Investigating the Influence of Socio-Environmental Cues of Harshness on Delay Discounting Behavior Utilizing Virtual Reality

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Abstract

Why are some people more affine to delay discounting than others, and which factors influence their decision-making? This paper argues that Life history theory predicts that experiences in harsh environments will influence an individual's cognitions and correlated behavioral patterns to favor immediate gratification in terms of smaller sooner rewards over delayed larger rewards. Many scholars have referred to this preference for a present orientation of decision-making as irrational and impulsive, suggesting individuals cannot have too much self-control. In this paper, however, it is argued that individuals' behavioral preferences are neither irrational nor impulsive but rather the most beneficial and adaptive way to cope in harsh environments. Consequently, the paper aims to investigate how experiences of socio-environmental cues of harshness influence behavioral patterns in human decision-making utilizing a monetary binary choice task to measure delay discounting behavior. Thereby, this study revolutionized priming cues of harshness by creating an immersive experience, in which participants walked through either a deprived or affluent neighborhood utilizing Virtual Reality scenes. Following the prime participants, preference of temporal discounting for a smaller immediate hypothetical reward versus larger delayed hypothetical rewards is measured utilizing a monetary binary choice task. However, the results of this study are not in line with previous research. The results showed participants did not engaged more in delay discounting after walking through a deprived virtual reality neighborhood being exposed to cues of harshness. Contrary to the expectation that the experience of harsh environments would increase delay discounting, the control group who walked through an affluent neighborhood engaged slightly more in delay discounting compared to the experimental group, which was primed with cues of harshness.

Keywords: harshness, intertemporal choice, delay discounting, life history theory, decision-making

Decision-Making from an Evolutionary Psychology Perspective

Every day, decision-making confronts individuals in their lives. While some individuals are more impulsive and risk-affine, others are more patient and tend to avoid risk. Therefore, the question arises why individuals decide how they do and the underlying cognitive processes and factors that guide decisions (Peters & Büchel, 2011). Although humans are considered a "rational animal," the behavior exhibited in decision-making tasks often does not seem to support this view, especially when viewed from an economic perspective (Santos & Rosati, 2015). Since rational decision-making from the economic perspective involves increasing expected gratification to a maximum. Ultimately, this suggests that the economic view alone cannot explain or account for variations in decision-making preferences. Therefore, this paper will delve into the theory of why socio-environmental cues, such as harshness, influence decision-making preferences since previous literature outlined that stress induced through high-demand, high-threat situations can disrupt performance when making decisions (Driskell et al., 2006). Consequently, the paper will draw on a nuanced evolutionary perspective when using delay discounting tasks to investigate decision-making processes. Therefore, the following paragraphs will introduce the main concepts and variables from an evolutionary psychology perspective.

Evolutionary psychology is not considered an academic field of study, like development or other areas. It can much rather be considered a way of thinking to discover and comprehend the composition of the human mind. (Cosmides & Tooby, 1997). By investigating topics such as the human brain, how it processes information, and how the processed information can generate behavior, evolutionary psychology enables the enhancement of understanding information-processing programs, which were formed through natural selection embodied within a distinct neural structure of the brain. Such programs originated from and target solving adaptive obstacles our ancestors used to face (Cosmides & Tooby, 1997). Therefore, our brain's neuroplasticity enables adaptive decision-making and behavior in line with evolutionary goals, guided by our neural circuits and contexts such as socio-environmental cues of harshness when confronted with decision-making scenarios.

Thus, the scientific community has investigated the topic of decision-making and its associated processes and behaviors regarding specific contexts, for instance, regarding the experience of harsh environments. Decision-making is the study of identifying and selecting among various options according to the individual's values and preferences (Fülöp, 2005).

Therefore, a decision-making scenario consists of three things, firstly the agent who must decide, secondly, possible options and third, a specific context (Fülöp, 2005). Decision-making is influenced by various factors, including personal convictions and, more importantly, in the context of this study, socio-environmental cues. Henderson and Nutt (1980) identified two types of reasoning that guide individuals' decision-making preferences. On the one hand, individuals deconstruct the problems to the fundamental core, analytical reasoning. On the other hand, some individuals draw on past experiences employing heuristic approaches that solve adaptive problems before (Henderson & Nutt, 1980). Variability in decision-making can partly be accounted for by such factors called trait-differences being relatively stable over time and consequently like a personality variable.

Moreover, additional influences in decision-making are considered state-differences, such variations within an individual's behavior depend on short-term situational factors (Peters & Büchel, 2011). Cannon-Bowers et al. (1996) identify variables such as uncertainty, meaningful consequences, time pressure, multiple goals, and cue-criterion relations (the degree to which the criterion can be predicted from the cue or cues) influencing decision-making. Depending on the environment, different decision-making systems are activated and governed based on the decision-makers' sex and age, socioenvironmental cues of the environment, and the individual's stage of development (Kendrick, 2009). Moreover, Frankenhuis et al. (2016) point out that socio-environmental cues of harshness are associated with individuals behaving more vigilant and impulsive , displaying present-orientated choices by favoring immediate benefits. Griskevicius et al. (2011) additionally outline findings that consistently propose that socio-environmental cues of harshness are linked to behaviors and psychology associated with phenotypic present orientated preferences of life history strategies regarding decision-making. Multiple variables such as those mentioned above can influence decision-making processes, and various settings can measure these kinds of relationships. In this study, however, the focus will remain on investigating individual differences induced through experiences of harshness in decision-making utilizing a delay discounting task of binary choice.

Socio-Environmental Cues of Harshness in Context of Life History Theory

Environmental factors are known to affect and can predict several behaviors. Such behaviors range from risk-taking to reproductive development (Chua et al., 2016). These behaviors are related to different kinds of strategies, which in Life History Theory (LHT) developed in response to ecological and environmental factors (Griskevicius et al., 2011). Before going into more detail about what LHT is concerned with, it is of importance to view this theory and the related concepts, such as the LH strategies, as an abstract theoretical framework, rather than a constant variable, which can be measured in individuals. LHT's original purpose was to investigate differences between species; therefore this framework is not supposed to be used to make long-term predictions or inferences regarding individual differences. In the context of this paper, LHT is of importance in the sense that it emphasizes the contingency of environmental dimensions regarding behavioral patterns and decision-making. Consequently, phenotypic strategies of LH are not a unidimensional variable that can be assessed in individuals but rather theoretical preferences in decision making patterns, adapting in response to their contexts. LHT states that humans and other organisms must manage trade-offs between current vs. future needs or somatic effort vs. reproductive effort (Griskevicius et al., 2011). The somatic effort, on the one hand, is the maintenance and investment of one's physiological system by acquiring knowledge and skills; reproductive effort is composed of factors such as reproduction, parenting, and intersex competition (Griskevicius et al., 2011). LHT aims to explain and put in context when and why organisms make such trade-offs.

According to LHT, every individual supposebly falls into the theoretical framework on a continuum between faster and slower LH behavioral patterns associated with what some researchers refer to as strategies. This preference for either faster or slower LH behavioral patterns expresses through individual differences in variables such as somatic development and maintenance, future orientations, risk-taking, and reproductive effort. In LHT choosing slower strategies is associated with less risk, whereas faster strategies are associated with more risk (Griskevicius et al., 2011). The preference for such behavioral patterns is thought to be shaped unconsciously throughout a critical period in childhood, comparable to how language is acquired (Belsky, 2007).

Behavioral patterns associated with different strategies of LHT develop in response to factors such as ecology, socio-environmental cues and the phase of the life cycle an individual finds themselves in. According to Griskevicius et al. (2013), behavioral patterns associated with fast LH strategies seem theoretically to be most likely to be utilized in response to harsh and unpredictable environments. According to Frankenhuis et al. (2016), “Harshness refers to the rates of mortality and morbidity caused by factors an individual cannot control” (p.76). In this study, the analysis will be constrained to the effects of harshness given the complexity of separating these two dimensions of harshness and unpredictability. Beyond this definition, environmental cues of harshness are measured through factors like socioeconomic status, family neglect and conflict, neighborhood crime, which are characteristic features of deprived environments (Hampson et al.; 2016; Carver et al., 2014; Brumbach et al., 2009; Chua et al., 2016). Morbidity is the condition of being unhealthy in respect to a particular illness or circumstance. At the same time, mortality refers to the total deaths that occur in a population within a certain period such as one year and have two dimensions, intrinsic mortality and extrinsic mortality defined through external factors (e.g., crimes leading to homicide or resource scarcity) on the other (Shaw et al., 2005). The latter is known to be the most frequent environmental cue used to explain variations in DD rates as it is the most straightforward reason why individuals could perhaps not collect their reward (Shaw et al., 2005). However, mortality solely cannot fully account for discounting rates. Wang et al. (2016) showed that the average mortality risk per year explains only 0.13% of the displayed discounting. This implies that additional sources contribute to increased DD within deprived environments, such as a great degree of competitiveness or fewer reliable social contacts, inducing increased volatility.

Besides these findings, individuals’ preferences for different time points in DD are not solely dependent on mortality rates. Instead, it might be adaptive to make decisions independently of collective risks (Chu et al., 2010). Adaptivity refers to the flexibility individuals respond with within a particular environment, as modifying strategies can be beneficial. In LHT, predictive adaptive responses (PAR) are assumed to react in response to external cues, which anticipate subsequent environmental conditions that elicit the employment of the optimal phenotypic strategy (Gluckman et al., 2005). PARs do not only react to external conditions but emerge from environmental cues that have an impact on individuals early in life; however, the induced phenotype becomes apparent predominantly in later life stages giving PARs the quality of developmental plasticity (Gluckman et al., 2005). Rather than immediately producing physiological adaptations, they work through this developmental plasticity altering the phenotype selectively in response to the environment which is predicted to be encountered. Two kinds of PARs exist, internal and external. Since solely the latter concept is of importance for this study, external PARs use socio-environmental cues such as harshness expressed in economic inequality and neighborhood turmoil to predict future outcomes to respond in ways that ancestrally wise would maximize fitness (Chua et al., 2016). Chua et al. (2016) demonstrated that exposure to socio-environmental cues of harshness indeed is associated with fast LH strategies and confirm the information of previous internal and external PARs models.

These findings of beneficial adaptive responses involving fast LH strategies stand in contrast to the fact that in psychology, DD is often used to assess impulsivity with the underlying assumption that an individual cannot have too much self-control as it is associated with beneficial long-term goals (Frankenhuis et al., 2016). As a result, decisions of individuals indicating a preference for immediate gratification is often viewed as shortsighted (André et al., 2021). This myopic induced by factors found in deprived environments containing cues such as harshness is often reduced to the label irrationality, implying dysfunction (Frankenhuis et al., 2016). While from an economic perspective, decision patterns within the context of DD seem to violate the rational principles of maximizing gains, from an evolutionary perspective, the same patterns can be interpreted as adaptive behaviors in line with natural selection (Frankenhuis et al., 2016). Environmental cues that are perceived as stressful do not permanently impair individuals. In contrast; they can even enhance cognitive performance. For example, children, in this case, orphans, growing up exposed to stressful episodes due to their circumstances growing up, tend to be more successful in tasks, which reward faster-risk taking strategies in comparison to children from the control group. However, when the task rewarded slower strategies, they seemed less successful than the control group (Humphreys et al., 2015).

This observation gains support by the influence mentioned above of environmental stressors on decision-making and indicates that expressions of impulsivity cannot only be functional but likewise beneficial. Consequently, it would be appropriate to redefine optimal decision-making within a context-sensitive framework, which does not solely have the goal of maximizing reward but considers the individual's somatic and reproductive goals. Rather than labelling individuals' strategies as short-sighted and ascribing permanent characteristic features such as irrationality or impulsiveness, it is essential not to stigmatize them, making room for interpretations of varying patterns in decision-making as practical adaptations.

The research design and the current study was based on and is informed by two other studies that have been conducted in the past. One of these studies is the experiment from Griskevicius et al. (2013), in which risk preferences and temporal discounting is examined. In this experiment, it was investigated how mortality cues influence risk-taking and time preferences. It was hypothesized that mortality cues induce individuals who were raised in resourceful environments to be future-oriented, corresponding with a slower LH strategy. In contrast, the same cues would induce a present orientation, corresponding with faster strategies, for individuals raised in resource scarcity environments (Griskevicius et al., 2013). Their study is based on a 2 x 2 design in which they manipulated the independent variable of mortality cues vs control group as between-participant factor and risk and time preference as a within-participant factor (Experiment two). Participants in the experimental condition were primed by reading a newspaper article including cues of mortality threats; individuals in the control condition were not primed at all. All participants answered financial risk items and items about childhood SES. Their hypothesis regarding the influence of mortality cues on time and risk preferences could be confirmed (Griskevicius et al., 2013).

The other study contributing to the framework surrounding this study is the study of Nettle et al. (2014), in which attitudes of a British sample regarding trust and paranoia were examined. The study consisted of two parts. Firstly, the British sample was composed out of two groups. One group of participants were residents of a deprived neighborhood, whereas the others were residents of a more affluent neighborhood (Nettle et al., 2014). It was observed that Individuals from the deprived neighborhood indicated lower levels of trust and higher levels of paranoia in comparison to individuals living in the affluent neighborhood. For the second part of the study, a set of students who were neither residents of the deprived nor affluent neighborhood were asked to carry out surveys in one of the respective neighborhoods. After being exposed to the environmental stimuli of harshness for approximately 45 minutes, they were questioned with the same items from the first part of the experiment. Attitudes of students reflected the findings from the first part of the study, and a significant difference between the groups visiting the deprived and affluent neighborhood could be found (Pepper et al., 2014). This indicates that not only exposure to harsh environments in the sensitive period of childhood influences cognitions, but also recent experiences of harsh environments are significant factors impacting attitudes.

Intertemporal Choice and Delay Discounting

One way of studying differences concerning subjective decisions is by creating a scenario in which agents must make valuations and corresponding decisions of intertemporal choice. Within the decision-making framework, the intertemporal choice task is a category in which individuals are confronted with receiving either a smaller sooner reward or a later larger reward (Read, 2004). The different points in time influence the subjective valuation of the future reward and create trade-offs between time vs reward varying in magnitude (Read, 2004). Consequently, intertemporal decisions create a conflict between the prevailing desire for instant satisfaction and the objective of maximizing the reward (Peters & Büchel, 2011). One common phenomenon in such trade-offs is that individuals tend to devalue rewards that are delayed and indicate a predilection for immediate rewards as they seek instant gratification (Santos & Rosati, 2015). This phenomenon is known as delay or temporal discounting (DD). DD can be demonstrated by the fact that, for example, the subjective value of 100 euros received today is greater than the subjective reward of receiving 100 euros in a week or a month. The following paragraphs will focus on the influences shaping decision-making (Santos & Rosati, 2015).

The Present Study

Within establishing the theoretical framework at hand, the research aims to test the theory further and investigate the decision-making patterns of agents performing a monetary binary choice task. Individuals will be exposed to the independent variable of harshness, which is manipulated in the way that two virtual reality scenarios were created. One of the environmental scenes in VR displays socio-environmental cues of harshness. The VR scenes make it possible for the participants to immerse into a deprived neighborhood characterized by features such as family conflict, crime, and resource scarcity, without bringing the subject into situations involving real risks of deprived environments (extrinsic mortality, crime). The other environment illustrates a clean, calm, and stable non-deprived environment as a control condition.

Using VR scenes is beneficial for this study in multiple ways. In contrast to priming individuals with an article, picture, or video, in which they have an interpretive scope, VR scenes allow increasing control on participants' imagination which otherwise might lead to inter-individual variations in results. Furthermore, the immersive experience of VR intends to implicitly activate participants' cognitions, which in turn are supposed to elicit preferences in behavioral patterns regarding LH strategy. Therefore, following the VR experience, individuals will be asked to perform a monetary binary choice task investigating how the socio-environmental cues of harshness influence the preferences of DD. This research includes the underlying proposal that individuals exposed to socio-environmental cues of harshness are more likely to indicate stronger discounting preferences than individuals who were not exposed to socio-environmental cues of harshness. Consequently, individuals are expected to adapt decision-making in response to their environmental context. This preference for specific behavioral patterns is associated with a strategy of LHT rather than maximizing the reward in terms of economic rationality.

Based on the previously established framework, two research questions arise and will be addressed in this paper. Consequently, this study aims to answer the following questions: Firstly, "Will participants who were exposed to socio-environmental cues of harshness experience lower levels of safety?". Secondly, "Will participants who were exposed to socio-environmental cues of harshness in the experimental condition display significantly higher discounting rates in comparison to participants in the control condition?" To answer these research questions, the following hypotheses have been constructed:

Hypothesis I: *Individuals who have been exposed to socio-environmental cues of harshness in the respective VR scene are expected to indicate significantly lower levels of safety.*

Hypothesis II: *Individuals who have been exposed to socio-environmental cues of harshness in the respective VR scene are expected to engage significantly more in DD than individuals in the control condition.*

This paper argues that participants who have been primed with socio-environmental cues of harshness are expected to engage more in delay discounting than participants from the control condition. Particularly since experiences of harsh environments are thought to activate psychological mechanisms biasing individuals to favor immediate hypothetical rewards over delayed hypothetical (Santos & Rosati, 2015).

Methods

Participants and Design

In the present paper, a between-subjects design was used with the independent variable (socio-environmental cues of harshness vs control) as a between-participant factor and the monetary binary choice task as measure of the dependent variable delay discounting. The other dependent variable that is measured is the level of feelings of safety participants indicate after being primed with the deprived neighborhood VR scene (experimental condition) versus the non-deprived, affluent VR scene (control condition).

Given the nature of the experiment using VR, only Individuals 18 years and older were collected. Thus, 38 participants (19 women, 18 men, and one diverse gender) were gathered by convenience sampling and snowball sampling. Furthermore, the link to sign up for the study was published on various social media platforms, including Facebook, Instagram, and WhatsApp. Additionally, posters and flyers encouraging participation were hung throughout university buildings as well as in local stores and on campus. Moreover, the survey was set up on the Sona platform, the Twente Student Research Participation System of the University of Twente. Provided that the study was completed, students were credited 1.5 points to participate in the experiment or a voucher in the amount of five euros.

Most of the participants (28 individuals) were of German nationality (73.3%), followed by six individuals of Dutch nationality (15.8%). Four of the remaining participants (10.5%) had another nationality. The mean age of the sample was M = 21.40 (SD= 1.88). Participants were allocated to either the experimental condition being the deprived neighborhood scene (DN) or the control group a non-deprived neighborhood scene (NN). Due to technical complications with the non-deprived neighborhood VR scene for the control condition the first 20 participants were allocated to the deprived neighborhood VR scene, and the remaining 18 participants were allocated to the control condition. Therefore, no random allocations to the conditions were possible; however, some random dimension was introduced since participants randomly signed up.

Apparatus and Materials

Questionnaires

Two surveys were created using Qualtrics, which is a webpage for creating research questionnaires. An electronic pre-questionnaire was filled out. The specific purpose of the research regarding the aim to elicit socio-environmental cues of harshness to investigate decision-making via DD paradigms was concealed from the participants to minimize any potential bias. Following the consent page, the survey requested basic demographic information such as their gender, education level, age, nationality, and country they lived in until they were about five years old. In addition, the participants had to fill in their Sona ID in case they wanted to collect Sona credit points instead of the five-euro voucher. Finally, in the last part of the pre-VR-questionnaire, they were guided through information on what to expect and how to behave while experiencing the VR neighborhood.

The post-VR questionnaire assessed whether the independent variable of harshness was successfully manipulated utilizing a manipulation check composed out of seven items (Appendix A). The items tested the sense of being there (in the VR scene), the feeling of safety, the stress level, the motivation to protect oneself, the feeling of being relaxed, and how dangerous the participants perceived the environment. They indicated their answers through sliding bars from 0 to 100, with 100 being the highest expression of agreement. Furthermore, they are asked to mention three things they paid most attention to and to mention technical issues in case they experienced some.

Manipulation of the Independent Variable through VR

VR scenes resembling one deprived neighborhood and one affluent neighborhood were used, creating an immersive experience for the participant. The Oculus Rift S PC-Powered VR Gaming-headset was used for the VR scenes, which comes with two controllers. The software of oculus must be downloaded as an App and is called Oculus Rift Software. The two respective VR scenes were created and played on the cross-platform game engine called Unity 2.3 2020.

The layout of both VR scenes was very similar see (Appendices B & C). Both scenes had a basketball court in the center of the map, surrounded by a Sidewalk. The court and the sidewalk were surrounded by a street that separated the center from the residential buildings. The infrastructure and type of buildings suggest that the VR neighborhood scenes resemble western countries. Between some of the houses are alleyways, in which simulations of characters were placed.

The VR scene of the experimental condition called deprived neighborhood illustrating socio-environmental cues of harshness was characterized by features indicating high crime rates and cues of mortality by placing police tape on some buildings and the floor and audio stimuli of police sirens. Furthermore, the infrastructure has come down, indicating unsustainability and dysfunction of fundamental functions and facilities such as public transport. No maintenance of public services was expressed by trash and tipped-over dumpsters laying in the streets, lack of benches and trash cans or a vandalized bus stop, and dilapidated houses (Lambie-Hanson, 2015). Such environmental cues indicate insufficient public spending on the maintenance of buildings and roads, which in turn obstructs the economic function of the area, which in turn facilitates resource scarcity (Lambie-Hanson, 2015). Additionally, an individual was sitting in a gloomy alley on a trash can between houses, seeming to be homeless. Cues of family conflict through the screaming of a fighting couple could be heard as well. The VR scene was predominantly held in different shades of grey and darker tones along with cloudy weather, emphasizing the mood of the scene further (Appendix B).

Contrary to the experimental VR scene, the control condition was a non-deprived neighborhood scene, more affluent. Here the infrastructure was intact. No dirt or trash could be found on the streets nor the basketball court. The sidewalk surrounding the court was equipped with multiple benches to sit on and available trash cans, indicating well-organized public spending and maintenance. The same applies to the private properties, which were intact and decorated with plants in their front yards. Bushes between the basketball court and the surrounding street were trimmed, indicating maintenance of public services. Moreover, between one of the houses, a couple was placed in the alley, calmly planning a camping trip. The sky illuminated the scene and was in shades of pink and blue with a few clouds, giving the impression of a sunset (Appendix C).

Delay Discounting Task as Dependent Measure

A monetary binary choice task was given to the participants on the computer via the program Open Sesame to assess behavioral patterns in delay discounting. Participants were, for example, asked, "If you had the choice, would you rather have $50 right now (SS = smaller sooner reward) or $1000 in 1 week (LL = larger later reward) from now?" (Appendix D). They had at least five decisions to make measuring their behavioral patterns regarding their preference of either smaller sooner (SS) hypothetical rewards or larger later (LL) hypothetical rewards. Each reward-magnitude condition in the binary-choice task involved multiple binary monetary choices. Five delay periods (one day, one week, three month, one year, 25 years) were used to monitor choices between the two respective hypothetical rewards. Each hypothetical option was represented by two boxes, one left the larger later reward, one right the smaller sooner reward. The value for the LL reward remained the same (1000 $). The hypothetical rewards in the SS reward category increased every time the participant chooses the LL reward option from $50 to $100, $200, $300, $400, $500, $600, $700, $800, up to $900. Whenever the participant chooses the smaller sooner reward over the larger later reward, the following binary choice would start again with the SS reward being 50$ along with a new larger delay period.

Procedure

The present study was authorized by the Ethics Committee of the Faculty of Behavioral and Management Sciences at the University of Twente. The approximate duration of the participation in the experiment was 40 to 50 minutes for each participant. All participants were exclusively provided with an English version of the pre-and post-VR- experience- questionnaire. Moreover, each participant were provided with an information sheet and approved the research conditions through a statement of consent before the participation (Appendix E). Additionally, the respondents were offered the option of deletion of the responses given at the end of the questionnaire. The participants could withdraw their participation at any point in the experiment.

In consideration of the Covid-19 pandemic, participants had to comply with general health guidelines, and the researcher cleaned the equipment in between every participant. Before the experiment started, they were requested to silence their Phones eliminating sounds and vibrations, possibly reducing the immersive experience of VR. The participants were introduced by outlining the four parts of the experiment: firstly, the pre-VR- questionnaire, secondly the experience in VR, thirdly the games as dependent measures and finally, the post-VR questionnaire.

Following the pre-VR-questionnaire, the researcher explains how the controllers are utilized in the VR scene. Before the participants put the VR glasses on, the practice world is started in Unity (Appendix F). Symbols such as circles and arrows guide the participant through the virtual neighborhood. Therefore, the same symbols are also in the practice world explained by the researcher while the participant tests the environment. The circles give the participants some point of reference in which they can take their time to get a good impression of the environment or in case participants would experience cybersickness. They are reminded to ask questions since, ideally, any interaction is prohibited as soon as the VR neighborhood scene starts playing. When the participants indicate that they feel ready to proceed with the VR neighborhood, the researcher asks them to close their eyes until they find themselves in their respective condition within the VR scenario. As soon as the participants say that they can see the VR neighborhood, the researcher starts documenting the time utilizing a stopwatch and reminds the participants that if the time of approximately seven minutes has passed, they will be informed by the researcher in case they do not want to explore the scene further.

After participants removed the VR headset, the scene was stopped in Unity, and the least interaction possible was required not to override the previous elicited stimuli. Therefore, the participants were simply asked if “they feel ready to continue with the next part.” When they answered with “yes,” they played three different games on the computer, one of which consisted of the monetary binary choice task with five different delay periods. The instructions participants received see (Appendix G). To the right, the smaller but sooner (SS) reward was displayed and could be chosen with the letter “s,” and to the left, the larger but later (LL) reward could be chosen with the letter “l.” Depending on their response, they were led to the next hypothetical choice until they finished all runs. To complete the task, people had to make at least one choice per delay period and could maximum make nine choices per delay period. The delay periods used in this study are one day, one week, three months, one year and 25 years, which refers to the extent in time the hypothetical reward is delayed versus the immediate reward. Once the games (two additional dependent measures, irrelevant for this study) are played, they automatically are guided to the second part of the electronic questionnaire in Qualtrics. At the end of the post-VR questionnaire, participants are asked for their email to receive the voucher and are debriefed about the study's real aim.

Results

Data Analysis

All analyses were performed with the statistical program R studios. First, a new variable was calculated, composed of all participants DD decisions on the five different delay points in time (one day, one week, three month, one year, 25 years), summing up the respective AUC value per participant under each of the five respective trapezoids. Furthermore, a descriptive analysis was performed together with a plot as a function of time for the average subjective values, grouped by respective condition. The assumption of normality was checked utilizing a density plot and the Shapiro Wilk test for the independent variables. If the assumption of normality will be violated a non-parametric alternative to the independent sample t-test will be used. If this case occurs, the Wilcoxon rank-sum test will be utilized in the inferential analysis to inspect if significant differences between the conditions can be found.

Data Preparation and Check for Response Pattern

Before the analysis was conducted, the data was filtered, meaning participants with missing values were sorted out. Additionally, participants who indicate atypical behavior in delay discounting, which means their discounting behavior does not monotonically increase with delay. One way to identify such non-systematic discounting behavior can be done by assessing if any indifference point was larger than the previous indifference point, which would mean that a further delay results in the reward increasing rather than decreasing in value. However, when the last indifference point was not smaller in comparison to the first indifference point, this again means that the participant did not discount. Overall, this would suggest that the delay did not affect the reward value, contrary to previous findings and the underlying assumption of this paper that a delay in time decreases the subjective value of an objective reward.

Some scholars argue that the whole theory of calculating the area under the curve is like an assumption test. Meaning that if one wants to calculate the area under the discounting curve the assumption for this is that the bigger, the delay period the higher the discounting. Consequently, participants indicating atypical discounting behavior in terms of not responding sensitive to delay will be filtered when the criterion above is fulfilled because it technically violates the assumption. Otherwise, their data might create too much noise, decreasing the data quality. Such noise in data is considered meaningless information possibly created by misunderstanding the task itself, which would corrupt the interpretation of the data. Consequently, three subjects from the deprived condition and two subjects from the non-deprived/affluent condition were filtered due to atypical discounting behavior. Furthermore, subject 32 (deprived) data was removed from the original data set due to missing values on all five indifference points. On the other side, it can be argued that it is not sufficient to remove participants who seem to discount in illogical ways from the data set, consequently, the results of the filtered data can be found in (Appendix J)

Table 1 shows that the participants concerning their perception of safety indicated an overall sample mean of (M = 54.50, SD = 35.10). In line with the expectations that the Deprived condition indicates a lower mean (M = 28.60, SD = 24.30) compared to the non-Deprived condition (M = 83.40, SD = 18.50) in the feeling of safety. Moreover, the mean of the overall sample concerning the AUC values equals (M = 3070, SD = 745). The deprived condition scored an AUC value mean of (M = 3070, SD = 903) and the non-deprived condition scored an AUC value (M = 3060, SD = 545). This can also be seen in Figure 1.

Table 1

Descriptive Statistics of Demographic Data, AUC values and values of the feelings of safety

	Deprived (N=20)	Non-Deprived (N=18)	Overall (N=38)
Gender			
Another gender	1.00 (5.0%)	0 (0%)	1.00 (2.6%)
Female	14.0 (70.0%)	5.00 (27.8%)	19.0 (50.0%)

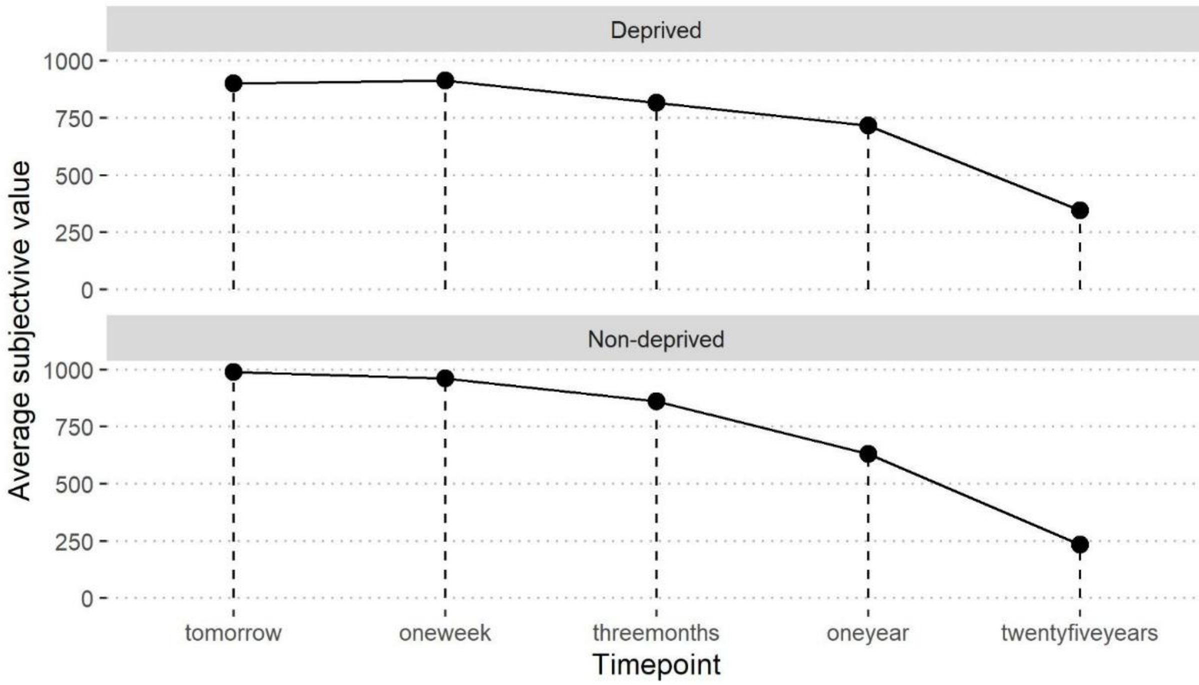
	Deprived (N=20)	Non-Deprived (N=18)	Overall (N=38)
Male	5.00 (25.0%)	13.0 (72.2%)	18.0 (47.4%)
AUC[1]			
Mean (SD)	3070 (903)	3060 (545)	3070 (745)
Median [Min, Max]	3500 [275, 4000]	3090 [1780, 3800]	3190 [275, 4000]
Safety[2]			
Mean (SD)	28.6 (24.3)	83.4 (18.5)	54.5 (35.1)
Median [Min, Max]	18.5 [0, 85.0]	89.5 [30.0, 100]	62.5 [0, 100]

[1]Lower values indicate higher levels of discounting.

[2]Higher values indicate higher levels of the feeling of safety.

Figure 1

Average subjective value plotted as a function of time and grouped by condition deprived (n=20) and non-deprived (n=18).



Check for Assumptions

To determine if a parametric test or a non-parametric test is suitable for the data at hand, it is necessary to test the assumption of normality by means of a Shapiro-Wilk's test. Both the AUC values and the variable of feelings of safety will be tested for the assumption of normality. Regarding the AUC values, the results of the Shapiro-Wilk's test were highly significant W (38) = 0.8361, $p < 0.05$, indicating the violation of normality. Consequently, it can be concluded that the AUC values are not normally distributed, which can also be seen in the density plot (Appendix H). Concerning the variable of feelings of safety, the Shapiro-Wilk's test was as well highly significant W (38) = 0.8866, $p < 0.05$, indicating that the values indicating levels of feelings of safety are not normally distributed. The violation of the Normality assumption regarding the levels of feelings of safety can also be visually inspected in the density plot (Appendix I). As the normality checks show that the AUC values and the values of the variable indicating feelings of safety are not normally distributed, the assumption of normality is violated. Therefore, we are using the nonparametric alternative to the independent sample t-test, the Wilcoxon Rank Sum test.

3.4 Inferential Statistics

Regarding the first hypothesis, whether individuals who have been exposed to socio-environmental cues of harshness indicate significantly lower levels of safety, it was found that the values show deviance from normality; therefore, it was chosen to test the hypothesis non-parametrically. A Wilcoxon Rank Sum test was performed for both the original data and the filtered data, in which data indicating atypical discounting behavior was removed to assess the difference between conditions.

As one can observe, the participants in the non-deprived condition indicated substantially higher levels of feelings of safety (Median= 89.5, $n = 18$) (see Table 1 for descriptives). Furthermore, the Wilcoxon Rank Sum test shows ($W = 16$, $p < 0.01$), which means that $p<0.05$, thus the null hypothesis for the non-filtered data can be rejected as well. Consequently, the first hypothesis can be confirmed in the original data as well as in the filtered data (Appendix J).

The Wilcoxon Rank Sum test for the original, unfiltered data shows ($W = 210$, $p = 0.39$), which means that $p > 0.05$, thus the null hypothesis cannot be rejected, and there is no evidence for an alternative hypothesis. In conclusion, the original, unfiltered data showed no significant difference of DD between the conditions through the AUC values at hand, leading to the rejection of Hypothesis II.

Discussion

This study suggested that variations in preferences of DD may result from responses to certain types of environmental stimuli like socio-environmental cues of harshness, which is the independent variable manipulated in this study. Moreover, it was investigated if seemingly irrational choices in inter temporal decision-making tasks indicate deeper evolutionary rationality and express adaptive behavior, rather than being considered impulsive, which can be stigmatizing for individuals. To address such questions, an evolutionary perspective including aspects of LHT was used to draw upon. LHT proposes that depending on the developmental stages of organisms and their socio-environmental context, they tend to adopt behavioral patterns, which some refer to as strategy, lying on a continuum extending from "slower" to “faster”. Strategies associated with an investment in somatic effort and future-orientated preferences are on the “slower” side of the continuum. The utilization of "faster" strategies is associated with behavioral patterns that refrain from somatic effort and are more likely to be risk affine. LHT forecasts that in the context of socio-environmental cues of harshness, cognitions will be biased in favor of immediate rewards. This preference for disregarding future consequences is associated with “faster” strategies. Therefore, the study tested how the independent variable harshness influences decision-making preferences utilizing a binary choice task of delay discounting. Furthermore, by introducing VR scenes rather than conventional primes, this study contributed to testing DD preferences in relation to socio-environmental cues of harshness in a profound and new way.

The key findings of this study show that the manipulation of the independent variables of harshness through the VR scene of a deprived neighborhood was successful as the experimental condition indicated lower levels of the feeling of safety than the control condition. Furthermore, individuals who have been exposed to socio-environmental cues of harshness through a deprived neighborhood scene in VR did not engage significantly more in delay discounting compared to individuals in the non-deprived condition. Contrary to the expectations that individuals in the deprived condition, who were initially expected to score lower area under the curve values in delay discounting, indicating discounting preferences for smaller, immediate rewards, than individuals in the control condition, the data shows that individuals from the experimental condition engaged slightly less in delay discounting than individuals from the control condition. This finding suggests that individuals who have been primed with socio-environmental cues of harshness have not engaged more in delay discounting than individuals, who have not been primed with socio-environmental cues of harshness. This suggest that although individuals in the deprived condition indicating significantly lower levels of safety in the manipulation check, they did not express a preference for smaller immediate rewards.

This finding is contrary to previous research, which found that mortality cues, which can be found in deprived environments, influence individuals’ preferences for delay discounting and risk-taking significantly in respect to self-reported measures of resource scarcity growing up (Griskevicius, Tybur, Delton, & Robertson, 2011). The study was not able to reproduce findings that are in line with previous literature and could be related to various reasons. Firstly, the validity of the study is questionable since only 39 Participants were collected. Both the experimental and the control conditions are consequently smaller than the approximate minimum sample size of n=30, which could also be a reason for violation of a normal distribution (Johanson & Brooks, 2010). Secondly, this study did not include variables in the statistical analysis that are known to influence behavioral preferences, such as indicators through which experiences of harsh environments are measured such as socioeconomic status (Hampson et al., 2016), family neglect (Carver et al., 2014) and neighborhood crime (Brumbach et al., 2009), regarding the “critical period” in childhood (Belsky, 2007). By taking such experiences of harsh environments into account, new insights could arise in the field of decision-making since these kinds of influences can be very formative in the sense of predictive adaptive responses. Finally, although approximately the same amount of each gender was collected, it was not considered how they were allocated to the respective conditions, which could also influence the findings. Kirby et al. (1996), for example found meaningful differences in discounting behavior between genders, in terms that men discounted more steeply in comparison to women. Moreover, Lighthouse et al. (2012) examined how induced stress impacts decision-making behavior utilizing a monetary reward decision-making task and found gender-specific stress effects. The impact of stress on reward related decision-making expressed itself on the one hand in females through a slower decision-making speed and the collection of lesser rewards and on the other hand in males through a faster decision speed and a greater reward collection (Lighthouse et al., 2012). Therefore, it would make sense to take the variable of gender into account when allocating participants to conditions and when interpreting the data. Since technical issues complicated the optimal allocation of participants, this was not possible in this paper. Despite such limitations, which leave room for further investigation, this paper contributed to the scientific community to shape future research. The various benefits of creating an immersive experience by exposing individuals to certain stimuli via VR could lead to insightful findings in future research.

Although a solid amount of research already exists building the framework for this study, there is plenty of room for further research. A couple of indicators allowing the measurement of harshness have already been identified as aforementioned and are thought to shape the preferences of LH strategies. Consequently, the question arises if additional stressors might influence such preferences, and if they could be discovered in future Research. The “critical period” has often been mentioned in this study and what is meant by that is that after birth, humans are very vulnerable and sensitive to their surroundings (Van den Berg et al., 2014). Especially throughout the first year of life, the physical development is most significant. Consequently, suboptimal conditions, such as those in deprived environments, can have adverse long-term implications on adult outcomes (Van den Berg et al., 2014). Consequently, “the critical period” of development in childhood is supposed to be incredibly influential in shaping later decision-making patterns associated with LH strategies which are in turn elicited in response to environmental circumstances throughout this period. However, this “critical period” is not yet explicitly defined to a certain age. Therefore, future research could investigate in which years and under what conditions children are most likely to adopt their phenotypical preference of LH strategy, which in turn is thought to influence DD behaviors.

In addition, mortality is also known to be a characteristic feature in deprived environments displaying cues of harshness. It would be interesting to distinguish more specifically between the two dimensions of intrinsic and extrinsic mortality and how individuals perceive them. Perhaps the two dimensions of mortality elicit different preferences in decision-making, and disentangling them in future research could explain variations of delay discounting behaviors, which are believed to be related to the same dimension of mortality until now.

Moreover, up to now, research relies on self-reported measures of variables such as childhood SES, mortality cues, or family conflict. Such measures, however come along with some possible disadvantages. Participants perhaps vary in their introspective ability to assess childhood experiences of harshness accurately. Furthermore, individuals have different levels of sensibility, meaning whereas some people perceive a shouting family member as verbally abusive, others could perhaps consider this as normal or the lesser evil when they are used to being disciplined through, e.g. physical punishment. Another aspect that could influence data collection regarding self-report measures is the honesty of participants. Socioeconomic status, family neglect and conflict are delicate topics. Some individuals may be either consciously or unconsciously biased by social desirability influencing their responses. Consequently, it can be argued that future research should try to assess variables utilizing more objective measurement methods reducing inter-individual variations.

Conclusion

Finally, it can be concluded that shedding light on the motives that shape individuals' preferences in decision-making and how they arise can potentially reduce labeling behaviors associated with faster LH strategies as irrational and impulsive when indeed they reflect deeper rationality in line with maximizing fitness in ancestrally terms. Thus, through the lens of an evolutionary perspective drawing on LHT, new insights contribute to the understanding of decision-making behavior in DD paradigms. These insights can account for variation, which could not be explained by economic theories, consequently decreasing stigmatization of individuals' phenotypic preference for behavioral patterns which are associated with either faster or slower LH strategies.

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Appendices

Appendix A

Manipulation-check items

Please rate your sensation of being in the virtual environment, on the following scale from 0 to 100, where **100 represents your normal experience of being in a place**.

0 10 20 30 40 50 60 70 80 90 100

I had a sense of "being there"... ()

safe_check
Please rate how **safe** you felt while being in the virtual neighbourhood,

where **100 represents the strongest possible feeling of safety** and **0 represents feeling not safe at all.**

0 10 20 30 40 50 60 70 80 90 100

My feeling of safety was... ()

stressed_check
Please rate how **stressed** you felt being in the virtual neighbourhood,

where **100 represents highest stress possible** and **0 represents not** feeling stressed at all.

0 10 20 30 40 50 60 70 80 90 100

My feeling of stress was... ()

self-protection_chec
Please rate how **motivated you felt to protect yourself from potential dangers** while being in the virtual neighbourhood,

where **100 represents the highest possible motivation for self-protection** and **0 represents not feeling motivated to protect youself at all.**

0 10 20 30 40 50 60 70 80 90 100

My motivation for self-protection was... ()

Page Break

relaxed
Please rate how **relaxed** you felt in the virtual neighbourhood,

where **100 represents highest relaxation possible** and **0 represents not** feeling relaxed at all.

0 10 20 30 40 50 60 70 80 90 100

My relaxation was... ()

dangerous
Please rate how **dangerous** you perceived the virtual neighbourhood to be,

where **100 represents most dangerous possible** and **0 represents not** dangerous at all.

0 10 20 30 40 50 60 70 80 90 100

How dangerous did the neighbourhood seem to you? ()

Q148
Please rate your perception of the trustworthiness of the residents in the virtual neighbourhood,

where **100 represents most trustworthy** and **0 represents not** trustworthy at all.

0 10 20 30 40 50 60 70 80 90 100

How trustworthy did the residents seem to you? ()

VR_attention What three things did you pay **most attention** to while you were in the virtual neighbourhood? These could be visual features of the environment, sounds or your own feelings. Please describe them briefly below.

○ 1. (4) ____

○ 2. (5) ____

○ 3. (6) ____

Appendix B

Screenshot of the deprived neighborhood scene

Appendix C

Screenshot of the non-deprived neighborhood scene

Appendix D

Monetary binary choice task

Which prize would you prefer?

50 Euro right now	or	1000 Euro tomorrow

Which prize would you prefer?

100 Euro right now	or	1000 Euro in 1 week

Which prize would you prefer?

50 Euro right now	or	1000 Euro in 3 months

Which prize would you prefer?

50 Euro right now	or	1000 Euro in 1 year

Which prize would you prefer?

50 Euro right now	or	1000 Euro in 25 years

Appendix E

Information sheet and informed consent

Welcome!
You are invited to take part in a study investigating how people experience a Virtual Reality neighbourhood.

The project is conducted by Salome Hackenfort, Stella Scholz and Maike Wohlgemuth (BSc Psychology students at University of Twente) and supervised by Jeanette Hadaschik, MSc (Department of Psychology of Conflict, Risk and Safety, University of Twente; Work and Social Psychology, Maastricht University) and Dr. Marielle Stel (Department of Psychology of Conflict, Risk and Safety, University of Twente) as well as Dr. Karlijn Massar and Prof. Dr. Rob Ruiter (Maastricht University). The study is approved by the Ethics Committee of the Faculty of Behavioural, Management and Social Sciences at University of Twente (request number 210124).

Please take time to read the following information carefully before you decide whether or not to take part, it is important for you to understand what participation in the study will involve.

Who can take part?
We are looking for women and men who are above 18 years old. Your English language skills need to be sufficient in order to understand instructions and answer the questionnaires. Participation is completely voluntary and anonymous.

What is involved?
If you decide to take part, your session will consist of the following parts:
1. You fill in a short questionnaire.
2. You experience Virtual Reality for about 10 minutes. You will receive instructions on how to put on the headset and how to move in the virtual world.
3. Right after experiencing the Virtual World, you play a series of short games on the computer. Instructions will be provided.
4. You fill in a questionnaire.
One session takes about 45 minutes.

Will I get paid?
If you are a SONA participant, you will receive 1.5 credits for your participation. Non-SONA participants will receive a 5 Euro VVV-voucher via email after completing the study. In addition, based on performance in two games among all participants, the **top 5 performing participants will each receive a 20 Euro VVV-voucher**. The winners will be announced once the data collection is finished. If you'd like to be notified in case you win one of the prizes, you need to provide your email address at the end of the study.

Are there risks?
Some people get nauseous during or after experiencing Virtual Reality. This usually goes away after a brief period of rest.
The questionnaire includes questions about positive and negative childhood experiences (which

some people might find uncomfortable).

What about Covid-19 prevention?
Our team will adhere to a strict safety protocol including thorough disinfection of equipment after every participant, opening windows, wearing masks, keeping distance, etc. You can participate only if you are free of relevant symptoms.

What happens with the data?
All data collected during the study will be kept strictly confidential and anonymous. That is, **your response cannot and will not be traced to you personally** and no identifying information will appear in any documents or in the final report. A unique, random identifier code will be sent to you via email after completing the study. You can use it in case you would like to withdraw your consent after taking part. Only the main researchers have access to the collected data. Therefore, we ask you to answer as honestly as possible.

Do you have any general questions?

If yes, please ask the researcher now.

Informed Consent

By clicking **YES** below, I agree to the following:

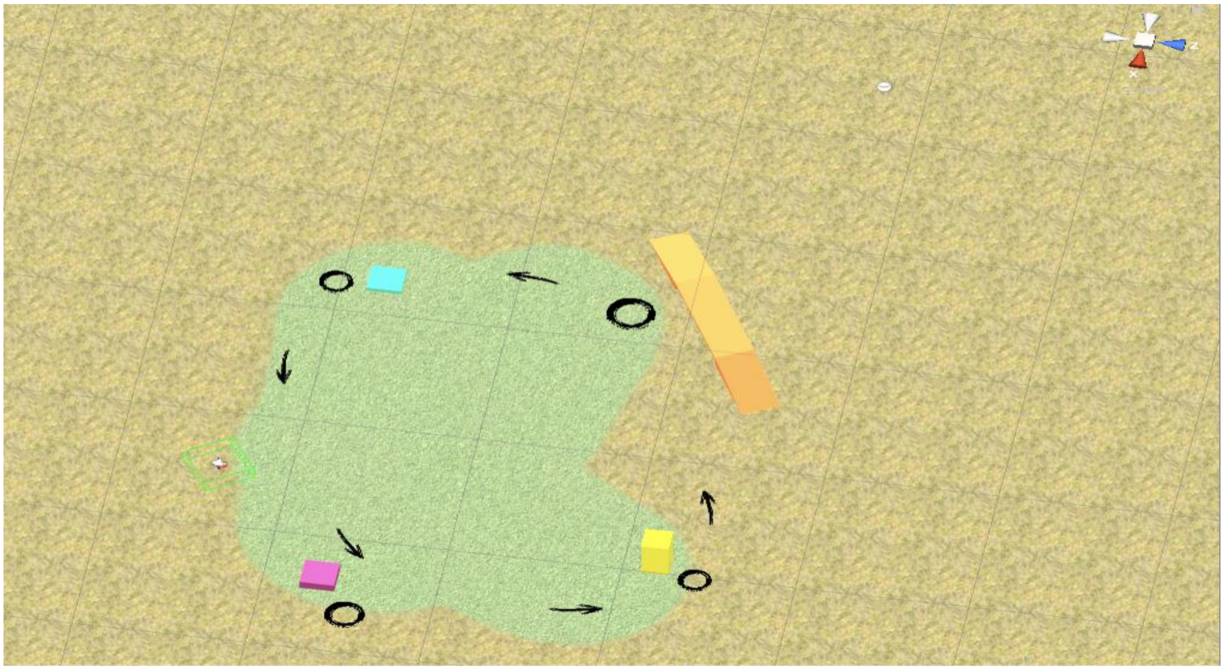
I understand that my participation is voluntary. I also understand that I have the right to withdraw my consent at any time without needing to give a reason, if I experience any discomfort or distress.

Furthermore, the following points are clear to me:
- All data that are collected by the researcher are treated completely anonymously and cannot and will not be traced back to me personally.
- I understand that I have to provide my email address if I want to be notified in case I win a prize. If I provide my email address, it will also be used to send me a copy of the debriefing information including my response identifier code (which is needed to request deletion of the data).
- I understand and agree that the purpose and hypotheses of the current study cannot be revealed to me because it could bias my answers. However, after completion of the study I will receive a full debriefing.
- I agree to keep the procedures and explanation of this study to myself and will not pass this information on to others because this might negatively influence the study results.

I agree to participate in the study:

Appendix F

Screenshot of the practice world scene



Appendix G

Game instructions

Wecome to the third and final game!

In this game you are asked to imagine the following scenario:

You have won the lottery and you can choose between two prizes.

One **smaller prize** that you could claim **today**,

and a **larger prize** that you can claim at **different points in the future**.

If you would prefer the smaller, sooner prize, press the **'S'** key.

If you would prefer the larger but later prize, press the **'L'** key.

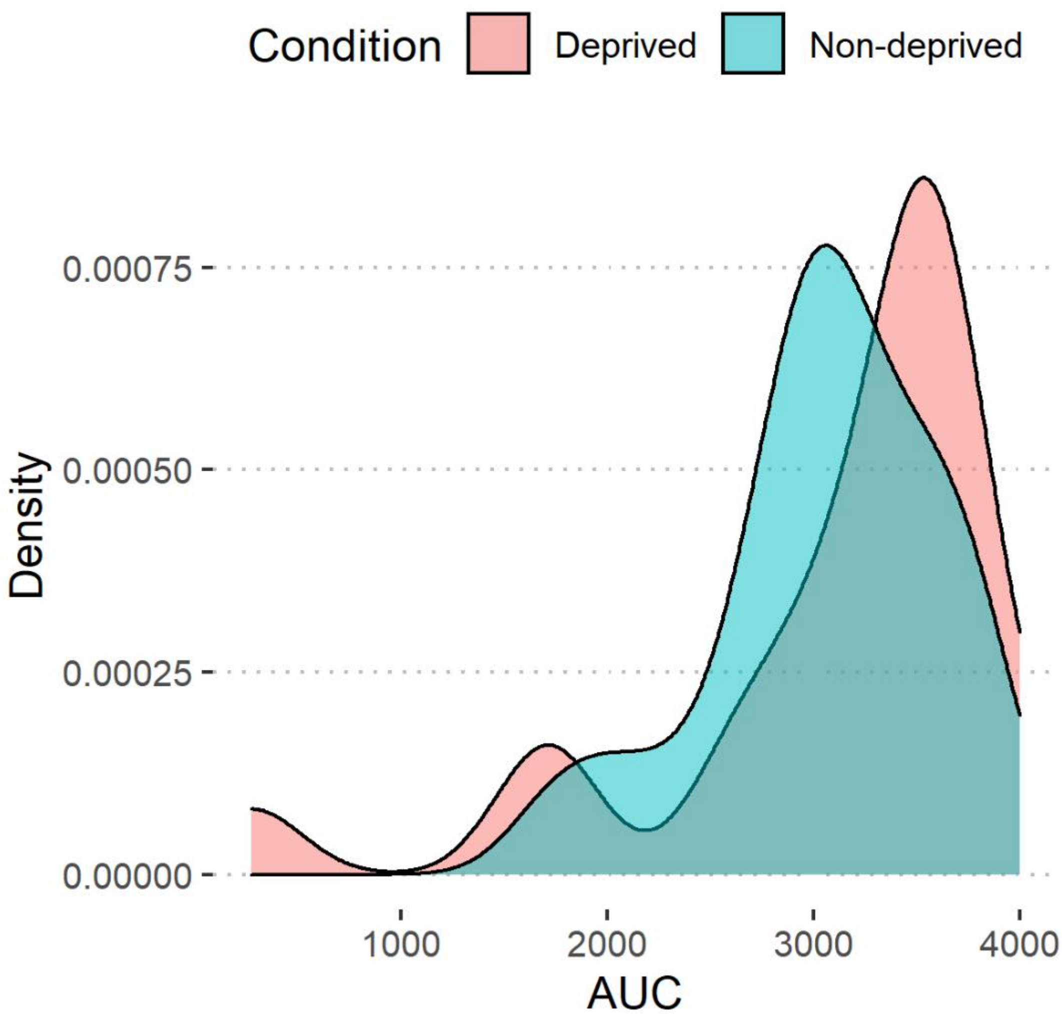
Please pay attention to the value of the prize and the time points as they will change multiple times during the game!

Press any key to start the game.

Appendix H

Figure 2

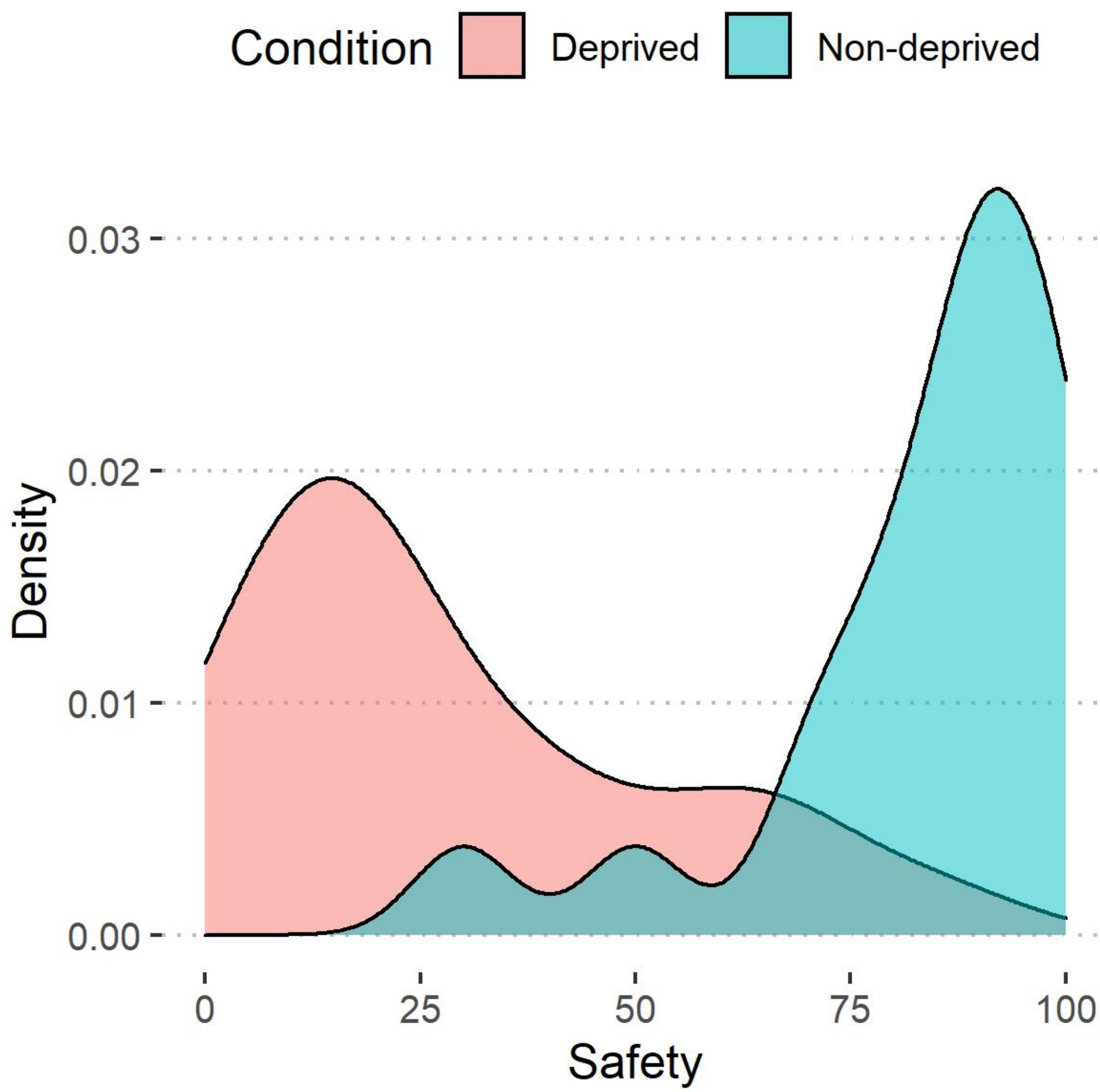
Density plot to check for normality of AUC values, grouped by condition



Appendix I

Illustration 3

Density plot to check for normality of safety values, grouped by condition



Appendix J

Results for the filtered data

Regarding the filtered data it can be observed that the manipulation check item assessing feelings of safety was significantly higher in the non-deprived (Median = 89, n = 16) condition (control) as compared to the deprived (Median= 19, n = 18) condition (experimental) (W = 15, p < 0.01). Consequently, it can be said that individuals within the non-deprived condition were successfully exposed to socio-environmental cues of harshness and indicated significantly lower levels of safety. This confirms the first hypothesis for the filtered data.

Regarding the second hypothesis the Wilcoxon rank sum test for the filtered data showed that the AUC values were not significantly different between deprived (Median = 3500, n =18) and non-deprived (M = 3075, n= 16) conditions (W = 163.5, p = .330), leading to the conclusion that the null hypothesis could not be rejected and there is no evidence for a significant difference in DD between the conditions, which is indicated by the AUC values.

Appendix K

R Studio commands

Filtering data with missing values

```
which(is.na(df$tomorrow)) # Observation 32 has only NA
```

```
## [1] 32
```

```
df[which(is.na(df$tomorrow)),c("tomorrow","oneweek","threemonths","oneyear","twentyfiveyears")]
```

```
## # A tibble: 1 x 5
##   tomorrow oneweek threemonths oneyear twentyfiveyears
##      <dbl>   <dbl>       <dbl>   <dbl>           <dbl>
## 1       NA      NA          NA      NA              NA
```

```
df %>% filter(ID!=32) -> df
```

Filtering data indicating response patterns of atypical discounting behaviour

```
df_filtered <- df %>%
  mutate(pattern_check = ifelse(tomorrow < oneweek | oneweek < threemonths | threemonths < oneyear | oneyear < tw
entyfiveyears,1,0)) %>%
  filter(pattern_check != 1) # Filter one observation with non-monotonic decrease
```

```
table(df$condition)  # 20 deprived, 18 normal
```

```
##
##  1  2
## 20 18
```

```
table(df_filtered$condition) # 17 deprived, 16 normal - that means, 3 deprived and 1 normal were filtered due to
no monotonic decrease (atypical discounting behavior)
```

```
##
##  1  2
## 17 16
```

Calculation of the variables

```
trap_area <- function(a,b) {(a+b)/2}

#### Example minimum AUC ####

trap_area(50,50)*4       # The minimum AUC value is 200 - this value will result, if chosen reward was 50€ at eve
ry timepoint ???
```

```
## [1] 200
```

```
trap_area(1000,1000)*4
```

```
## [1] 4000
```

```
df <- df %>%
  mutate(trap1 = trap_area(tomorrow,oneweek),                    # Area of first trapezoid
         trap2 = trap_area(oneweek,threemonths),                 # Area of first trapezoid
         trap3 = trap_area(threemonths,oneyear),                 # Area of first trapezoid
         trap4 = trap_area(oneyear,twentyfiveyears),             # Area of first trapezoid
         auc = trap1 + trap2 + trap3 + trap4,                    # Calculated AUC as sum of all trapezoids
         Condition = ifelse(condition==1,"Deprived","Normal"),
         Gender = case_when(Gender == 1 ~ "Male",
                            Gender == 2 ~ "Female",
                            Gender == 3 ~ "Another gender"))  # Rename conditions
```

```
kable(df %>%
        dplyr::select(ID,condition,
                      tomorrow,oneweek,threemonths,oneyear,twentyfiveyears,
                      trap1,trap2,trap3,trap4,auc))
```

Descriptive analysis and plots

```
plot_df <- df %>%
  dplyr::select(Condition,auc,tomorrow,oneweek,threemonths,oneyear,twentyfiveyears) %>%
  pivot_longer(cols=c(tomorrow,oneweek,threemonths,oneyear,twentyfiveyears),names_to = "timepoint",values_to = "v
alue") %>%
  mutate(timepoint = factor(timepoint,levels=c("tomorrow","oneweek","threemonths","oneyear","twentyfiveyears")))
%>%
  group_by(Condition,timepoint) %>%
  summarize(avg_value = (mean(value,na.rm=T)))
```

```
## `summarise()` has grouped output by 'Condition'. You can override using the `.groups` argument.
```

```
mark_tomorrow <- plot_df %>% filter(timepoint=="tomorrow")
mark_oneweek <- plot_df %>% filter(timepoint=="oneweek")
mark_threemonths <- plot_df %>% filter(timepoint=="threemonths")
mark_oneyear <- plot_df %>% filter(timepoint=="oneyear")
mark_25 <- plot_df %>% filter(timepoint=="twentyfiveyears")
```

```
ggplot(aes(x=timepoint,y=avg_value),data=plot_df) +
  geom_point(size=3) +
  geom_line(group="Condition") +
  facet_wrap(~Condition,ncol=1) +
  geom_segment(aes(x=1,xend=1,y=0,yend=avg_value),data=mark_tomorrow,linetype="dashed") +
  geom_segment(aes(x=2,xend=2,y=0,yend=avg_value),data=mark_oneweek,linetype="dashed") +
  geom_segment(aes(x=3,xend=3,y=0,yend=avg_value),data=mark_threemonths,linetype="dashed") +
  geom_segment(aes(x=4,xend=4,y=0,yend=avg_value),data=mark_oneyear,linetype="dashed") +
  geom_segment(aes(x=5,xend=5,y=0,yend=avg_value),data=mark_25,linetype="dashed") +
  #geom_vline(xintercept = c(1,2,3,4,5),) +
  theme_pubclean() +
  ylab("Average subjectvive value") +
  xlab("Timepoint")
```

Density plot to check for normality of AUC values grouped by condition

```
ggplot(aes(fill=Condition,x=auc),data=df) +
  geom_density(alpha=.5) +
  theme_pubclean() +
  ylab("AUC")
```

Statistically testing AUC values for normality by means of the Shapiro-Wilk test

```
shapiro.test(df$auc) # Highly significant, normality violated
```

```
##
##  Shapiro-Wilk normality test
##
## data:  df$auc
## W = 0.8361, p-value = 6.217e-05
```

Density plot to check for normality of feeling of safety values grouped by condition

```
ggplot(aes(fill=Condition,x=safe_check_1),data=df) +
  geom_density(alpha=.5) +
  theme_pubclean() +
  ylab("Safety")
```

Statistically testing values of feeling of safety for normality by means of the Shapiro-Wilk test

```
shapiro.test(df$safe_check_1)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  df$safe_check_1
## W = 0.8866, p-value = 0.00109
```

Wilcoxon rank sum test for AUC values

```
wilcox.test(df$auc[df$condition==1],df$auc[df$condition==2],alterna
tive = "two.sided")
```

```
## Warning in wilcox.test.default(df$auc[df$condition == 1], df$auc
[df$condition
## == : cannot compute exact p-value with ties
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  df$auc[df$condition == 1] and df$auc[df$condition == 2]
## W = 210, p-value = 0.3873
## alternative hypothesis: true location shift is not equal to 0
```

Wilcoxon rank sum test for safety values

```
wilcox.test(df$safe_check_1[df$condition==1],df$safe_check_1[df$conditi
on==2])
```

```
## Warning in wilcox.test.default(df$safe_check_1[df$condition == 1],
## df$safe_check_1[df$condition == : cannot compute exact p-value with
ties
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  df$safe_check_1[df$condition == 1] and df$safe_check_1[df$con
dition == 2]
## W = 16, p-value = 1.715e-06
## alternative hypothesis: true location shift is not equal to 0
```