delay discounting and probability discounting correlate among experimental measures as well as real-life behavior in humans (for example, Benzion et al., 1989; Bixter & Luhmann, 2015; Johnson et al., 2020; Mishra & Lalumière, 2017), we tested for this relationship in chimpanzees to address the question if this correspondence is a human-specific effect. We found no relationship between chimpanzees' behaviour in a patience task and their risk preferences. A computerized version of the HDT worked well in an initial sample of human participants, and this instrument is a promising candidate to be used in future behavioural delay discounting experiments.

Our goal in the current study was not to directly compare performance of chimpanzees and humans in the HDT. Considering the small sample size and that no variations of the task were being compared in humans, we cannot make strong inferences from the human data at this point. What we report here are first steps toward implementing a delay discounting task that is less abstract and descriptive than the widely-used, questionnaire-based intertemporal choice tasks (e.g., Kirby & Maraković, 1996) and that can dissociate a preference for larger-delayed rewards from the ability to maintain delays. Research on the Description-Experience Gap has established that risk preferences can differ depending on how options are encountered, namely whether they are described to participants verbally or whether participants experience the odds and outcomes directly (see e.g., Hertwig et al., 2004; Ludvig & Spetch, 2011). For delay discounting, it might similarly make a difference whether participants receive explicitly described information about the delay options, or whether they need to actively maintain an experienced delay (see Dai et al., 2019). Crucial next steps will be to vary the parameters of the HDT (reward size of the options, speed of reward transition into the bank, whether participants know the number of decisions in advance, immediate gratification), to test the task with a larger sample, and look at potential correlates of the HDT with different measures from the human literature. Once the HDT yields sufficient variation between individuals, we will assess relationships between HDT and established risk preference procedures in humans.

For a direct comparison between humans and nonhuman primates it will be important to align additional procedural details as best as possible, such as the immediacy of gratification and opportunities for distraction. Furthermore, it would be important to test additional samples of chimpanzees with a combination of risky choice and HDT task to assess if the low association replicates.

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