Pontifícia Universidade Católica
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Wayson Maturana de Souza

Effects of context, alexithymia and COVID-19 pandemic related stress on decision-making

Tese de Doutorado

Thesis presented to the Programa de Pós-graduação em Psicologia of PUC-Rio in partial fulfillment of the requirements for the degree of Doutor em Psicologia.

Advisor: Prof. Daniel Correa Mograbi

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Abstract

Maturana, Wayson; Mograbi, Daniel Correa (Advisor); **Effects of context, alexithymia and COVID-19 pandemic related stress on decision-making.** Rio de Janeiro, 2023, 147p. Tese de Doutorado – Departamento de Psicologia, Pontifícia Universidade Católica do Rio de Janeiro.

Decision-making has been studied by various fields of knowledge and can be understood as the ability to process information from a context, choose between two or more options, and learn from the results of these choices. In addition to being related to cognitive processing of information, in recent decades, several studies have pointed out the effects of emotion and context on decision-making ability. Alexithymia, a condition characterized by difficulties in identifying, understanding, and verbalizing emotions, has been associated with poorer decision-making performance. The stress caused by the COVID-19 pandemic has been associated with a higher prevalence of mental disorders and affective changes, however, few studies have explored the impact of COVID-19 on decision-making. Therefore, the objective of this study is to explore context effects on decision-making, investigating its relationship with individuals' levels of alexithymia and variables related to the COVID-19 pandemic. To achieve the objectives of this thesis, four manuscripts were produced. The first manuscript presented a review of the history of neuroeconomics, an interdisciplinary perspective of decision-making that integrates cognition, behavior, and nervous system functioning. The second manuscript compares two Brazilian versions of the Monetary Choice Questionnaire (MCQ-27; one converting the dollar to the equivalent value of the real and the other converting it by exchange rate), a task of delay discounting used to measure intertemporal decisions. This study showed no differences between the two versions of the MCQ-27. The third manuscript investigated the relationships between alexithymia and intertemporal decision-making under risk and ambiguity. In this study, alexithymia was related to deficits in decision-making in intertemporal and ambiguous contexts, but not for risk. Finally, the fourth manuscript explored the influence of COVID-19 on both decision-making contexts. The results showed positive relationships only for decision-making under risk, with the severity of COVID-19 symptoms in the participant and severity of symptoms in their family members. For both empirical studies, a same sample of 438 volunteers (M = 29.09

years, SD = 7.80, 67.8% female) was used. The results of this study contribute to the understanding of decision-making and to the comprehension of the influence of alexithymia and pandemic-related variables on individuals' choices.

Keywords

Decision-Making; Neuroeconomics; Emotional Processing; Alexithymia; COVID-19

Resumo

Maturana, Wayson; Mograbi, Daniel Correa; **Efeitos de contexto, alexitimia, e estresse relacionado à pandemia de COVID-19 sobre a tomada de decisão.** Rio de Janeiro, 2023, 147p. Tese de Doutorado – Departamento de Psicologia, Pontifícia Universidade Católica do Rio de Janeiro.

A tomada de decisão vem sendo estudada por diversos campos do conhecimento e pode ser entendida como a capacidade de processar informações de um contexto, escolher entre duas ou mais opções e apreender com os resultados destas escolhas. Além de ser relacionada ao processamento cognitivo de informações, nas últimas décadas, diversos estudos têm apontado efeitos do processamento emocional na capacidade decisória. A alexitimia, uma condição caracterizada por dificuldades de identificar, compreender e verbalizar emoções têm sido relacionados com pior desempenho da tomada de decisão. O estresse causado pela pandemia de COVID-19 vem sendo associado com maior prevalência de transtornos mentais e alterações afetivas, contudo, poucos estudos têm explorado o impacto da COVID-19 na tomada de decisão. Sendo assim, o objetivo do presente trabalho é explorar efeitos de contexto na tomada de decisão, explorando a relação desta com níveis de alexitimia dos indivíduos e variáveis relacionadas a pandemia de COVID-19. Para concluir os objetivos desta tese, quatro manuscritos foram produzidos. No primeiro manuscrito foi apresentado uma revisão sobre a história da neuroeconomia, uma perspectiva interdisciplinar do estudo da tomada de decisão que integra cognição, comportamento e o funcionamento do sistema nervoso. O segundo manuscrito apresenta uma comparação entre duas versões brasileiras (uma convertendo o dólar ao real por valor equivalente e outra convertendo pelo câmbio) do *Monetary Choice Questionnaire* (MCQ-27), uma tarefa de desconto de futuro usada para medir decisões intertemporais. Este trabalho não mostrou diferenças entre as duas versões do MCQ-27. O terceiro manuscrito investigou as relações entre alexitimia e a tomada de decisão intertemporal de risco e de ambiguidade. Neste estudo a alexitimia esteve relacionada a déficits na tomada de decisão em contexto intertemporal e de ambiguidade, e não para risco. Por fim o manuscrito quatro explorou a influência da COVID-19 em ambos os contextos de tomada de decisão. Os resultados mostraram relações positivas apenas para a tomada de decisão sob risco, frente as variáveis gravidade dos sintomas de COVID-19 no participante e gravidade dos sintomas em seus familiares. Para ambos os estudos empíricos uma mesma amostra de 438 voluntários (M = 29.09 anos, DP = 7.80, 67.8% mulheres) foi utilizada. Os resultados deste estudo contribuem para o entendimento da tomada de decisão e para compreensão da influência do processamento emocional e de variáveis de uma pandemia nas escolhas dos indivíduos.

Palavras-chave

Tomada de Decisão; Neuroeconomia; Processamento Emocional; Alexitimia; COVID-19.

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I. THEORETICAL BACKGROUND

1. Decision-making

Decision-making, understood as the process of choosing a response among two or more alternatives that have distinct expected outcomes (Lee, 2013), is an essential function for everyday life (Brand et al., 2006). Varied behaviors such as eating healthily (e.g., Snider et al., 2019), saving money for retirement (e.g., Bidewell et al., 2006), adhering or not to a medical treatment (e.g., Sandman et al., 2012) are examples of real life decision-making. Due to the importance of decision making for humans, it has been studied by different disciplines such as philosophy, economics, psychology, and neuroscience.

In his work called Phaedrus, Plato (370 BCE/1995) presents the allegory of the chariot, where he describes a driver (human reason) destined to control two horses - a disciplined and well-educated horse (rational and moral impulse) and another horse undisciplined and skittish (irrational appetites and passions) - preventing them from rushing to opposing decisions. This story highlights the role of reason and passion in human decisions, with the intellect being responsible for weighing these forces in favor of a desirable decision. As the allegory emphasizes, the decision maker needs to consider both cold (e.g., available options and contextual information) and hot information (e.g., how desirable an option is and what its costs are), to generate satisfactory choices.

In the field of economics, different authors have dedicated themselves to understanding consumer behavior in the market, developing mathematical models to understand this type of decision-making (Glimcher & Fehr, 2014). In contrast to rational economic models, psychology has developed to understand information processing during decisions and emphasized the fallibility of human rationality, susceptible to heuristics and biases (e.g., Kahneman, 2003; Kahneman et al., 1982; Tversky & Kahneman, 1974), that can lead to incorrect or suboptimal decisions. The field of neuroscience has been responsible for presenting the relationship between decision-making and the nervous system. The discovery of the reward-system, (Olds & Milner, 1954), the relationship between the prefrontal cortex and judgments/decisions (Rosenbloom et al., 2012) and the influence of bodily somatic markers on decision-making (Bechara et al., 1994; Damasio, 1996; Poppa & Bechara, 2018) are some examples of neuroscientific contributions. The knowledge derived from these different disciplines gave rise, in the late 1990s, to the multidisciplinary field of neuroeconomics (Glimcher & Fehr, 2014), which has as one of its main contributions the empirical study of the associations between neural mechanisms, mental functioning, and choice behaviors (Camerer, 2013).

One important variable for the decision-making process is the subjective value assigned to different outcomes and rewards. In principle, a higher subjective value attributed to one option compared to another, is related to choosing that option over the other (Vlaev et al., 2011). This subjective value can be measured through neural activity, like a greater activation of the nucleus accumbens in function of the magnitude of gains (Knutson et al., 2005). Other external variables, such as time and uncertainty, also modulate decision-making (Rangel et al., 2008).

Intertemporal decision-making involves choosing an action between response options with immediate/sooner or delayed outcomes (Mcclure & Cohen, 2004). Given intertemporal decisions, humans and other animals tend to discount the subjective value of future rewards, showing a preference for immediate or short-term results (Vanderveldt et al., 2016). The ability to delay rewards is associated with greater self-control, as opposed to immediate choice, which is considered impulsive (Bickel et al., 2018; Odum, 2011). Decision-making in the context of uncertainty refers to those where the expected outcome of an options is not guaranteed (Weber & Huettel, 2008). Within scenarios of uncertainty, those known as risk scenarios are those in which the probabilities of outcomes are known or easily intuited, while uncertainty scenarios are those in which probabilities are unknown (Bechara et al., 2005; Rangel et al., 2008).

Although both risk and ambiguity scenarios are decision-making under uncertainty, the literature has pointed out some differences between them (Brand et al., 2006, 2014; Huettel et al., 2006). Decision-making under ambiguity are more aversive than risk (Camerer & Weber, 1992; Rangel et al., 2008), and while decisions under risk seem to be related to greater activation of areas linked to executive functions, such as the dorsolateral prefrontal cortex, decision-making under ambiguity seems to be related to a complex system associated with emotional processing (Brand et al., 2006, 2007; Huettel et al., 2006; Levy et al., 2010).

2. Emotional processing and decision-making

The idea that the decision-making process is influenced by emotion is supported by different currents of psychological and neuroscientific research. Within the field of neuropsychology, decision-making was presented as a skill related to executive functions (e.g., Diamond, 2013; Mackenzie et al., 2017). Some studies have proposed that executive functions can be divided into "cold" and "hot" types (e.g., Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Zelazo, 2015; Zelazo & Carlson, 2012). According to this perspective, the so-called cold EFs comprise skills with lower emotional processing, such as cognitive flexibility and working memory. On the other hand, the hot executive functions comprise skills related to greater emotional and affective processing, such as inhibitory control and decision-making (Hongwanishkul et al., 2005; Zelazo, 2015). Hongwanishkul et al. (2005) point to the dorsolateral prefrontal cortex as a structure strongly involved in cold executive function tasks, while the most pronounced brain regions of hot executive functions processing are the orbitofrontal cortex and the ventromedial prefrontal cortex.

Similar to the idea of hot executive functions, the somatic marker hypothesis (Damasio, 1996) can be understood as an explanatory proposition that suggests that visceral autonomic activation influences our responses to stimuli at different levels of operation. According to this hypothesis, the somatic markers can influence our choices independently of our awareness (Bechara et al., 1997). These bioregulatory processes seems related to the orbitofrontal and ventromedial prefrontal functioning, and deficits in these structures (as observed by Bechara et al., 1994) would disrupt the processing of visceral information, making such individuals less sensitive to punishment and less aware of risks (Damasio, 1996). Bechara et al. (1994, 1997), using the Iowa Gambling Task (IGT), a decision-making under ambiguity task, showed that somatic markers linked to affective process guide the learning during decision-making under ambiguous scenarios.

Evidence of the influence of emotional process on intertemporal decisions was also found. During the choice between an immediate lower and a delayed greater reward, affective processes related to the reward system interact with cognitive controlled processes related to long-term goals (Mcclure & Bickel, 2014;

Mcclure & Cohen, 2004). During this decision-making scenario, immediate rewards prominently activate limbic brain areas such as the nucleus accumbens, amygdala, and ventromedial prefrontal cortex, while long-term decisions are marked by their relationship with planning and executive functions areas, such as the dorsolateral prefrontal cortex (Frost & McNaughton, 2017; Mcclure & Cohen, 2004). In other words, a self-controlled response during an intertemporal decision involves refusing an emotionally salient reward and rationally inhibiting this temptation in favor of a greater long-term benefit.

In line with the theory of hot and cold executive functions, as well as the idea of dual processing during intertemporal decisions, Kahneman (2003) presents an idea of two decision-making systems: the system 1, intuitive, fast, based on heuristics and biases, and linked to affective and motivational issues; and the system 2, rational, slow, and cognitive. According to Kahneman (2003), the two systems are not dissociated, although many decisions made, especially in daily life, are made without deliberation by system 1.

Another evidence of the influence of emotions on decision-making comes from studies with induced (Johnson & Tversky, 1983; Lee & Andrade, 2015) and incidental emotions (Lemer & Keltner, 2001). A study conducted by Johnson and Tversky (1983), induced positive or negative emotions in participants through reading stories in newspapers, asking them to subsequently estimate the frequency of fatality for various conditions. Participants who read negative stories tended to be more pessimistic in their estimates than those who read positive stories. In another study (Lemer & Keltner, 2001), emotions of fear and anger were related to risk perception, with fear related to more pessimistic perceptions and risk-averse behaviors and anger related to more optimistic estimates and riskier choices. Transient variables such as weather and mood can also have effects on judgment and decision-making (Lerner et al., 2015).

As we can see, decision-making seems to be influenced or at least modulated by affective and emotional aspects. As pointed out by Bechara et al. (1994) and Damasio (1996), individuals with orbitofrontal and ventromedial deficits exhibit difficulties in decision-making, particularly due to the difficulty in processing somatic markers arising from emotional responses associated with negative outcomes. Similar to individuals with prefrontal lesions, it is possible that people who have deficits in identifying and satisfactorily processing their own affective responses may exhibit difficulties in decision-making.

2.1. Alexithymia

Alexithymia can be defined as a deficit in identifying, distinguishing, and communicating emotions in an orderly way (Goerlich, 2018; Taylor, 2000). Research has linked this condition to various health problems, such as eating disorders (Westwood et al., 2017) alcoholism (Betka et al., 2018), addiction (Morie et al., 2016), autism (Griffin et al., 2016), depression (Honkalampi et al., 2001), bipolar disorder (Herold et al., 2017) and anxiety (Kumar et al., 2018; Šago et al., 2020). Despite the association with these health problems, alexithymia is considered a common personality trait that varies in intensity within the population (Luminet et al., 2004). One hypothesis suggests that this trait may be a vulnerability factor for mental disorders (Luminet et al., 2004).

Several instruments have been developed to assess alexithymia. The Toronto Alexithymia Scale (TAS-20), which was developed by Bagby et al. (1994), was the most well-known scale to measure alexithymia. The TAS-20 identifies three factors of alexithymia: difficulty identifying emotions, difficulty describing emotions, and an externally oriented thinking style. However, Vorst and Bermond (2001) criticized the TAS-20, arguing that the scale fails to capture important symptoms such as reduced fantasy and reduced experience of feelings in individuals with alexithymia. As an alternative, the authors developed the Bermond-Vorst Alexithymia Questionnaire (BVAQ), a 40-item scale that includes five factors: Verbalizing, difficulty in describing emotions; Identifying, difficulty in identifying emotional cues; Analyzing, externally oriented thinking and a lack of attention to emotional information; Emotionalizing, reduced emotional experience; and Fantasizing, reduced fantasy and imagination (Vorst & Bermond, 2001).

Studies have revealed links between alexithymia and alterations in decision-making (e.g., Ferguson et al., 2009; Scarpazza et al., 2017; Zhang et al., 2017). Scarpazza et al. (2017) found that individuals with higher levels of alexithymia traits tended to choose smaller and more immediate rewards over larger and delayed rewards in intertemporal decision-making tasks, compared to those with lower levels of alexithymia traits. Regarding decision-making under uncertainty, alexithymia was associated with poorer performance in ambiguity decision-making (Ferguson et al., 2009; Zhang et al., 2017) and a preserved performance in a risk task (Zhang et al., 2017). However, studies examining the relationship between alexithymia and decision-making are scarce. No study was found that compared alexithymia traits in risk, ambiguity, and intertemporal contexts or investigated the relationship between the specific factors measured by alexithymia scales and decision-making.

3. COVID-19 pandemic and decision-making

In December 2019, a novel coronavirus outbreak (COVID-19) began in Wuhan, a city located in the Hubei province of China. Within a few weeks, the number of cases and deaths surpassed that of SARS (Wang et al., 2020). By January 30, 2020, COVID-19 cases had spread to 34 regions in China, and on the same day, the World Health Organization (WHO) declared it a public health emergency of international concern (Wang et al., 2020). Soon after, the infection spread globally, triggering a worldwide pandemic on March 11, 2020 (Suresh & Suresh, 2020). COVID-19 quickly became a global public health threat, with 7.21 million reported deaths and an estimated 17.79 million deaths as of December 08, 2022, according to the Institute for Health Metrics and Evaluation (IHME, 2023). As of March 10, 2023, Brazil had confirmed 37.09 million of COVID-19 cases and 699.31 thousand of deaths (Coronavírus Brasil, 2023).

A global economic impact and a disruption of daily routines caused by the COVID-19 pandemic led to widespread panic and intense fear (Jiao et al., 2020). Several studies presented relationships between pandemic and mental health. Disorders such as anxiety (Lakhan et al., 2020; X. Liu & Chen, 2021; Pashazadeh et al., 2021), depression (Bueno-notivol et al., 2021; Lakhan et al., 2020; X. Liu & Chen, 2021), and post-traumatic stress disorder (Machado et al., 2022; Portugal, et al., 2022; Janiri et al., 2021) have been found to be associated with the COVID-19 pandemic. The COVID-19 public health crisis is an example of an incidental influence that has been shown to impact people's mood and affective processing

(Bera et al., 2022; Burrai et al., 2022; Canet-juric et al., 2020). Given its impact on mental health and perceived stress (Aslan & Pekince, 2020; Brown et al., 2020; Lakhan et al., 2020), it is likely that the pandemic context is related to changes in decision-making. However, few studies have examined the relationship between the pandemic and decision-making.

In a theorical article, Bavel et al. (2020) suggest that negative emotions can impact how people perceive threat, risk, and make decisions during a pandemic. Fear can cause individuals to overestimate risks and activate defensive responses, but it can also prompt behavior change if individuals believe in their ability to respond effectively (Bavel et al., 2020). Negative emotions can bias a person's interpretation of information and lead them to prioritize information that aligns with their current emotional state (Bavel et al., 2020). This bias in information processing may result in individuals ignoring important information, such as the severity or likelihood of a problem, during decision-making. These poor decisions and biases can increase the risk of contagion and exacerbate negative emotions.

In a study focused on decision-making under ambiguity, Tarantino et al., (2021) found that young adult males who reported higher perceived stress and a more vulnerable immune system obtained higher scores and made fewer risky choices in the Iowa Gambling Task (IGT) compared to those who reported lower perceived stress and a less vulnerable immune system. However, the authors reported that for older adult males, the opposite result was found. Another study that used the IGT showed that COVID-19 recovered patients had worse performance in the task than the control group (Egeli et al., 2021). Furthermore, studies of intertemporal decision-making showed relationships between delay discounting rate and physical/social distancing (DeAngelis et al., 2022; Lloyd et al., 2021), and stockpiling (DeAngelis et al., 2022) behaviors during the pandemic. To date, no study has focused on decision-making tasks under risk.

4. The current thesis

The present study aims to better understand the process of intertemporal, risky, and ambiguous decision-making, exploring both the relationship between alexithymia and COVID-19-related variables in the decision-making process. To achieve this, the following steps are proposed: (1) a comprehensive examination of the theoretical aspects of decision-making research, (2) adaptation of an intertemporal decision-making measures to the Brazilian context, exploring their attributes (3) an exploration of the association between alexithymia and decision-making, and (4) an investigation into how the COVID-19 pandemic affects decision-making. The subsequent sections of this paper will focus on each of these components in detail.

5. General sample

For the empirical articles (articles 2, 3, and 4), data from the same sample and collection were analyzed differently, aiming at specific objectives. Participants were recruited by social media (i.e., Facebook, Instagram, and WhatsApp), email and invited directly by researchers or other participants. An initial sample with data from 465 participants was collected between December 2020 and October 2021. The eligibility criteria to participate in this study was living in Brazil and being 18 years or older. Participants were excluded in case of medication use (antipsychotics, sedatives, and other medications with possible impact on cognition) and outlier results. A total of 438 participants (M=29.09 years, SD=7.80, 67.8% female) were included in the final sample used in both empirical articles. All subjects in the sample were Brazilian, covering all regions of the country, although the data was mostly from the Southeast region (82.2% of the sample). All the instruments were administrated online through Gorilla Experiment Builder (Anwyl-Irvine et al., 2020). The demographic characteristics of the participants and their relationships with decision-making were addressed in more detail in the articles.

II. OBJECTIVES

1. General objectives

- Explore the relationship between alexithymia and COVID-19-related variables in the decision-making process.

2. Specific objectives

- Better understand the study of decision-making, its stages, involved processes, and modulatory factors.
- Explore the stability of the Brazilian adaptation of the MCQ-27, a delay discounting task, by checking possible effects of currency conversion.
- Study the relationship between alexithymia and intertemporal, risky, and ambiguous decision-making.
- Explore how variables linked to the context of the COVID-19 pandemic are related to decision-making.

To achieve the listed objectives, four articles/manuscripts were prepared. The first article provides a historical overview of neuroeconomics, an interdisciplinary field that studies decision-making from a perspective that encompasses cognition, behavior, and the functioning of the nervous system. It presents some decision-making models, modulatory factors, and possible applications of this knowledge. The second article compares two Brazilian versions of the Monetary-Choice Questionnaire (MCQ-27; Kirby et al., 1999): one in equivalent values between the dollar and the Brazilian real, and the other converted by exchange rates. This article aims to not only test a Brazilian version but also to discuss aspects related to delay discounting measures. The third article explores the relationship between alexithymia and different types of decision-making, including intertemporal, risky, and ambiguous. This study also examines how specific factors of alexithymia, rather than just a general factor, are related to decision-making. Finally, the fourth manuscript investigates how COVID-19 variables impact intertemporal, risky, and ambiguous decision-making.

III. ARTICLES

1. Article 1

Maturana, W., Landeira-Fernandes, J., Mograbi, D. C. (Manuscript submitted). Neuroeconomics: A multidisciplinary approach to the study of decision-making.

Neuroeconomics: A multidisciplinary approach to the study of decision-making

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Abstract

The study of decision-making has flourished in different fields of knowledge for centuries. Recently, Neuroeconomics has emerged as an integrative approach that combines economic, psychological, and neuroscientific knowledge to study decision-making behavior. This review aims to present the trajectory of this discipline, its field of study, and its possible contributions. To achieve this, we will present the antecedents of neuroeconomics in the fields of economics, psychology, and neuroscience, as well as the consolidation of the field as a multidisciplinary approach. Models for understanding decision-making, and their modulatory aspects (e.g., uncertainty, intertemporal, and social contexts) were also presented. Finally, we suggested future directions and applications of this knowledge.

Keywords

Neuroeconomics; Decision-making; Uncertainty; Intertemporal decision; Social decision.

1. Introduction

Decision-making is an essential part of our daily lives. We are constantly pondering different options, choosing between different alternatives, and learning from the results of our choices. This fundamental activity of human life has been the focus of attention from different disciplines such as economics, psychology, and neuroscience (Glimcher & Fehr, 2014; Loewenstein et al., 2008; Rangel et al., 2008). From the second half of the twentieth century, despite a relatively parallel development in each field, the interdisciplinary dialogue on the decision-making process has been intensified (Glimcher & Fehr, 2014; Thaler, 2015). In 1990 decade, neuroeconomics emerged as a new interdisciplinary perspective for the study of decision-making as a result of this exchange of ideas (Glimcher & Fehr, 2014).

This work aims to present an overview of the development of neuroeconomics. To achieve this, we will cover the following topics: (1) antecedent contributions to the establishment of the discipline from economics, psychology, and neuroscience, (2) the development of neuroeconomics as a discipline and theoretical models for the understanding of decision making, (3) variables that influence decision-making, including contexts of uncertainty, intertemporal and social decision-making, and (4) the application of knowledge derived from neuroeconomics and directions for future development.

2. Contributions of Economics to the study of decision-making

Economics has made significant contributions to the study of decision-making. To understand individuals' decisions, especially the behavior of consumers in relation to the market, some authors (e.g., Bernoulli, Bentham, Pareto, Von Neumann & Morgenstern) developed parameters and mathematical models capable of explaining the choice process (Glimcher & Fehr, 2014). "Utility" is a fundamental economic concept in the study of decision-making (Bentham, 2000; Bernoulli, 1954). This concept assumes that the preference for one option over another reflects a greater utility (satisfaction or happiness) attributed to the chosen option, to the detriment of the rejected alternative. In other words, if an individual chooses a banana over an apple, this means that the utility value attributed to the banana is greater than the utility value attributed to the apple (Glimcher & Fehr, 2014).

In addition to the role of utility in the decision process, the concept of "expected utility" (Bernoulli, 1954; Von Neumann & Morgenstern, 1944) adds another variable to the decision-making process: the probability of event occurrences. According to the theory of expected utility, the preference or choice must follow a weighted average that considers both the utility value of the options and the probability of expected events (Loewenstein et al., 2008; Sanfey et al., 2006)

The concept of expected utility is considered an important legacy of neoclassical economics, as it contributed to a systematization of decision-making that considered both the magnitude of the value of the options (utility) and the probability of occurrence of expected outcomes (uncertainty; Glimcher & Fehr, 2014). As pointed out by Glimcher and Fehr (2014), two important aspects of this theory are: (1) the presumption that the individual decision-maker obeys a utility function that weighs a relationship between options and outcomes, and (2) that these individuals seek to maximize utility through their actions. These ideas are based on the principle that human decisions are rational and considered, and that each subject seeks to obtain the outcome that they believe is most advantageous by following a subjective utility function.

The theories of utility and expected utility were not immune to criticism. Authors such as Pareto, Simon, and Allais pointed out both limitations and axiomatic violations of the respective theories (Glimcher & Fehr, 2014). However, from the point of view of contributions to neuroeconomics, the criticisms made by psychologists Daniel Kahneman and Amos Tversky (e.g., Kahneman, 2003; Kahneman & Tversky, 1979; Tversky & Kahneman, 1974) were perhaps the most significant. The work of these authors caused a severe changes in the field decision-making, being fundamental for the emergence of behavioral economics (Thaler, 2015).

3. Contributions of Psychology to the study of decision-making

In the second half of the twentieth century, while economics was developing decision-making theories based on the behavior of individuals in the market and consumer goods, psychology was focused on understanding mental functions and human behavior. Some cognitive psychologists aimed to understand how people inferred causality and coped with the uncertainties of their environment. Research on "intuitive statistical judgments" was undertaken in this context, which studied tendencies and patterns of decision-making, as well as processing failures that led individuals to erratic and dysfunctional responses (Gigerenzer, 1991).

Tversky and Kahneman (1974) presented how heuristics and biases can influence human decisions in line with the movement that attested to the fallibility of human information processing through experiments. Heuristics are shortcuts that simplify information processing, reducing the complexity, time, and cognitive load allocated to a decision (Kahneman, 2003; Kahneman et al., 1982; Tversky & Kahneman, 1974). Biases, on the other hand, are systematic errors that result from the limits of our processing capacity (Kahneman et al., 1982). Heuristics don't necessarily produce errors and can be functional shortcuts in contexts where quick responses are required or where the cost of a possible error is less than the cognitive load generated by a deliberate response (Haselton et al., 2005; Kahneman, 2003).

Several examples of heuristics include availability heuristics, where the individual evaluates outcomes that are quickly mentally available as more likely (e.g., intuiting a greater probability of a plane crash after remembering a recent one; Kahneman et al., 1982; Tversky & Kahneman, 1974); representativeness heuristics, where the individual evaluates the probability of an outcome under the influence of how representative of a group or concept this outcome is (e.g., saying that Peter is a lawyer and not an engineer just because Peter's personal characteristics "match" those of a lawyer; Tversky & Kahneman, 1974); and anchoring, where the estimate of the response is adjusted in reference to a pre-established initial value (an anchor; Tversky & Kahneman, 1974).

The work of Tversky and Kahneman presented evidence of the limitations and shortcuts that humans use when processing information during decision-making. Their findings showed discrepancies in relation to the rational model of economics. This discrepancy became even clearer after the development of the "prospect theory" (Kahneman & Tversky, 1979), which demonstrated that individuals attribute different levels of utility to outcomes in scenarios of gain and loss. In other words, they showed that the loss of something generates more negative utility than a gain of the same magnitude causes positive utility.

Additionally, the authors demonstrated that behavioral tendencies change based on the scenario and reference point. In scenarios of imminent gains, individuals tend to avoid risks and present more conservative responses (risk-aversion over gains; Kahneman & Tversky, 1979). However, in scenarios of imminent losses, individuals tend to take more risks to avoid a possible loss (risk-seeking over losses; Kahneman & Tversky, 1979).

In terms of decision-making, Kahneman and Tversky (1979) made significant contributions by demonstrating the differences between an economic and rational decision-making model and a model based on the behavioral and psychological experiences of individuals. They presented a functional difference between these two perspectives: the first is a normative theory, which is ideal for obtaining greater utility, based on maximizing gains and minimizing losses, and the second is a descriptive theory, which studies the decision-making process as it happens in humans. The normative theory follows rational and mathematical models of economics, while the descriptive theory is anchored in empirical and experimental studies, especially from psychology and behavioral economics (Thaler, 2015).

4. Contributions of neurosciences to the study of decision making

In parallel with psychological research, the field of neuroscience aims to explain mental and behavioral phenomena through an understanding of brain function. In relation to decision-making, various neuroscientific findings have been fundamental in elucidating the underlying brain processes involved. Specifically, discoveries of the reward system (Olds & Milner, 1954), the experiment on the conscious intention of voluntary actions by Benjamin Libet (1983) and the theory of somatic markers proposed by Damasio (1996) have been noteworthy contributions to the study of decision-making.

In the 1950s, James Olds and Peter Milner (1954) conducted an experiment to investigate the role of the septal area in reward processing. The researchers implanted an electrode into the septal area of rats and placed the animals in a Skinner box. The rats received electrical stimulation directly in the brain after pressing a bar. The results showed that upon receiving stimulation in the septal area, the rats pressed the bar to exhaustion, indicating the involvement of this brain region in motivation and reward processing. In later years, other studies have associated various brain regions with the reward system, such as the ventral tegmental area, the nucleus accumbens of the ventral striatum, the amygdala, and the prefrontal cortex (Marschner et al., 2005). These findings have been instrumental in the understanding of the brain processes involved in decision-making.

The ventral tegmental area (VTA) plays a crucial role in the production and secretion of dopamine, a neurotransmitter linked to motivated behavior in response to rewards. This area sends dopaminergic projections to the nucleus accumbens. Activation of this circuit is associated with both the prediction and presentation of rewards (Ranaldi, 2014; Schultz, 2000). In response to a primary stimulus (an unconditioned stimulus), the presentation of the stimulus triggers dopamine secretion by the VTA and activation of the nucleus accumbens. Through the process of conditioning, where a neutral stimulus is paired and presented before the unconditioned stimulus, this brain circuit becomes activated in response to the neutral stimulus after a few presentations. The neutral stimulus becomes a conditioned stimulus (Ranaldi, 2014). Although this learning process has been widely studied by psychology, its neural bases were unknown for a long time (Ranaldi, 2014).

Knutson et al. (2005) reported that the nucleus accumbens is sensitive to the size of rewards, exhibiting a greater anticipatory response to rewards of larger magnitude. In contrast, the probability of obtaining a reward was associated with a greater activation of the medial prefrontal cortex. These findings revealed different neural mechanisms for processing the magnitude and probability of rewards, and they also provided neural evidence supporting the idea of expected value or expected utility.

Another neuroscientific landmark in the study of decision-making was the work of Benjamin Libet (1983) analyzing the time between the intention of action and the beginning of the neural activity related to it. In an experimental context, five participants were instructed to present voluntary movements of the fingers or wrist of the right hand. These participants were asked to move voluntarily at any time, as spontaneously as possible. The volunteers had to record and later communicate to the researchers the position of a pointer on a circular clock at the exact moment they consciously decided to move. Brain electrical potentials during the activity were monitored using electroencephalography (EEG). This study demonstrated that brain activity related to the spontaneous movement started on average 350 milliseconds before the beginning of the conscious wish of performing the movement (Libet et al., 1983).

Although Libet was relatively conservative in discussing the implications of his study, his work presented evidence in opposition to the causality typically established between the conscious deliberation of action and the execution of the action itself. In fact, Libet's experiment evidenced a possible “explanatory elucubration” made by consciousness to explain the ongoing act. Thus, this work provided an important debate in the field of mind and brain sciences, due to the logical implications of the results for scientific and philosophical issues such as self-control and free will (Braun et al., 2021). However, a recent meta-analysis (Braun et al., 2021) showed that although similar studies have corroborated Libet's findings regarding brain activity related to movement starting before conscious intention, the number of works observing this relationship still is scarce, which requires parsimony in the interpretation of the results, mainly due to the degree of impact and importance of this information.

Emotional processing also seems to influence decision-making. The theory of somatic markers, proposed by Antônio Damásio (Bechara et al., 1994; Damasio, 1996) is one of the main neurocognitive theories about decision-making and emphasizes the importance of somatosensory markers related to emotions and feelings in our choices (Poppa & Bechara, 2018). Damasio et al. (1996) studied patients with specific damage to the ventromedial prefrontal cortex and showed that their decision-making was compromised in real-life situations despite preserved intellectual capacities and logical reasoning. These patients also exhibited emotional deficits, which suggested a possible relationship between decision-making and emotional processing.

Bechara et al. (1994) developed the Iowa Gambling Task (IGT) to assess the role of the ventromedial cortex in decision-making. This task simulates real-life decision-making scenarios involving monetary rewards and punishments. The participant is required to choose a card from four decks (A, B, C, and D) during a total of one hundred rounds. Each chosen card can have a reward or a reward plus a fee. The participant is instructed to choose cards from different decks and to obtain the greatest gain while avoiding great losses. In the IGT, two decks are advantageous, while the other two are disadvantageous in the long term. However, volunteers have to learn this by trial and error, as this information is not initially presented. Bechara et al. (1994) found that individuals with ventromedial prefrontal lesions obtained fewer choices from advantageous decks and less learning throughout the task, unlike controls (Bechara et al., 1997).

Bechara et al. (1997) used skin conductance response, an indirect measure of emotional response through sweating, to analyze decision-making during IGT. They found that control subjects had an anticipatory skin conductance response to disadvantageous decks after a few trials of the task. On the other hand, individuals with ventromedial prefrontal lesions did not exhibit such anticipatory response. Studies using IGT have provided significant evidence of the emotional response in decision-making, especially the importance of somatic markers in avoiding disadvantageous choice options.

5. Consolidation of the field of Neuroeconomics

As presented, behavioral economics is the result of an integration between economics and psychology in the study of decision-making. Another relevant approach was between cognitive psychology and neuroscience. Since the beginning of its development, cognitive psychology has seen neuroscience as an ally in the study of the mind, both fields composing the interdisciplinary range of cognitive science (Miller, 2003). However, the object of cognitive psychology was the information process and the functional aspects of the mind. To achieve this, a series of experiments and models have been developed (Boone & Piccinini, 2016; Miller, 2003). The relationship between mind and brain, although evident, lacked techniques capable of studying their combination, which made cognitive science and neuroscience walk independently. The advent of neuroimaging techniques, such as functional magnetic resonance imaging (fMRI), made it possible to study the brain of living individuals and measure physiological changes in neural structures in response to specific tasks (Boone & Piccinini, 2016).

Cognitive neuroscience emerged in the late 1970s and was established as an area that studies the relationship between cognitive processes and neural activity (Boone & Piccinini, 2016). The cognitive neuroscience view has complemented the study of many cognitive processes, including decision-making, which has been the subject of research by several authors (e.g., Bechara et al., 1994, 1997; Libet et al., 1983; Newsome, Britten & Movshon, 1989). In the late 1990s, the interest in the same topics and the exchange of information led researchers from economics, psychology, and neurosciences to gather around a multidisciplinary approach to decision-making (Glimcher & Fehr, 2014).

During the formation of neuroeconomics, two communities of researchers with overlapping interests developed in parallel. One group was composed of behavioral economists and psychologists who saw the potential to use functional markers of the brain as an alternative to economic neoclassical theories on decision-making. The other group consisted of cognitive neuroscientists and physiologists who saw an opportunity to develop and test algorithmic models for neural processes involved in decision-making (Glimcher & Fehr, 2014). These divergences continue to be present and, as a beneficial consequence, neuroeconomics has developed both in the study of basic decision-making behaviors of humans and other animals (such as perception, attention, and motor behavior) and in relation to complex decisions (such as monetary and social decisions).

Despite the differences, the field of neuroeconomics has become a prolific discipline. According to Glimcher and Fehr (2014), scientific production in neuroeconomics has grown dramatically. The authors showed that, around 1990, there were approximately 50 articles in PubMed that used the keywords "decision-making" and "brain." By 2003, this number had increased to between 200 and 250 papers. Finally, in 2012, over 900 papers were found with these keywords, demonstrating the growing interest in this topic by the scientific community.

To better understand decision-making, some researchers have proposed explanatory models for this process (e.g., Rangel et al., 2008). According to a three-step model presented by Sonuga-Barke et al. (2016), the decision-making process can be divided into stages of: a) evaluation, b) management and decision, and c) appreciation and accommodation. During the evaluation stage, the individual processes the response options present in each situation and estimates the subjective utilities of each possible outcome. For this processing, some information about the outcome of the options serves as a parameter, such as valence (gain or loss), magnitude (large or small reward), time (immediate or late reward), and probability (probable reward or improbable).

This processing of information is essential for the subject to understand the information on time and cost/benefit in relation to the outcome of the alternatives (Sonuga-Barke et al., 2016). The evaluation stage of the decision-making scenario is influenced by implicit and explicit processes. The authors presented an implicit value system involving preference as an example of implicit processes. This system includes the individual's preference for one option over another, indicating greater utility for the preferred option, as well as implicit values given to time and risk, such as risk aversion and time delay in expected results. On the other hand, explicit value systems recruit autobiographical and self-referential processes, allowing individuals to reflect on past experiences and anticipate future outcomes.

During the decision management stage, the subjective utility estimates of each alternative are compared, and the option with the highest subjective utility is selected. An execution plan is then put into action to ensure the effectiveness of the decision (Sonuga-Barke et al., 2016). Finally, the appreciation and accommodation stage involve learning and reinforcement mechanisms, where a prediction error occurs from comparing the expected utility to the actual utility received. As a result, the feedback obtained updates the subjective expected utility matrix, which in turn feeds the autobiographical memory with new information about the decision-making process in a specific context (Sonuga-Barke et al., 2016).

A similar model with distinct characteristics was proposed by Rangel, Camerer, and Montague (2008). Unlike the model proposed by Sonuga-Barke et al. (2016), the model presented by Rangel et al. (2008), consists of five stages: a) representation, b) evaluation, c) selection of action, d) evaluation of results, and e) learning. In addition to the steps of the previous model, Rangel et al. (2008) present a representation stage, prior to evaluation, where the options and possible courses of action are presented (e.g., buying a snack or not), as well as the evaluation of internal states (e.g., hunger) or external states (e.g., nearby snack bars). In this model, the processes of evaluating the results (outcome monitoring) and learning (updating the other stages of the model) are presented as distinct stages. Compared to Sonuga-Barke et al. (2016), the model presented by Rangel et al. (2008) is more widely recognized in the literature. Although these models do not present a consensus on the division of stages and processes of decision-making, such descriptions are important for formulating new hypotheses, as well as for encouraging the testing of existing propositions.

6. Decisions in intertemporal, uncertainty and social scenarios

When considering an economic decision-making scenario, many variables can influence individuals' choices. In addition to reward magnitude, outcome probability, and time, the influence of social context is also a frequently studied variable. Probability is particularly important when the outcome of a choice is uncertain, as in contexts of uncertainty (Bechara et al., 2005), which vary depending on how much probability can be inferred from the available information.

Risk contexts are scenarios in which the probabilities of outcomes are given or easily inferred, such as in games of dice or coin tosses, while ambiguity contexts refer to scenarios where the probabilities are not known, such as the likelihood of rain or the timing of a red car passing on a particular street (Bechara et al., 2005; Levy et al., 2010). Some ambiguous scenarios allow for learning through trial and error, which can improve probabilistic inferences through experience, even if intuitive (as in the IGT task; Bechara et al., 2005). Thus, probabilistic scenarios can vary on a continuum from complete inability to make a probabilistic inference (ambiguity) to fully known probabilities (risk; Tobler & Weber, 2014).

Despite the fact that risk and ambiguity contexts show common activation of some brain areas, such as the medial prefrontal cortex, striatum, amygdala, and posterior cingulate cortex (which are involved in the subjective representation of values; Levy et al., 2010), some evidence points to important differences in neural functioning in each condition. Hsu (2012) showed that regions such as the amygdala (in both hemispheres) and the orbitofrontal cortex appear to be more activated in ambiguity scenarios, while another study (Huettel et al., 2006), indicated activation of the pre-inferior frontal cortex (in the lateral prefrontal cortex), the anterior insular cortex, and the posterior parietal cortex in this decision-making context. In contrast, risk scenarios were associated with greater activation of the dorsal striatum, precuneus, and premotor cortices than ambiguity scenarios (Hsu, 2012). Greater activation of areas linked to emotional processing (such as the amygdala, orbitofrontal cortex, and insula) during contexts of ambiguity seems to support the somatic marker hypothesis (Bechara et al., 2005; Damasio, 1996; Poppa & Bechara, 2018).

Many real decisions require choosing between an immediate/short-term reward or a longer-term reward of greater magnitude. This type of decision has been extensively studied in the laboratory and is known as intertemporal decision-making (Kable, 2014). Faced with an intertemporal decision, it is common for a subject to feel as if he/she had two minds with antagonistic wills: an immediate mind, which wants to take advantage of the present, and another that makes plans and ponders the consequences of its possible choices (Madden & Bickel, 2010). Immediate choices are generally characterized as impulsive, while the postponement of the reward in the function of a more advantageous outcome, tends to be considered a self-controlled response (Kable, 2014).

Studies in both humans and other animals have highlighted individuals' inclination toward short-term choices (Vanderveldt et al., 2016). An important aspect of intertemporal decision-making is that future rewards tend to be discounted, so that at decision time, the subjective value of a future reward is less than its absolute value (e.g., $100 to be received within 15 days has less subjective value than $100 now; Kable, 2014). This process of devaluing long-term rewards is called delay discounting, and the discount rate can vary considerably between people, possibly as a personality trait (Odum, 2011).

Evidence indicates that intertemporal dilemmas reflect a conflict of activation between two relatively parallel neural systems (McClure & Cohen, 2004). Immediate or short-term decisions are associated with greater activity in limbic areas such as the ventral striatum and the orbitofrontal, ventromedial prefrontal, medial prefrontal, and posterior cingulate cortices (β areas; McClure & Cohen, 2004). In contrast, regions such as the intraparietal cortex, dorsolateral prefrontal, ventrolateral prefrontal, and right orbitofrontal cortices are activated when people make choices regardless of delay (δ areas; McClure & Cohen, 2004). McClure and Cohen, (2004) showed that the activation of the β areas varied according to the delay of the short-term reward (immediate, one week, or one month after the choice), with the sooner scenarios responsible for greater activation. The authors also divided the decision scenarios into difficult (monetary differences from 5 to 25% between short and long-term rewards) and easy scenarios (differences above 25%), finding greater activation of the δ areas in the hardest scenarios. Finally, the study showed that the frequency of choosing short-term or long-term rewards was positively correlated with greater activation of β and δ areas, respectively. These results show how short and long-term rewards in intertemporal scenarios seem to compete, not only at the behavioral level but also at the neural activity level.

In addition to the information about choices in decision-making scenarios, specific contexts involve processing social information. Many daily decisions require acting based on the behaviors and mental states of other social agents (Rilling & Sanfey, 2011). Since they involve inferences of other people's intentions, social dilemmas engage high-order cognitive and affective functions such as theory of mind (the ability to explain and predict other people's behavior, taking into account the independent mental state of its actors) and empathy (the ability to place oneself in the perspective of the other; Frith & Singer, 2008). Social games are used to study social decision-making in the experimental context. These tasks are relatively easy for participants to understand and offer attractive scenarios that are accessible for experimental purposes (Rilling & Sanfey, 2011). Another advantage of these games is their ability to investigate complex social behaviors, such as justice (or injustice), responses to injustice, trust, and altruism (Frith & Singer, 2008).

An example of a social decision that can be studied is trusting other people, which can be investigated using the "Trust Game". In this task, a player must decide how much of a donation to invest in a partner. If the participant chooses to invest, the invested amount will be multiplied by a factor greater than one, and the resulting amount will be divided into two halves, with one half being returned to the participant and the other half to the partner. The player is informed that the partner is free to not return the invested money. According to game theory, a rational and selfish player should not trust first and make the investment without guarantees of return. However, most players invest approximately half of the amount received (Rilling et al., 2008).

Regarding neural activation, the frontopolar cortex, anterior cingulate, ventromedial, and dorsomedial prefrontal cortex are implicated in trust behavior (Rilling & Sanfey, 2011). Other social games such as the prisoner's dilemma (trust), the ultimatum game (justice and response to injustice), and the dictator game (altruism) are used in experimental situations, and their neural activities are relatively similar (Lee, 2008; Rilling et al., 2008; Rilling & Sanfey, 2011).

7. Applications and future directions

The above passage highlights that neuroeconomics is a relatively new discipline that is still in the process of experimental development. However, the knowledge acquired in this area can be used to inform relevant interventions outside of the academic and laboratory settings. By recognizing the limitations of human rationality and being aware of the heuristics, biases, and impulsive responses that can influence individuals to make unfavorable decisions, public policy strategies can be adjusted to better account for these factors (Felsen & Reiner, 2015).

The Nudge theory emerged as a way to develop subtle interventions to address everyday decision-making problems in which choices perceived as dysfunctional or disadvantageous by decision makers and/or society are frequent (Thaler & Sunstein, 2008). According to the Nudge theory, decision scenarios are not neutral and have the potential to favor certain unwanted decisions, and as such, governments and other organizations can use "nudges" to encourage people to adopt more functional behaviors (Thaler & Sunstein, 2008). However, nudges are interventions derived from behavioral economics, and neuroscience studies exploring the neural aspects involved in these interventions are still scarce. Mapping the circuits involved in different decisions can promote the development of public policies and improve the effectiveness of Nudges.

The study of decision-making has practical applications in assessing decision-making capacity, particularly for elderly, neurological and psychiatric patients who may put themselves and their assets at risk. (Moye et al., 2011; Wood et al., 2020). Decision-making capacity refers to whether a person has the cognitive, physical, and practical abilities to make specific decisions. Assessing decision-making capacity involves a delicate balance between respecting the individual's autonomy and protecting their well-being. As such, the literature has sought to develop reliable methods for assessing decision-making capacity, including neuropsychological assessments that evaluate important functions for everyday decisions such as semantic knowledge, language, autobiographical memory, working memory, and other executive functions (Wood et al., 2020). However, this approach is limited to explicit and conscious measures and overlooks implicit and affective aspects involved in decision-making. Thus, there is a need to further explore implicit and automatic measures that take into account the heuristics and affective aspects of decision-making (Moye et al., 2011; Wood et al., 2020).

Another important contribution of decision-making research refers to the understanding of behavioral patterns in different psychopathologies. According to Sonuga-Barke et al. (2016), mental disorders such as attention deficit hyperactivity disorder (ADHD), conduct disorder, depression, and anxiety have specific decision-making patterns, which can be an important part of their symptoms. ADHD can be associated with impulsive, unreflective, and inconsistent decision-making, while individuals with conduct disorder may be more insensitive to negative consequences. Depression is characterized by a lack of engagement, perseverance, and pessimistic expectation of outcomes. Finally, the decision-making profile of anxiety is associated with hesitation and risk aversion (Sonuga-Barke et al., 2016). In addition, intertemporal decision-making problems have been linked to various maladaptive conditions such as compulsive gambling, obesity, and substance abuse (Odum, 2011). Knowing the decision-making patterns of different mental disorders and health conditions is essential to understand the extent of deficits and plan interventions.

Finally, neuroscience has contributed to both marketing (neuromarketing) and finance. Understanding how the consumer's brain processes rewards and values different stimuli and choice options can provide valuable insights for the marketing industry (Ariely & Berns, 2010). Through neuroimaging studies, companies can obtain implicit information that goes beyond what is explicitly provided, allowing for the discovery of true preferences without relying on conscious judgment. This information can then be used to improve product design and marketing campaigns, ultimately leading to increased sales (Ariely & Berns, 2010).

While marketing can use knowledge about the decision-making process to increase consumption and sales, understanding these processes can also help individuals make better financial decisions. In the financial market, variables such as the magnitude of the reward, value, uncertainty (risk or ambiguity), intertemporal choices, and the impact of others on our decisions (social decision-making) are present (Bossaerts, 2009). In these complex scenarios, individuals are also influenced by emotional heuristics and biases, rather than purely rational considerations. Therefore, the first step towards better emotional regulation and thoughtful decision-making is to be aware of the impact of these effects on our behavior (Richard & Peterson, 2007). Knowledge of how humans make decisions and how our lives are affected by them can be very useful for favorable economic planning.

8. Conclusion

Neuroeconomics is an interdisciplinary area of study that explores decision-making processes. As we have seen, this discipline is based on economic theories, decision-making models, and empirical and theoretical studies from psychology, as well as on research into the neural processes involved in decision-making, conducted by neuroscientists. In addition to these domains, neuroeconomics has been enriched by computational models, genetic and pharmacological studies, and comparative studies between species, which have broadened the scope of this field (Glimcher & Fehr, 2014). Since its inception, neuroeconomics has developed models for understanding decision-making and conducted experiments ranging from decision-making in basic behaviors (e.g., at the perceptual, motor, and attentional levels) to experiments focused on decision-making in scenarios involving goal-directed choices (e.g., the choice of products, foods, and monetary amounts).

Although many studies have elucidated how the brain processes preferences, uncertainty scenarios, and intertemporal and social scenarios, there are still gaps and room for development. A challenging aspect of this discipline is to integrate experimental results and theoretical models coherently. This step is crucial to the decision-making process becoming even more complete and integrated. As in different scientific disciplines, it is expected that theoretical models on the decision-making process will undergo adjustments based on new findings and the consolidation of hypotheses. As presented, the study of decision-making can have practical relevance. Therefore, an essential point for future studies in neuroeconomics is the development of research with greater ecological validity, which can contribute to different contexts and have everyday applications.

9. References

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2. Article 2

Maturana, W., Salles, B.M., Ridolfi, M., Mograbi, D. C. (Manuscript submitted). An exploratory study on the effects of currency conversion on delay discounting

An exploratory study on the effects of currency conversion on delay discounting

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Abstract

Delay discounting is the process of discounting the value of later larger rewards compared to smaller sooner rewards. A challenge in the literature on delay discounting is the currency value discrepancy between countries, which can lead to difficulties in cross-cultural adaptation of tasks. The present study investigated the effect of currency conversion on the delay discounting rate. This work also explored whether the magnitude effect is related to the absolute value of the reward. A sample of 438 Brazilian participants were divided into two groups: those who performed a "non-converted" or a "converted" (USD to BRL) version of Monetary-Choice Questionnaire (MCQ-27). The delay discounting rate of the groups was compared to test an effect of currency conversion, as well as if the groups presented different magnitude effects during the task. There were no differences between the delay discounting rates for the groups, regardless of the size of the rewards. The magnitude effect was identified in both groups, with no significant differences between them. The results indicated an irrelevance of currency conversion in the delay discounting rate, suggesting that the magnitude effect does not seem to be related to the absolute values of the rewards, being perhaps influenced by relative comparison.

Keywords

Delay discounting; Impulsivity; Monetary Choice Questionnaire; Transcultural adaptation; Intertemporal decision.

1. Introduction

Many of our present decisions involve future consequences. The process of deciding between options in which outcomes occur at different times is called intertemporal choice (Kable, 2014). Everyday situations such as planning for retirement (Bidewell et al., 2006), physical activity (Epstein et al., 2021) and maintaining a healthy diet (Barlow et al., 2016; Epstein et al., 2021) are examples of decisions where there is a contrast between the possibility of receiving a small value reward sooner or a larger value reward later. The process of postponing rewards in favor of future greater gains is attributed to the capacity of self-control, as opposed to sooner choices, which are considered impulsive (Bickel et al., 2018; Odum, 2011).

Delay discounting tasks are an experimental procedure where a participant chooses between a short-term reward or a later larger reward (da Matta et al., 2012; Odum, 2011). These tasks focus on the discounting behavior of delayed gratifications, that is, the rate at which the future reward is devalued compared to the present one (Reynolds et al., 2002; Reynolds & Schiffbauer, 2005). A body of evidence has shown that both humans and other animals tend to discount future rewards (Reynolds et al., 2002; Vanderveldt et al., 2016). Although delay discounting is a tendency in our species, the discounting rate of individuals may be linked to clinical conditions such as pathological gambling (Ciccarelli et al., 2016; Cosenza et al., 2017; Cosenza & Nigro, 2015), obesity (Amlung et al., 2016; Barlow et al., 2016), drug addiction (Kirby et al., 1999; De Wit, 2009) and ADHD (Barkley et al., 2001; Jackson & Mackillop, 2016). Demographic characteristics such as lower socioeconomic status (Ishii et al., 2017; Reimers et al., 2009), intelligence quotient (IQ; Shamosh & Gray, 2008), younger age (Bixter & Rogers, 2019; Green et al., 1994; Reimers et al., 2009) and educational level (Reimers et al., 2009; Wilson et al., 2015) have been associated with a greater delay discounting rate. Some studies suggest that males show greater delay discounting rate than females (e.g., Kirby & Maraković, 1996; Malesza, 2021).

Regarding cultural effects on delay discounting rate, a study by Kim et al. (2012) showed that Americans had a high delay discounting rate compared to Koreans. Another study showed that both Americans, Chinese and Japanese had a higher discounting rate for smaller than larger rewards, but with less discounting in

Japanese participants (Du et al., 2002). More recent work has found differences in delay disconting rate between Americans and Chinese samples (Croote et al., 2020). These studies highlight the relevance of exploring further specific cultural influences on the delay discouting rate.

In relation to cross-cultural studies with Latin America samples, a study including participants from 53 countries found that Latin-Americans (Argentina, Chile, Colombia, México) and Latin-Europeans showed greater discount than Western-European participants (Wang et al., 2015). Research comparing an Argentinian and a British sample investigated the influence of inflaction rates on delay discounting (Macchia et al., 2018), showing that both groups discounted future rewards more steeply under higher (20%) than lower (2%) inflaction, but with the Argentinian group presenting higher discounting rate in both scenarios. Similarly, Todorov et al. (2003), during the Brazilian 1990's high inflation scenario, replicated a study conducted by Rachlin et al. (1991) using Brazilian currency (BRL). In this work, the authors used a BRL magnitude similar to US$ 1000 and found a high rate of delay discounting in the Brazilian sample, compared to the US sample. Todorov et al. (2003) also investigated the delay discounting rate when the value was in USD, obtaining results similar to those found by Rachlin et al. (1991). Despite these results, few cross-cultural studies have been conducted in Latin-American countries, and, to the best of our knowledge, only the studies by Macchia et al. (2018) and Todorov et al. (2003) explored contextual effects such as high inflation and currency devaluation in delay discounting. In addition to comparative studies, the adaptation of delay discounting instruments to the Brazilian cultural context is also relevant.

One of the most used delay discounting instruments is the Monetary-Choice Questionnaire (MCQ; Kirby et al., 1999), composed of 27 binary-choice scenarios, with pre-established monetary values and temporal distances (Kaplan et al., 2016). The MCQ allows to calculate a discounting rate (*k*) for the entire task or to three groups based on the size of the long-term reward (e.g., small *k*, medium *k* and large *k)*, permiting comparisions between individuals and groups in different decision-making scenarios. The MCQ has already been used in studies with clinical groups (e.g., Cosenza et al., 2017; Kirby et al., 1999), as well used in other countries than US (e.g., Ciccarelli et al., 2019; Michalczuk et al., 2011; Veillard & Vincent, 2020). Some transcultural adaptations of the MCQ tend to convert the original values (offered in dollars) to the currencies used in the respective countries (e.g., Euros in Ciccarelli et al., 2016 and Mayer et al., 2019; Pounds in Michalczuk et al., 2011; Veillard & Vincent, 2020; Yen in Kawamura et al., 2013 and Takahashi et al., 2008). In some adaptations, the dollar value was converted by a ratio of 1 to 1 (e.g., Mayer et al., 2019; Michalczuk et al., 2011; Veillard & Vincent, 2020) but in other cultures (e.g. Japan), where the currency unit is very discrepant, a conversion based in some exchange rate has been used (e.g., Kawamura et al., 2013; Takahashi et al., 2008).

One example of monetary discrepancy is Brazil, where the current unit (*real;* BRL) is very different than USD. For example, the average Brazilian salary is much lower than the American wages, and this leads to two methodological problems. First, the value converted from USD to BRL can be inconsistent in comparison to the values of the original MCQ (e.g., the amount of USD 11 considered small is equivalent to BRL 62.15, a medium value). Second, the comparative value between USD and BRL changes reasonably over time, due to exchange rates fluctuations. Changes in equivalence values of these two monetary units can lead to misunderstandings and misinterpretations. At the same time, little is known about the impact of conversion on the discounting rate.

Some delay discounting studies describe a “magnitude effect”, in which as the reward value increases, individuals have a lower discounting rate (e.g., Kirby & Maraković, 1996; Myerson et al., 2014; Smith & Hantula, 2008). Studies using the MCQ have found evidence of the magnitude effect, showing significant differences between the low, medium and high reward groups (Kirby & Maraković, 1996; Myerson et al., 2014), indicating that lower rewards values produced steeper discounts. In addition to magnitude effects, some studies have shown context or application effects of delay discounting tasks on the discounting rate (see Koffarnus et al., 2013 for a review). One of these effects is the “reward contrast effect”, a tendency of the individual's discounting rate to vary for a given choice (e.g., $500) based on a previous decision scenario (e.g., $50 or $5000; Dai et al., 2009). In these contexts, a phenomenon similar to the anchoring effect (Tversky & Kahneman, 1974) takes place, and the participants who had responded to a previous greater reward scenario tend to discount more than those submitted to a decision with lower reward. As delay discounting tasks usually present multiple decisions in sequence and with different magnitudes of reward, it is possible that the magnitude effect is influenced by the anchoring effect (i.e. value relative to other decision-making scenarios of the same task), rather than reflect a magnitude difference in absolute value.

The aim of this study is to explore the behavior of the MCQ in a Brazilian sample, investigating differences in the delay discounting rate between groups responding to converted by the exchange (converted) or converted to the same value rewards (non-converted). We also verified if the delay discounting rates for the reward magnitude groups (small *k*, medium *k*, and large *k*) were different for these two versions of the task. The comparison between versions allows assessing whether the magnitude effect was related to the size of the rewards in absolute or relative values. Based on the magnitude effect, the discounting rate of total MCQ and of the different reward groups is expected to be different, because the "converted" version was 5.65 times higher. If there are no differences between the discounting rate of the reward groups for the different versions, this may indicate that the magnitude effect is dependent on the comparison between a decision-making scenario and previous anchoring choices.

2. Materials & methods

2.1. Sample

An initial sample of 465 participants, collected between December 2020 and October 2021, was included in the study. Participants were excluded in case of medication use (antipsychotics, sedatives, and other drugs with possible impact in cognition) and outlier results. After the exclusion criteria a total of 438 participants (M = 29.09 years, SD = 7.80, 67.8% females) were included in the final sample. All subjects in the sample were Brazilians, and all regions of the country were covered, although the data were mostly from the Southeast region (82.2% of the sample). Demographic characteristics of participants can be seen in Table 1.

INSERT TABLE 1 HERE

2.2. Procedures

Participants were recruited by social media (i.e., Facebook, Instagram, and WhatsApp), email and invited directly by researchers or other participants. The eligibility criteria to participate in this study was living in Brazil and being 18 years or older. This study is part of a larger survey, reporting here sociodemographic characteristics and results of a delay discounting task. All the instruments were administrated online through Gorilla Experiment Builder (Anwyl-Irvine et al., 2020).

2.3. Instruments

Demographic Questionnaire – Demographic data such as age, sex, education, country region, marital status, family income was collected.

Monetary-Choice Questionnaire: 27 items version (MCQ-27) – The MCQ-27 was composed by 27 fictitious binary monetary choices. During MCQ the participant chose between fictitious Smaller Immediate Reward (SIR) or fictitious Late Delayed Reward (LDR). The monetary magnitudes and the moment of time to receive the reward change between choice scenarios. The choice scenarios can be classified in three groups by LDR size (i.e., small, medium, and large reward), with 9 scenarios in each group. To analyze the data of MCQ-27, the discounting rate (*k*) was used (Kaplan et al., 2016). A larger *k* represents a larger tendency to discount the reward (impulsive behavior), while small *k* is related to greater tendency to wait delay rewards (self-controlled behavior). For this work, a computer version of MCQ-27 was used (Figure 1). To test differences between “converted” (exchange between USD and BRL; 1 = 5.65) and “non-converted” (equivalent exchange between USD and BRL; 1 = 1) versions, the sample was randomly allocated by the Gorilla experiment platform to these two conditions (n = 225/51.37% and n = 213/48.63%, respectively).

INSERT FIGURE 1 HERE

2.4. Calculating the discounting rate of MCQ

To construct the *k* variable, the procedures described by Kaplan et al. (2016) were followed: (a) the SIR choices were computed as 0 while the LDR choices were computed as 1 and (b) the *k* referring to each decision scenario was calculated according to the subsequent equation:

$$V = \frac{A}{1+kD}$$

In this equation, V represents the value of SIR, while A refers to LDR and D refers to the delay of LDR option. To facilitate the calculation, the value of *k* can be moved to the left side of the equal sign, causing the subsequent rearrangement of the equation:

$$k = \frac{\frac{A}{V} - 1}{D}$$

After calculating the *k* for each 27 decision-making scenarios, a *k* for the reward size groups was constructed (i.e., small *k*, medium *k*, and large *k*). A geometric mean (geomean) *k* was calculated by the mean of these groups. After building all *k* parameters, logarithmic natural transformations (*ln k*) were used to approximate data to a normal distribution, as suggested by Kaplan et al. (2016). The *k* and *ln k* parameters were calculated using the spreadsheet presented by Kaplan et al. (2016).

2.5. Calculation

Descriptive statistics were used to illustrate the sample characteristics, with differences between groups being tested with independent sample t-tests (for continuous variables, such as age, years of education), Mann-Whitney tests (for ordinal variables, such as family income) or chi-square tests (for dichotomous variables, such as sex). A t-test was used to compare the geomean *ln k* between groups. Differences between groups in delay discounting were explored with a 2x3 mixed-design ANOVA, with group as a between-subjects factor (converted or non-converted values) and LDR size condition as a within-subjects factor (small, medium, and large *ln k*). Additionally, correlational analysis (Pearson's r) explored associations between delay discounting and variables such as sex, age, educational level, and family income. Correlation was also used to explore associations between LDR size and geomean. For all analyses, α was set at .05. The IBM SPSS Statistics (Version.26) was used for all statistical procedures.

2.6. Ethical issues

The study was approved by the Cardoso Fontes Federal Hospital research ethics committee (CAAE: 34702620.3.0000.8066) and all participants provided written informed consent.

3. Results

3.1. Sample characteristics

Results can be seen in Table 2. There were no significant differences in sex, age, family income and scholarity, suggesting that the randomization procedure was effective.

INSERT TABLE 2 HERE

3.2. Delay discounting

The t-test for geomean *ln k* between converted and non-converted groups was not significant (t (436) = -0.18, p = 0.857). In the ANOVA, there was no significant interaction (F (1.947, 436) = 0.05, p = 0.943, $\eta_p^2 < 0.001$) or main effect of group (F (1, 436) = 0.03, p = 0.857, $\eta_p^2 < 0.001$), but there was a significant effect of condition (F (1.947, 436) = 86.97, $p < 0.001$, $\eta_p^2 = 0.17$). Post-hoc analysis indicated significant differences between all *ln k* ($p < 0.001$), indicating smaller delay discounting with larger rewards. Means and standard errors for each group and delay interval can be seen in Figure 2.

INSERT FIGURE 2 HERE

3.3. Correlation analysis

No significant correlation was found to age, sex, educational level, and family income for both groups, converted and not converted reward. Correlations between reward size and geomean was strong and significant for both groups and reward condition. The results are presented in Table 3.

INSERT TABLE 3 HERE

4. Discussion

The present study explored the effect of currency conversion on the delay discounting rate of a Brazilian sample. Results did not indicate a currency conversion effect on the delay discounting rates in MCQ, regardless of the LDR magnitude examined. Effect sizes for non-significant results were very small, suggesting this was not due to the limited sample size. Correlational analysis indicated no correlation between sociodemographic variables and delay discounting rate. A strong correlation between all LDR sizes (small, medium, and large *ln k*) and a very strong correlation between these LDR sizes and the geomean *ln k* of MCQ was found, suggesting a good internal coherence of the task in both converted and non-converted version.

Based on these results, we suggest the use of the non-converted MCQ in Brazilian studies. As this version maintains the same monetary values than original (Kirby et al., 1999), it is not affected by the currency update, which facilitates cross-cultural comparisons. As far as we know, this is the first Brazilian study using the MCQ and at a first glance, the instrument showed similar results to other countries studies (e.g., Kirby et al., 1999; Kirby & Maraković, 1996; Michalczuk et al., 2011). In line with these previous studies, a magnitude effect was found in both comparisons by LDR size, with greater discounting rate for smaller rewards.

Despite the converted version of the MCQ being 5.65 times higher in magnitude than the non-converted, there were no significant differences for any reward size (small, medium, and large *ln k*) or geomean *ln k*. This result may suggest that the magnitude effect does not occur in relation to the absolute value of rewards.

It is possible that the magnitude effect may be the result of an “anchoring effect” (Tversky & Kahneman, 1974), in which the magnitude of the SIRs and LDRs (small, medium, or large) in each decision-making scenario are analyzed in relation to the other scenarios of the task. Thus, each option would be considered small, medium, or large, through an automatic and “naive average” of the decision-making scenarios available in the test. The results shown by Dai et al.(2009), with the “reward contrast effect”, support the hypothesis that the discount rate of a given decision-making scenario is influenced by the magnitudes presented previously.

Contrary to previous evidence (e.g., Liu et al., 2016; Reimers et al., 2009; Shamosh & Gray, 2008; Wilson et al., 2015), we did not find relationships between sociodemographic variables and delay discounting. The low diversity in our sample (mostly young residents of richer regions and with a fairly high level of education) may explain the absence of significant correlations. However, other Brazilian studies did not find a relationship between delay discounting and sociodemographic variables, such as sex (Barbosa & Bizarro, 2012; Silva & Howat-rodrigues, 2015), age and educational level (Barbosa & Bizarro, 2012; with the exception of family income), in line with current results, which may suggest that these associations are modulated by cultural effects.

The present study has some limitations, such as a sampling participants mostly from richer regions in Brazil, with high educational level for the region, and a large number of young adults, which may limit the generalization of results, especially for relations between delay discounting and sociodemographic variables. Another limitation concerns online data collection, which prevents the standardization of the testing environment, increasing the chances that external variables might influence performance. Nevertheless, both these limitations were linked to the context of the pandemic, during which data collection occurred. Future studies using in-person testing may provide further evidence for the findings reported here.

Some additional directions for future studies can also be considered. Investigations in different countries with discrepancies in currency evaluation are needed, shedding light on factors that may influence cross-cultural adaptations of delay discounting tasks. To better investigate whether the magnitude effect on delay discounting is related to the absolute value of rewards or to the relative value of the other task scenarios, studies in which each LDR size (small, medium, and large reward scenarios of the MCQ or other delay discounting task) is examined separately at random different times can be conducted. This type of manipulation could limit the anchoring effect, as the values of the different blocks would not be compared with each other. Finally, regional studies with delay discounting are still scarce. New studies should be done to clarify the relationship between delay discounting and sociodemographic variables in samples from developing countries.

5. Conclusion

The present study aimed to investigate the effect of currency conversion on the delay discounting rate, as well as to explore whether the magnitude effect reflected a comparison between absolute reward values. Our results did not show significant differences between the converted and unconverted versions for both the delay discounting rate and the magnitude effect between the two versions, which suggests that the magnitude effect is not based on the absolute value of the rewards. New studies can expand this perspective by studying the effects of conversion to other currency units. This effort is necessary to allow cross-cultural comparisons and ensure conceptual equivalence and standardization of delay discounting measurements across different regions.

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7. Declaration of interest

None

8. References

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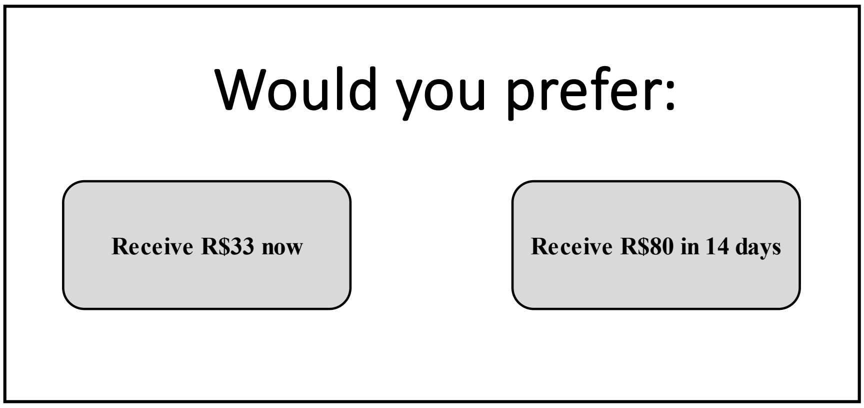
Table 1 – Sample characteristics

	Group	Mean/n (SD/%)
Age		29.09 (7.80)
Education (years)		16.79 (3.05)
Sex	Male	141 (32.2%)
	Female	297 (67.8%)
Family income	Less than R$ 2090 (≅ USD 370)	50 (11.4%)
	Between R$ 2090 and R$ 4180 (≅ USD 370 - 740)	137 (31.3%)
	Between R$ 4180 and R$ 10450 (≅ USD 740 - 1849)	145 (33.1%)
	Between R$ 10450 and R$ 20900 (≅ USD 1849 - 3700)	64 (14.6%)
	Higher than R$ 20900 (> ≅ USD 3700)	42 (9.6%)
Country region	South	24 (5.5%)
	Southeast	360 (82.2%)
	Midwest	15 (3.4%)
	North	2 (0.5%)
	Northeast	37 (8.4%)

Figure 1 – Computer version of Monetary Choice Questionnaire: 27 items version



The participant have to choose between two options in 27 items. The rectangles show the buttons with the smaller sooner reward (left) and the larger late reward (right).

Table 2 – Demographic characteristics by converted and non-converted groups

	Group	Converted n/mean (%, SD)	Non-converted n/mean (%, SD)	Significance (p value)
Age		28.64 (7.15)	29.52 (8.36)	0.235
Scholarity		16.78 (3.11)	16.79 (2.99)	0.993
Sex	Female	154 (68.44%)	143 (67.14%)	0.770
	Male	71 (31.56%)	70 (32.86%)	
Family	Less than R$ 2090	25 (11.7%)	25 (11.1%)	0.264
Income	R$ 2090 to R$ 4180	75 (35.2%)	62 (27.6%)	
	R$ 4180 to R$ 10450	61 (28.6%)	84 (37.3%)	
	R$ 10450 to R$ 20900	34 (16.0%)	30 (13.3%)	
	Higher than R$ 20900	18 (8.5%)	24 (10.7%)	

Figure 2 – Discounting rate of converted and non-converted group in MCQ.

Table 3 – Correlations between demographic and delay discounting variables.

	Converted (yes/no)							
	Small *ln k*		Medium *ln k*		Large *ln k*		Geomean *ln k*	
	yes	no	yes	no	yes	no	yes	no
Age	-0.04	0.08	-0.05	-0.02	-0.09	0.03	-0.07	0.03
Education	-0.02	0.04	-0.05	-0.01	-0.12	0.03	-0.07	0.02
Sex	-0.01	-0.06	-0.08	-0.03	-0.05	-0.06	-0.06	-0.06
Family Income	-0.04	-0.09	-0.04	-0.04	-0.07	-0.08	-0.05	-0.09
Small *ln k*	-	-	0.76**	0.71**	0.71**	0.64**	0.89**	0.86**
Medium *ln k*	0.76**	0.71**	-	-	0.77**	0.75**	0.93**	0.92**
Large *ln k*	0.71**	0.64**	0.77**	0.75**	-	-	0.91**	0.90**
Geomean *ln k*	0.89**	0.86**	0.93**	0.92**	0.91**	0.90**	-	-

* $p < .05$; ** $p < .01$. Negative correlations indicate a higher discounting rate for men.

3. Article 3

Maturana, W., Salles, B.M., Ridolfi, M., Fioravanti, A. C., Mograbi, D. C. (Manuscript submitted). Relationships between Alexithymia, Intertemporal, Risk and Ambiguity Decision-Making

Relationships between alexithymia, intertemporal, risk and ambiguity decision-making

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Abstract

The decision-making process involves both cognitive and affective/emotional skills. Alexithymia, a condition characterized by difficulties in identifying, distinguishing, and communicating emotions in an organized way, has been linked to several mental disorders and functional deficits, including decision-making. This study aimed to identify the relationships between alexithymia and decision-making in intertemporal, risky, and ambiguous contexts. To achieve this, 438 participants (M = 29.09 years, SD = 7.80, 67.8% female) were divided into high and low alexithymia groups based on their scores on the Bermond-Vorst Alexithymia Scale (BVAQ). The participants were submitted to three decision-making tasks: the Monetary-Choice Questionnaire (MCQ-27), the Game of Dice Task (GDT), and the Iowa Gambling Task (IGT). The same procedure was performed the specific factors of alexithymia measured by the BVAQ. The results showed that the high alexithymia score group was associated with a higher delay discounting rate on the MCQ-27 but did not exhibit significant differences for the GDT and IGT. However, significant differences were found for the specific factor "Analyzing," with a high score on this factor being associated with a higher delay discounting rate of MCQ-27 and a lower score in block 5 of the IGT. These findings suggest that people with greater alexithymia may have deficits in intertemporal and ambiguity, but not in risk decision-making.

Keywords
Alexithymia; Decision-making; Intertemporal; Risk; Ambiguity

1. Introduction

During the process of making decisions in daily life, numerous contextual factors can influence people's responses. In addition to the valence (i.e., gains or losses) and the magnitude of potential rewards (or costs), other factors such as the time between outcomes (e.g., McClure & Cohen, 2004; Vanderveldt et al., 2016) and the probability of their occurrence (e.g., Brand et al., 2008; Levy et al., 2010) can act as modulators. For example, intertemporal decisions may require individuals to choose between a smaller, more immediate reward and a larger reward that is delayed (Madden et al., 2003; Scarpazza et al., 2017; Vanderveldt et al., 2016). In such scenarios, decision-makers may experience two distinct modes of cognition: one that is immediate and impulsive, driven by the desire to seize the moment, and another that is self-controlled, characterized by thoughtful planning and consideration of the potential consequences of their choices (Madden & Bickel, 2010).

When making decisions under uncertainty, individuals face situations where the outcomes are not guaranteed. Uncertainty can be divided into two scenarios: risk and ambiguity (Bechara et al., 2005). In a risk scenario, probabilities of each outcome are either known or easily estimated, while in an ambiguity scenario, the probability of each outcome is unknown (Bechara et al., 2005; Brand et al., 2006; Levy et al., 2010). Intertemporal decisions can also be thought of as involving uncertainty, similar to other decision-making scenarios (He et al., 2012). In ecological contexts, long-term rewards are not guaranteed, as events may occur between the decision and the receipt of the reward, which may affect its effectiveness (He et al., 2012). Despite these similarities, research investigating both decision-making scenarios is not as prevalent in the literature.

Research has identified characteristic decision-making patterns in intertemporal and uncertainty contexts in different pathologies. While both humans and animals have shown a preference for immediate rewards (Reynolds et al., 2002; Vanderveldt et al., 2016), clinical conditions such as obesity (Amlung et al., 2016;

Barlow et al., 2016), ADHD (Barkley et al., 2001; Jackson & Mackillop, 2016), pathological gambling (Ciccarelli et al., 2016; Cosenza et al., 2017) and drug addiction (Kirby et al., 1999; De Wit, 2013) have been linked to greater difficulty in delaying rewards. In the context of risk, Kahneman and Tversky (1979) found that people without any disorder can exhibit risk aversion, but individuals with anxiety disorders have been shown to be more risk-averse and conservative in their responses than controls (Maner et al., 2007; Raghunathan & Pham, 1999). In contrast, disorders such as ADHD (Matthies et al., 2012), bulimia nervosa (Brand et al., 2007) and pathological gambling (Brand et al., 2005) have been associated with riskier response patterns. Additionally, ambiguity scenarios are generally more aversive than risk scenarios (FeldmanHall et al., 2016). However, in some cases, the ambiguity context can allow for learning through experience (Bechara et al., 1994, 1997). Studies using the Iowa Gambling Task (IGT) have demonstrated impaired learning in patients with obesity (Brogan et al., 2011; Davis et al., 2010), ADHD (Garon & Waschbusch, 2006; Malloy-Diniz et al., 2008), gambling disorders (Brevers et al., 2013; Kovács et al., 2017) and alcohol use (Kovács et al., 2017).

In contrast to the utilitarian perspective of neoclassical economics, which considered the decision-maker as a rational agent (Glimcher & Fehr, 2014), new perspectives have emerged highlighting the role of emotional processing in decision-making. Theories such as the dual system process (Kahneman, 2003; Mcclure & Cohen, 2004), the prospect theory (Kahneman & Tversky, 1979) and the somatic marker hypothesis (Damasio, 1996; Poppa & Bechara, 2018) emphasize the role of affective information in decision-making.

Alexithymia is a condition characterized by difficulties in identifying, distinguishing, and communicating emotions in an organized way (Goerlich, 2018; Taylor, 2000). While it is commonly found in various disorders such as eating disorders (Westwood et al., 2017), alcoholism (Betka et al., 2018), and addiction (Morie et al., 2016), it is also considered a personality trait that can vary in intensity among individuals (Luminet et al., 2004). However, the impact of alexithymia on decision-making remains understudied, despite the increasing recognition of emotions in this process.

Research has shown that high levels of alexithymia are associated with more impulsive decision-making, particularly when the immediate reward is available

(Scarpazza et al., 2017). Furthermore, alexithymia has been linked to learning deficits in decision-making under ambiguity (Aïte et al., 2014; Ferguson et al., 2009; Kano et al., 2011; Zhang et al., 2017), but not in decision-making under risk (Zhang et al., 2017). However, a limitation of the literature is the lack of studies that have investigated the specific impact of different factors of alexithymia on decision-making. For instance, alexithymia can be composed of deficits in affective cognition (e.g., difficulty in verbalizing, identifying, and analyzing emotions; Goerlich, 2018; Taylor et al., 1992; Vorst & Bermond, 2001) or affective behavior (e.g., difficulty expressing emotions or fantasizing; Vorst & Bermond, 2001), and these factors may have distinct effects on different types of decision-making.

Cultural and demographic factors can influence decision-making. While some studies have shown cultural (Du et al., 2002; Kim et al., 2012) and ethnic differences in intertemporal decision-making (Andrade & Petry, 2014), evidence does not support differences in decision-making related to gender and age (Macedo et al., 2022). Studies have found that Brazilians and Americans differ in their learning during the IGT, with Brazilians exhibiting poorer learning (Bakos et al., 2010). Gender comparisons, shows a significantly higher scores for men on an ambiguity decision-making (Cross et al., 2011). In relation to decision-making under risk, a Brazilian study demonstrated gender differences in the chosen pattern of the Game of Dice Task, but not in the net-score (Rzezak et al., 2012). For age and education effects, a systematic review of studies using the IGT in Brazil reported that only one of five studies found differences in age, and no articles found differences in education (Rutz et al., 2013). Despite the evidence presented, there are still many gaps to be filled regarding the effects of cultural and demographic variables in decision-making, particularly in samples from developing countries.

The objective of this study is to examine the association between alexithymia and decision-making in scenarios involving intertemporal, risk, and ambiguity decisions. The study aims to investigate the impact of specific alexithymia factors, such as difficulty verbalizing, identifying, analyzing, fantasizing, and emotionalizing, on decision-making. Furthermore, sociodemographic variables will be considered to contextualize possible cultural effects on decision-making and alexithymia.

2. Methods

2.1. Participants

Participants for this study were recruited through open calls on social media platforms such as Facebook, Instagram, and WhatsApp, as well as through email and direct invitations from the authors or other participants. Eligibility criteria included being over 18 years of age and living in Brazil. A total of 465 individuals were initially included in the study, with data collected between December 2020 and October 2021. After excluding individuals with previous mental health conditions (except anxiety and depression) and those taking medications that may affect cognition (excluding users of antipsychotics, sedatives, and other relevant drugs), a final sample of 438 participants (M = 29.09 years, SD = 7.80, 67.8% female) was obtained. Demographic characteristics of the participants are presented in Table 1.

INSERT TABLE 1 HERE

2.2. Instruments

Bermond-Vorst Alexithymia Questionnaire (BVAQ) – The BVAQ (Vorst & Bermond, 2001) is a scale used to measure alexithymia that comprises 40 items with a five-point Likert rating (1 = “Strongly Disagree” to 5 = "Totally Agree"; Vorst & Bermond, 2001). The BVAQ consists of five subscales: Verbalizing, which measures difficulty in verbalizing emotions; Identifying, which measures impairment in differentiating or identifying emotions; Analyzing, which measures reduced capacity to analyze and tendency to think oriented by external stimulus; Fantasizing, which measures difficulty in building fantasies and elaborated stories; and Emotionalizing, which measures impaired capability to experience feelings (Goerlich, 2018; Salles et al., 2023; Vorst & Bermond, 2001). For this study, the total and the five factor scores of the 38-item Brazilian version of BVAQ (BVAQ-BR; Salles et al., 2023) were used. The BVAQ-BR had a satisfactory internal consistency (α = .83; Salles et al., 2023).

Monetary-Choice Questionnaire: 27-item version (MCQ-27) – The MCQ-27 consists of 27 fictitious binary monetary choices in which participants choose between a Smaller Immediate Reward (SIR) and a Late Delayed Reward (LDR). The monetary magnitudes and the timeframes for receiving the rewards vary across choice scenarios, which are grouped according to the size of the LDR (i.e., small, medium, and large) with 9 scenarios in each group. To analyze the data from the MCQ-27, the discounting rate (k) was used (Kaplan et al., 2016). A larger k value indicates a greater tendency to discount the delayed reward, indicating impulsive behavior, while a smaller k value is associated with a greater tendency to wait for delayed rewards, indicating self-controlled behavior. The computerized version of the MCQ-27 was used in this study.

Game of Dice Task (GDT) – The GDT is a computerized task developed to assess decision-making under risky scenarios (Brand et al., 2005). In this task, participants are presented with the choice of selecting a number or a combination of numbers (options with two, three, or four dice) during 18 attempts. After each choice, a die is rolled, and the participant either wins a fictitious amount of money if they chose the drawn number or loses an amount of equal size if they do not. The GDT allows participants to make either riskier or safer choices with high-stakes ($1000 or $500) or low-stakes ($200 or $100), respectively. Participants are instructed to maximize their winnings and begin with a betting capital of $1000. To analyze the results of the GDT, the number of less risky choices (three and four numbers) is subtracted from the number of riskier choices (one and two numbers), forming a net-score.

Iowa Gambling Task (IGT) – The IGT is a computerized task developed by Bechara et al. (1994) to assess decision-making under ambiguous scenarios. In the IGT, participants are presented with four decks (A, B, C, and D) and are instructed to draw cards from them during 100 trials. After each draw, they can either win or lose money. The participants are required to maximize their gains and start the task with $2000 of betting capital. Two decks (C and D) are advantageous, while the other two (A and B) are disadvantageous over time. During the IGT, it is expected that individuals initially explore the decks in a close-random pattern and gradually learn to choose more cards from the advantageous decks, which can be implicit or explicit by the end of the task; Turnbull et al., 2014). To analyze the results of the IGT, a net-score can be calculated by subtracting the disadvantageous decks from the advantageous decks ((C + D) - (A + B)). Learning in the IGT can also be assessed by comparing scores across five blocks of 20 trials (Blocks 1-5).

2.3. Procedures

First, participants completed a sociodemographic questionnaire, answered the BVAQ to assess alexithymia, and performed three decision-making tasks (intertemporal, risk, and ambiguity). To avoid any potential biases caused by fatigue, the order of the decision-making tasks was randomized. No significant differences were found between the different task orders (F (3, 465) = 2.85, p = .059). The entire procedure was conducted online using the Gorilla Experiment Builder (Anwyl-Irvine et al., 2020).

2.4. Data reduction

For this study, the factors, and general scores of BVAQ was used. In relation to the decision-making measures, the five-block scores of IGT, the GDT net-score and the discounting rate (*k*) of each group of rewards (small, medium, and large) of MCQ-27 was used.

Calculating the discounting rate (k)

To construct the *k* variable, the procedures described by Kaplan et al. (2016) were followed: (a) the SIR choices were computed as 0 while the LDR choices were computed as 1 and (b) the *k* referring to each decision scenario is calculated according to the equation:

$$V = \frac{A}{1+kD}$$

In this equation V represent the value of SIR, while the A is referent to LDR. The letter D is the delay of LDR. To facilitate the calculation, the value of *k* to be computed can be moved to the left side of the equal sign, making the following rearrangement of the equation:

$$k = \frac{\frac{A}{V} - 1}{D}$$

After calculating the *k* for 27 decision-making scenarios, a *k* for the reward size groups was constructed (i.e., small *k*, medium *k*, and large *k*) and logarithmic natural transformations (*ln k*) were used to approximate data to a normal distribution (Kaplan et al., 2016).The *k* and *ln k* parameters were calculated using the spreadsheet presented by Kaplan et al. (2016).

2.5. Data analysis

To separate the sample into high and low alexithymia groups, the median of each factor and the total score of BVAQ-BR were used. Similarly, a median cutoff was used to divide participants into younger and older adult groups based on age. Sociodemographic comparisons were conducted using t-tests and ANOVAs. A t-test was used to compare GDT scores between groups. A mixed-design ANOVA was employed to analyze the performance of the same participants in the five blocks of the IGT (learning between blocks) and the difference in the discounting rate (*ln k*) for small, medium, and large rewards of the MCQ-27. Data analysis was conducted using SPSS version 26 (SPSS Inc., Chicago, IL).

2.6. Ethical Issues

This study was approved by the Brazilian Ethics Committee (Plataforma Brasil, CAAE: 34702620.3.0000.8066), and prior to data collection, all participants provided informed consent by accepting and signing a consent form. No financial incentives were provided to any participant for their involvement in this study.

3. Results

3.1. Sample Characteristics

A general descriptive data for all sample was presented in Table 2. Males and females were compared in terms of their BVAQ scores and decision-making performance. Regarding the BVAQ score, significant difference was found for the total score (t (438) = 4.27, p < .001) with males having higher alexithymia scores than females. In terms of decision-making performance, males performed better than females in the GDT net-score (t (438) = 4.19, p < .001), but no significant gender differences were found for the IGT net-score (t (438) = .80, p = .425) or small (t (438) = .825, p = .410), medium (t (438) = 1.19, p = .236), and large *ln k* (t (438) = 1.22, p = .225) of MCQ-27.

Significative differences in BVAQ total (F (4, 438) = 3.553, p = .007; η_p^2= .032) and GDT net-score (F (4, 438) = 4.74, p = .001; η_p^2 = .042) was found in relation to family income, however, differences in the IGT net-score (F (4, 438) = 1.57, p = .182; η_p^2 = .014) and the small (F (4, 438) = .51, p = .725; η_p^2 = .005), medium (F (4, 438) = .30, p = .881; η_p^2 = .003), and large ln k (F (4, 438) = .64, p = .635; η_p^2 = .006) of MCQ-27 was not found. Post-hoc analysis with Bonferroni's corrections revealed that participants with higher family income had lower alexithymia scores and higher net-score in the GDT. Differences were significant for BVAQ total between participants: (a) with up to R$ 2090 and those with R$ 10450 to R$ 20900 (10.55, p = .010), (b) with R$ 2090 to R$ 4180 and those with R$ 10450 to R$ 20900 (8.31, p = .012) and (c) with R$ 4180 to R$ 10450 and those with R$ 10.450 to R$ 20900 (7.24, p = .045) family income. For GDT net-scores, differences were significant participants: (a) with up to R$ 2090 and those with R$ 4180 to R$ 10450 (-5.06, p = .005), and (b) with up to R$ 2090 and those with more than R$ 20900 (-6.01, p = .013) family income.

Low education was associated with higher scores in the BVAQ total (M = 97.61, SD = 17.67; t (438) = 3.05, p = .002), compared to high education (M = 92.27, SD = 16.56). No significant differences in education were found for GDT net-score (t (438) = -1.14, p = .257), IGT net-score (t (438) = .740, p = .460), or the small (t (438) = .185, p = .854), medium (t (438) = .234, p = .815), and large *ln k* (t (438) = 1.30, p = .193) of MCQ-27. Differences of age were not found in BVAQ total (t (438) = .18, p = .858), GDT net-score, (t (438) = -.37, p = .709), IGT net-score (t (438) = .41, p = .679), and small (t (438) = .46, p = .644), medium (t (438) = 1.05, p = .296), and large *ln k* (t (438) = .65, p = .519).

The high and low alexithymia groups differed in number of females (low alexithymia = 172, high alexithymia = 125) and males (low alexithymia = 53, high alexithymia = 88) based on BVAQ total scores (χ^2 (1) = 15.81, p < .001; ϕ = 0.438). However, the effects on decision-making tasks could not be attributed to gender, as only the GDT showed significant differences. No differences in age (*t* (438) = .47, $p = .638$) or family income (U = 21651.000, z = -1,81, p = .070) were found between the high and low alexithymia groups.

INSERT TABLE 2 HERE

3.2. Relationship between alexithymia total scores and decision-making

GDT. In relation to the groups divided according to the BVAQ total score, the GDT total score differences were not significant (*t* (436) = .14, $p = .602$).

IGT. For comparisons between IGT block scores, a main effect of blocks was significant (*F* (3.56, 438) = 17.20, $p < 0.001$; $\eta_p^2 = .001$), without significant between-subject (F (1, 438) = .60, p = .438; $\eta_p^2 = .103$) or interaction (F (3.56, 438) = .64, $p = .618$; $\eta_p^2 = 0.103$) effects. Bonferroni's post-hoc analysis showed significant differences in scores between block 1 and all of others blocks (block 2, -1.34, $p = .011$; block 3, -2.76, $p < .001$; block 4, -3.18, $p < .001$; and block 5, -3.18, $p < .001$). Block 2 differed from block 3 (-1.42, $p = .013$), block 4 (-1.84, $p = .001$) and block 5 (-1.84, $p = .005$). Finally, the block 3 did not show significant differences in relation to block 4 (-.423, $p = 1.00$) and block 5 (-.418, $p = 1.00$), as happened with the comparison between block 4 and block 5 (-.005, $p = 1.00$). Figure 1 shows the scores of the two groups over the five blocks of 20 trials of IGT.

INSERT FIGURE 1 HERE

MCQ-27. Significant differences were found in the comparison between scores on the MCQ-27. There were main effects of reward magnitude (*F* (1.95, 438) = 87.03, $p < .001$; $\eta_p^2 = .166$) and group (*F* (1, 438) = 4.56, $p < .033$; $\eta_p^2 = .01$), but no significant interaction effects (*F* (1.95, 438) = .12, *p* = .883; η_p^2 = .000). Bonferroni's post-hoc analysis for within-group effects revealed significant differences between small and medium (-.356, $p < .001$), small and large (.806, $p < .001$), and medium and large *ln k* (.449, $p < .001$). The group with high alexithymia had a higher delay discounting rate, as shown in Figure 2.

INSERT FIGURE 2 HERE

3.3. Relationship between alexithymia factors and decision-making

3.3.1. Differences between alexithymia factors in the GDT

There were no significant differences found in GDT for the sample split according to verbalizing (*t* (436) = -1.57, *p* = .116), identifying (*t* (436) = -1.36, *p* = .174), analyzing (*t* (436) = -.21, *p* = .832), emotionalizing (*t* (436) = .83, *p* = .408), and fantasizing (*t* (436) = 1.45, *p* = .149) factors.

3.3.2. Differences between alexithymia factors in the IGT

The within-group effect (effect by blocks) for groups divided into high and low scores by each of the five specific BVAQ factors: verbalizing (*F* (3.56, 438) = 17.21, $p < .001$; η_p^2 = .038), identifying (*F* (3.56, 438) = 17.149, $p < .001$; η_p^2 = .038), analyzing (*F* (3.57, 438) = 2.78, *p* = .031; η_p^2 = .006), fantasizing (*F* (3.56, 438) = 17.14, $p < .001$; η_p^2 = .038), and emotionalizing (*F* (3.56, 438) = 18.09, $p < .001$; η_p^2 = .040) presented almost identically pattern than what happened to the BVAQ total. Bonferroni’s post-hoc showed that blocks 1 and 2 significantly differed between them and in relation to the other blocks. Blocks 3, 4, and 5 showed no differences between them.

The results for the verbalizing factor showed no significant differences between groups (*F* (1.95, 438) = .12, p = .883; η_p^2 = .000) or interaction effects (*F* (3.56, 438) = .75, *p* = .542; *η2* = .002). To the identifying factor, no significative differences between groups (*F* (1, 438) = .02, *p* = .882; η_p^2 = .000) or interaction effects (*F* (3.56, 438) = .42, *p* = .772; η_p^2 = .001) was found. Regarding the fantasizing factor, no significant differences between groups (F (1, 438) = .02, p = .904; η_p^2 = .000) or interaction effects (F (3.56, 438) = .44, p = .760; η_p^2 = .001) was found. In relation to the emotionalizing factor shows an interaction effect (F (3.56, 438) = 2.57, p = .043; η_p^2 = .006), without significant differences between groups (F (1, 438) = 1.42, p = .234; η_p^2 = .003). Bonferroni's post-hoc analysis of interactions showed no significative differences in any blocks of IGT between groups based on the emotionalizing factor.

Finally, in the analyzing factor (Figure 3), an interaction effect was found (F (3.57, 438) = 16.20, $p < .001$; η_p^2 = .036), without significant differences between groups (F (1, 438) = .39, p = .531; η_p^2 = .001). Bonferroni's post-hoc analysis of significant interactions showed differences in the block 5 of IGT between groups based on the analyzing factor (-2.24, p = .028), with less IGT score in the block 5 for the group with high analyzing.

INSERT FIGURE 3 HERE

3.3.3. Differences between alexithymia factors in the MCQ-27

The within-group effect (effect by reward size) for groups divided into high and low scores by each of the five specific BVAQ factors: verbalizing (F (1.95, 438) = 87.03, $p < .001$; η_p^2 = .166), identifying (F (1.95, 438) = 87.54, $p < .001$; η_p^2= .167), analyzing (F (1.95, 438) = 85.98, $p < .001$; η_p^2 = .165), fantasizing (F (1.95, 438) = 88.32, $p < .001$; η_p^2 = .168) , and emotionalizing (F (1.95, 438) = 85.92, $p < .001$; η_p^2 = .165) was significative, and presented almost identically pattern than what happened to the BVAQ total. Bonferroni's post-hoc showed that the *ln k* for small size rewards was greater than for medium and large size rewards. Additionally, the *ln k* for medium size rewards was greater than for large size rewards.

No group (F (1, 438) = 2.65, p = .104; η_p^2 = .006) or interaction effects (F (1.95, 438) = .175, p = .834; η_p^2 = .000) was found between high and low verbalizing in the MCQ-27. To the identifying factor, no between groups (F (1, 438) = 1.01, p = .315; η_p^2 = .002) or interaction effects (F (1.95, 438) = 1.11, p =

.331 η_p^2= .003) was found. In relation to the fantasizing factor, an interaction effect between reward size conditions and the groups of high and low fantasizing scores was found (F (1.95, 438) = 3.37, p = .036; η_p^2 = .008), with no significant differences between groups (F (1, 438) = .44, p = .508; η_p^2 = .001). Bonferroni's post-hoc analysis for the interaction effect showed no significant differences for any reward size between groups based on the fantasizing factor. For emotionalizing factor did not show differences between groups (F (1, 438) = 2.65, p = .106; η_p^2 = .006) or interaction (F (1.95, 438) = .14, p = .860; η_p^2 = .000).

Finally, for the analyzing factor (Figure 4), interaction effects were not found (F (1.95, 438) = .12, p = .885; $\eta 2$ = .000), but a significant differences between groups was found (F (1, 438) = 6.55, p = .011; η_p^2 = .015). People with high analyzing scores have a greater discounting rate in small (.403, p = .006), medium (.386, p = .023), and large reward size conditions (.345, p = .049) than people with low analyzing scores.

INSERT FIGURE 4 HERE

4. Discussion

The objective of this study was to examine the association between alexithymia and decision-making under intertemporal, risky, and ambiguous conditions. Our findings revealed that individuals with high levels of alexithymia, as measured by the BVAQ total score, performed worse on the intertemporal decision-making task compared to those with low levels of alexithymia. However, there were no differences between the groups for the risky and ambiguous decision-making tasks. Furthermore, participants who reported greater difficulties in analyzing emotions, as measured by the analyzing factor, scored lower on the intertemporal and ambiguity decision-making tasks, but not on the risk decision-making task. Similar to previous research (e.g, Scarpazza et al., 2017; Aïte et al., 2014; Ferguson et al., 2009; Kano et al., 2011; Zhang et al., 2017), alexithymia was linked to intertemporal and ambiguous decision-making. Consistent with the study by Zhang et al. (2017), decision-making in a risk scenario, measured by the GDT, does not vary based on levels of alexithymia.

These results suggest that high levels of alexithymia affect intertemporal decision-making, as measured by the MCQ-27. Specifically, individuals in the high-alexithymia group, based on BVAQ total, demonstrated higher delay discounting rates (*ln k*) compared to the low-alexithymia group and the same pattern was found to the analyzing factor of BVAQ. This finding was in line with a previous study by Scarpazza et al. (2017), which found that the high-alexithymia group showed a greater preference for immediate rewards (now) compared to the low-alexithymia group, but not for rewards received in 60 days (not-now). Together, these findings suggest that a high degree of alexithymia may affect sensitivity to the urgency during intertemporal tasks.

Regarding decision-making under ambiguity, the BVAQ analyzing factor was associated with score differences in block 5 of the IGT. Participants with high analyzing scores obtained lower scores in block 5 of the IGT, which is similar to the findings of Zhang et al. (2017) who found this difference for the general alexithymia score measured by the Toronto Alexithymia Scale (TAS-20). Kano et al. (2011) also found impaired learning during the IGT in alexithymics compared to controls and suggested that the medial prefrontal cortex is involved in the processing of somatic markers, which play a crucial role in learning in ambiguous scenarios and successful decision-making in this context. Despite our results only referring to the analyzing factor of the BVAQ, and not for a general score, they are consistent with the limited literature available.

The absence of a relationship between alexithymia and decision-making in the context of risk may be understood based on the literature. By presenting explicit or easily calculated probabilities, decision-making under risk tasks, such as the GDT, tend to require less affective processing and more executive functioning than tasks under ambiguity, such as IGT. (Brand et al., 2006, 2008). Alexithymia is characterized by thinking guided by the external environment (Taylor, 2000; Vorst & Bermond, 2001), and probably the decision-making deficits linked to it are only observed when the subject must complement external information gaps with internal and intuitive information. In addition to this idea, a study by Ferguson et al. (2009) found that high-alexithymia subjects perform even worse on the IGT when cumulative feedback is not provided, suggesting that a smaller amount of explicit information and greater ambiguity is proportionally related to the degree of decision impairment in alexithymics.

The analyzing factor was the only BVAQ specific factors related to decision-making, showing an interaction effect between the high and low alexithymia groups in the IGT blocks, as well as a difference between these groups for the MCQ-27. One hypothesis for these results is that decision-making in intertemporal and ambiguous contexts depends not only on the ability to identify and express emotions (like measured by the identifying and emotionalizing factors, respectively), but also on the importance attached to them. This data was in line with the hypothesis of Kano et al. (2011) on the role of the medial prefrontal cortex in the interpretation of somatic markers during the initial phases of IGT. The lower activation of this area in alexithymics during the task may impair their ability to learn from emotional feedback, resulting in more losses in the final trials compared to control subjects. In terms of intertemporal decision-making, the lack of importance placed on somatic markers may lead to an underestimation of their role in decision-making, potentially leading to impulsive choices. If a factor that influences decisions is not perceived, it is not possible to control it. The lack of reflection before a decision is one of the characteristics that underlies impulsiveness (Robbins et al., 2012).

Of the three decision-making tasks used in this study, only the GDT was influenced by sociodemographic data. Males presented higher GDT scores than females, in dissonance with a work by Rzezak et al. (2012) that not found differences in a Brazilian Sample. Differences in income were also found, with people with higher family incomes scoring higher on the GDT. The income results in the GDT are ambiguous, as both a deficit in risk decision-making can affect income or a higher income can impact the decision-making profile of the subjects. New studies are necessary to identify the direction of this relationship.

In terms of alexithymia, sociodemographic characteristics such as sex, age, family income, and education were related to the measure. Men were found to be more alexithymics than women, A study on beliefs about emotion with a Brazilian sample (Mograbi et al., 2018) identified that men had greater beliefs about the unacceptability of experiencing and expressing negative emotions than women. They speculated that Brazilian men may consider the expressiveness of emotions as a sign of weakness. In line with this explanation, it is possible that because these beliefs, men less endorse the BVAQ items. Older adults presented lower scores in identifying and analyzing but higher scores in fantasizing and emotionalizing factors than youngers (in line with correlations founded by Vorst & Bermond, 2001). A possible explanation for the first two factors may be the experience of understand their feelings acquired with age, however, this data was in opposite direction than a general literature of alexithymia (e.g., Mattila et al., 2006). In relation of the fantasizing and emotionalizing results, the findings should be interpreted with caution, due to possible instability of the affective factors of BVAQ (Morera et al., 2005).

Similar pattern was found to education and family income. Higher education group obtained lower scores for verbalizing, identifying, and analyzing and higher scores for fantasizing and emotionalizing, while higher income was related to lower scores for verbalizing, identifying, and analyzing. These results may be associated with the privileged position of people with higher income and education to access information about the importance of emotions. However, the hypothesis that alexithymia may impact financial and academic decisions cannot be rejected. Longitudinal studies exploring these factors are needed to clarify these issues.

The present study has limitations that need to be acknowledged. Firstly, data collection was conducted online, which limits our control over the procedures for completing the scales and responses in the tasks. Secondly, the use of the BVAQ-BR, a non-consolidated alexithymia scale. The instability of the BVAQ for the affective factors (fantasizing and emotionalizing), which behave in the opposite way to the other factors, and the recent adaptation of the scale to the Brazilian context, limit the interpretation of the results. To address these limitations, new studies in a laboratory context are recommended. These studies should also explore the relationship of specific factors of the TAS-20 with decision-making to provide a better understanding of the impact of alexithymia on decision-making.

The study has several merits, including the investigation of the impact of alexithymia on decisions in intertemporal, risk, and ambiguity contexts in the same study, which allows for comparisons between conditions. Another strength was exploring the relationship between specific factors of alexithymia and decision-making, which has not been extensively researched in the literature. Finally, the study also used the BVAQ, which, despite some limitations, as a tool to investigate the relationship between affective factors of alexithymia and decision-making.

5. Conclusion

This work investigated the relationship between alexithymia and its specific factors with intertemporal, risk, and ambiguity decision-making. Both a general score and an analyzing factor of alexithymia measured by BVAQ were related with deficits in intertemporal and ambiguity decision-making. Risk decision-making may be not affected by alexithymia. Despite the contribution of these results, further studies are needed to corroborate the findings and explore points that were not covered in this study. Integrating alexithymia scales with other emotional processing measures, as well as behavioral, physiological, and neuroimaging measures may contribute to a more comprehensive understanding of this topic.

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Table 1. Sociodemographic characteristics of the sample.

Characteristic	*N* = 438 *n* (%) / *M* (*SD*) / range
Gender	
Men	141 (32.2%)
Woman	297 (67.8%)
Age	29.1 (7.8) / 18-65
Educational level	
Higher	303 (69.2 %)
Lower	135 (30.8%)
Family income	
Up to R$2090	50 (11.4%)
Between R$ 2090 and R$ 4180	137 (31.3%)
Between R$ 4180 and R$ 10450	145 (33.1%)
Between R$ 10450 and R$ 20900	64 (14.6%)
More than R$ 20900	42 (9.6%)

Table 2. Descriptive data for alexithymia and decision-making.

Characteristic	*M* (*SD*) / range*
BVAQ	
BVAQ total	93.92 (17.07) / 48 – 148
Verbalizing	22.79 (7.65) / 8 – 40
Identifying	20.53 (5.87) / 9 – 40
Analyzing	17.32 (5.24) / 9 – 35
Emotionalizing	13.73 (3.88) / 6 – 24
Fantasizing	17.90 (6.34) / 7 – 35
Decision-Making	
GDT net-score	7.21 (9.00) / (-18) –18
IGT net-score	-4.41 (33.93) / (-88) –100
IGT (block 1)	-2.98 (6.93) / (-20) – 20
IGT (block 2)	-1.63 (9.04) / (-20) – 20
IGT (block 3)	-.22 (9.47) / (-20) – 20
IGT (block 4)	-.21 (9.89) / (-20) – 20
IGT (block 5)	-.21 (10.50) / (-20) – 20
MCQ-27 (small *ln k)*	-3.95 (1.53) / (-8.75) – (1.40)
MCQ-27 (medium *ln k)*	-4.30 (1.76) / (-8.75) – (-1.39)
MCQ-27 (large *ln k)*	-4.30 (1.76) / (-8.75) – (-1.39)

* Parenthesis for negative values of range.

Figure 1. Performance of groups of high and low alexithymia on the IGT.

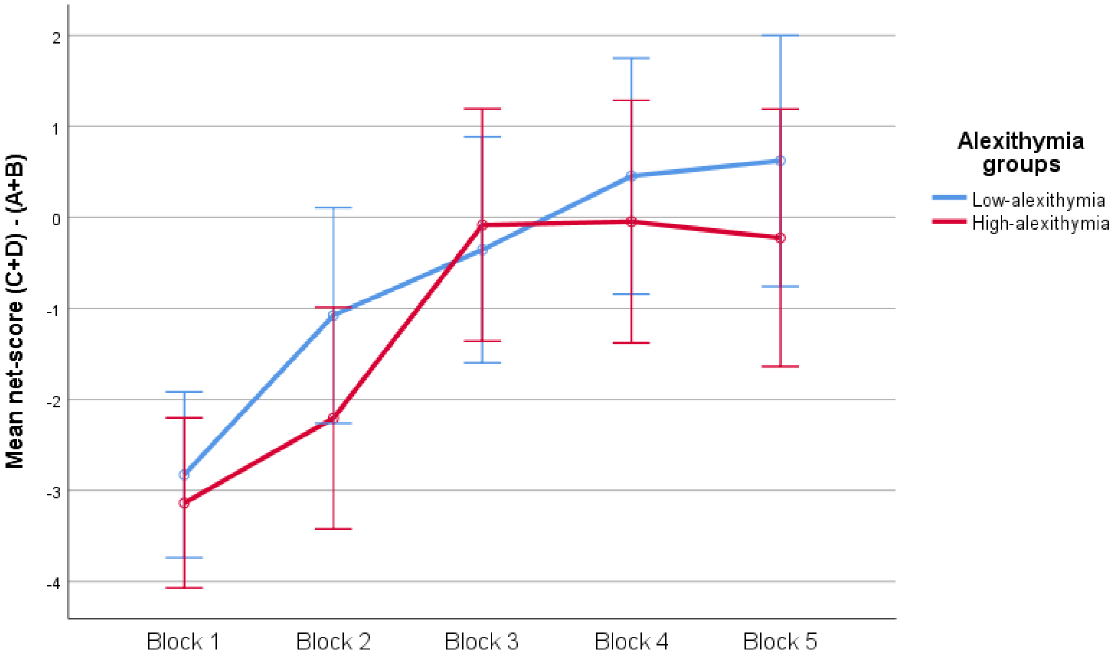


Figure 2. Performance of groups of High and low alexithymia on the MCQ-27.

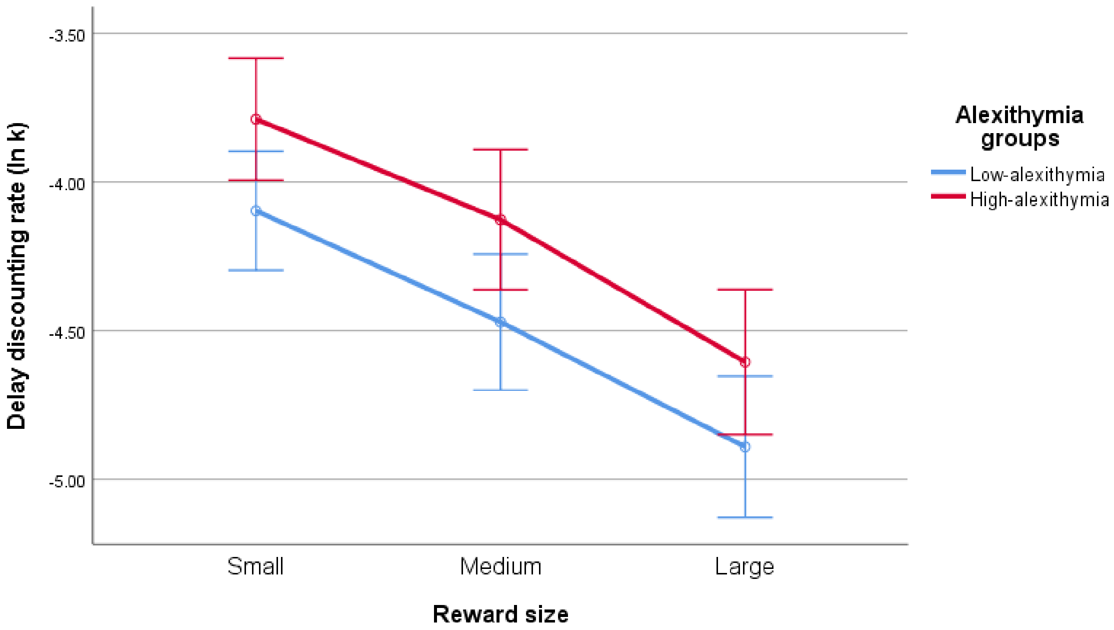
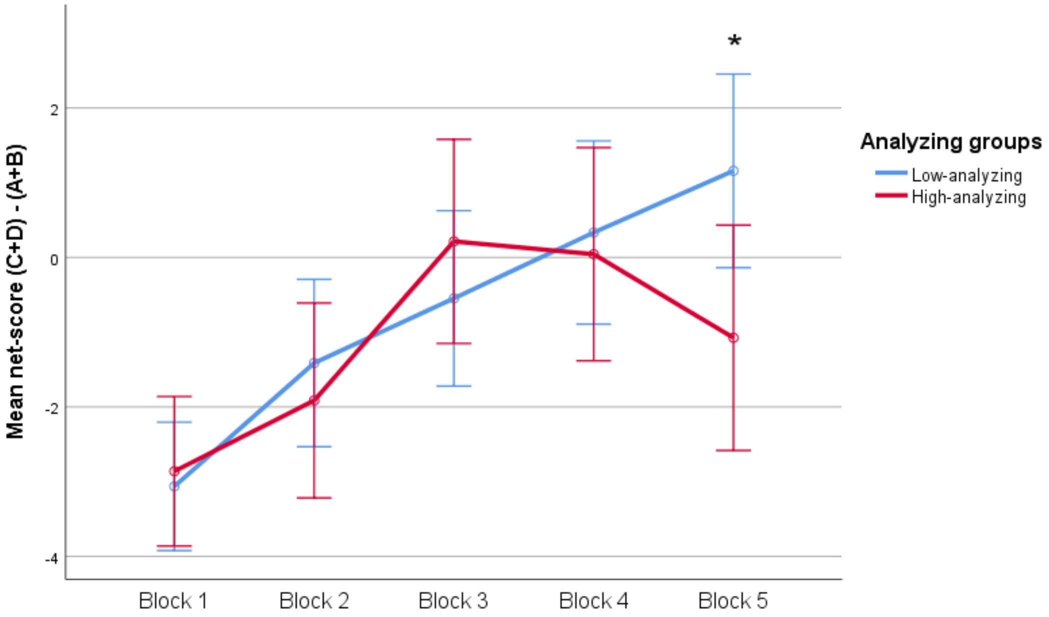
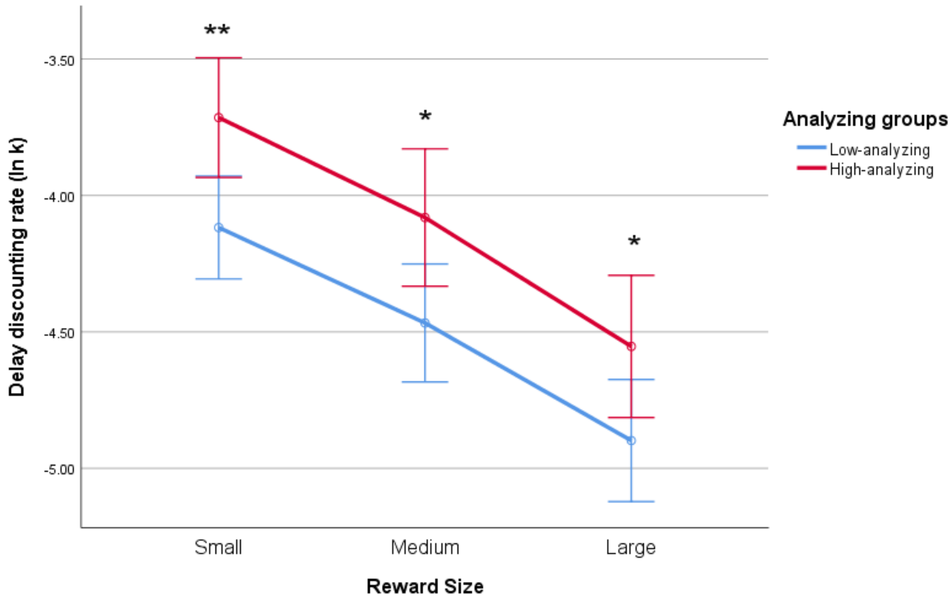


Figure 3. Performance of groups with high and low analyzing on the IGT.



*p < .05.

Figure 4. Performance of groups with high and low analyzing on the MCQ-27.



*p < .05, **p < .01

7. Article 4

Maturana, W., Salles, B.M., Ridolfi, M., Mograbi, D. C. (Manuscript submitted). Decision-making in a Pandemic Context: The Effect of COVID-19 in the Intertemporal, Risky, and Ambiguous Decisions.

Decision-making in a pandemic context: The effect of COVID-19 in the intertemporal, risky, and ambiguous decisions

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Abstract

This article aims to investigate the influence of the COVID-19 pandemic on intertemporal, risk, and ambiguity decision-making. For this study 438 participants (M = 29.09 years, SD = 7.80, 67.8% females) completed a sociodemographic questionnaire containing variables about COVID-19 and three decision-making tasks (intertemporal, risk and ambiguity). There were significant differences for the COVID-19 variables in a task exploring decision-making under risk, but not in those investigating intertemporal and ambiguous decisions. Participants with more severe COVID-19 symptoms made riskier/disadvantageous choices in the Game of Dice Task (GDT) than patients with milder symptoms. In the same task, more severe symptoms of COVID-19 in a family member were related to less risky/advantageous choices than milder symptoms. The findings suggest that the pandemic have impacted individuals' decision-making under risk, with COVID infection potentially leading to decision-making impairments, whilst having relatives with the condition may have increased aversion to risk. The study highlights the importance of tracking possible changes in individuals' decision-making due to the pandemic.

Keywords

Decision-making, Intertemporal decision, Risk, Ambiguity, COVID-19

1. Introduction

Decision-making can be defined as the process of selecting a particular option from among alternative choices that present different outcomes (Lee, 2013). This activity is a fundamental aspect of daily life that requires an intricated integration of multiple sources of information, such as sensory input, memory of past experiences, cognitive and emotional processes (Lerner et al., 2015; Rangel et al., 2008; Rosenbloom et al., 2012). Due to its dependence on multiple channels of information and involvement of broad and complex brain regions (Rosenbloom et al., 2012), deficits in decision-making can be found in many clinical conditions such as ADHD (Garon & Waschbusch, 2006; Mowinckel et al., 2015), gambling disorders (Aïte et al., 2014; Brand, et al., 2005), drug use (Kirby et al., 1999), neurodegenerative diseases (Gleichgerrcht et al., 2010), anxiety and depression (Bishop & Gagne, 2018; Paulus & Stein, 2010).

Beyond the subjective value attributed to each option, modulatory variables such as time and uncertainty can also influence decision-making (Rangel et al., 2008). Intertemporal decision involves choosing between a small sooner or delayed large rewards (Kable, 2014), while decision-making under risk and ambiguity involves making choices when the probability of outcomes is uncertain (Bechara et al., 2005; Huettel et al., 2006). In risk contexts, the probabilities of outcomes are explicit or can be easily intuited, while in ambiguity contexts, the probabilities of outcomes are obscure (Bechara et al., 2005; Rangel et al., 2008). Although there are some similarities in both decision-making contexts, distinct cognitive and brain processes are related to each of these modulators (Huettel et al., 2006; Levy et al., 2010; Mcclure & Cohen, 2004; Rangel et al., 2008).

According to the literature, decision-making in both contexts can be influenced by emotional variables. In intertemporal decision-making, more immediate outcomes have been linked to greater activation of brain areas related to motivation and emotion such ventral striatum, medial orbitofrontal cortex, medial prefrontal cortex and posterior cingulate cortex (Mcclure & Bickel, 2014; Mcclure & Cohen, 2004). In decision-making under risk, cognitive emotional regulation has been linked to less risk choices than absence of emotional regulation (Martin & Delgado, 2011). Finally, decision-making under ambiguity conditions has been presented as even more aversive than risk conditions (Huettel et al., 2006; Levy et al., 2010), and some studies have indicated that somatic markers linked to emotions may modulate learning in these contexts (Bechara et al., 1994, 1997; Poppa & Bechara, 2018). Furthermore, part of the literature has indicated that decision-making can be affected by contextual emotions (e.g., Hirsh et al., 2010; Hu et al., 2014; Shukla et al., 2019) and stress (Cano-lópez et al., 2016; Starcke & Brand, 2012). Based on these findings, it is possible that stressful life events such as financial and professional problems, or calamity experiences such as environmental catastrophes and public health emergencies alter the subjects' decision-making pattern.

The COVID-19 pandemic is an example of a public health event with affective and mood impacts (Bera et al., 2022; Burrai et al., 2022; Canet-juric et al., 2020), being related to perceived of stress (Aslan & Pekince, 2020; Brown et al., 2020; Lakhan et al., 2020), anxiety (Lakhan et al., 2020; Liu & Chen, 2021; Pashazadeh et al., 2021), depression (Bueno-notivol et al., 2021; Lakhan et al., 2020; Liu & Chen, 2021), and post-traumatic stress disorder (Machado et al., 2022; Portugal, et al., 2022; Janiri et al., 2021). These mental health impacts of COVID-19 have also been found in the Brazilian population, in different demographic groups such as healthcare workers (Machado et al., 2022; Portugal et al., 2022) and adolescents (Carvalho et al., 2022), but also in the general population (Ferraz et al., 2021; Passos et al., 2020).

Some studies investigating the relationship between COVID-19 and decision-making have also been conducted. One study showed that young male adults, with higher rates of perceived stress and that self-reported more vulnerable immune system, made more advantageous and less risky choices in the Iowa Gambling Task (a decision-making task under ambiguity) than young male adults with lower perceived stress and less vulnerable immune system self-reported (Tarantino et al., 2021). The opposite pattern, more disadvantageous and risky decisions, was identified in older male adults with the same characteristics (Tarantino et al., 2021). In other study, Egeli et al. (2021), found differences in the Iowa Gambling Task between COVID-19 recovered participants and controls, where the COVID-19 recovered group showed more risky and disadvantageous decisions than controls. Regarding intertemporal decision-making, some studies have focused on the relationship between delay discounting and behaviors such as physical/social distancing (DeAngelis et al., 2022; Lloyd et al., 2021), and stockpiling (DeAngelis et al., 2022). To the best of our knowledge, no study has specifically focused on decision-making tasks under risk.

The present study aims to explore how variables related to COVID-19 are associated to intertemporal, risky, and ambiguous decision-making. Unlike studies that aimed to identify how intertemporal decision-making predicted behaviors during the pandemic (DeAngelis et al., 2022; Lloyd et al., 2021), this study aims to identify how decision-making behaves under influence of COVID-19 variables. Given the impact of emotional and affective factors on decision-making, and with the pandemic being a global stressor, our hypothesis is that some variables related to this health calamity will influence individuals' decision-making patterns.

2. Methods

2.1. Participants

Participants were recruited by social media (i.e., Facebook, Instagram, and WhatsApp), e-mail and invited directly by the authors or other participants. The eligibility criteria were living in Brazil and being over 18 years of age. An initial sample of 465 participants, collected between December 2020 and October 2021, was included in the study. After excluding participants by previous mental health conditions (except anxiety and depression) and medications (excluding users of antipsychotics, sedatives, and other drugs with possible impact in cognition) a total of 438 participants (M = 29.09 years, SD = 7.80, 67.8% females) were included in the final sample. Outliers scores were excluded only in the respective deviant score and the subject was preserved for other analysis. Demographic data of sample was presented in Table 1.

INSERT TABLE 1 HERE

2.2. Instruments

Sociodemographic Questionnaire – Relevant sociodemographic information (e.g., gender, age, education, and family income) was collected by a brief questionnaire. To measure the exposure to the COVID-19 pandemic, information about if the person is a health worker or a general worker, how much on a scale of 1 to 5 the participant was concerned about the pandemic (1 = "not at all concerned" to 5 = "very concerned"), how much the participant was looking for news about COVID-19 (1 = "I don't follow the news to 5 = I see the news all the time"), work status (e.g., work in the home office, in personal work with regular or reduced schedule), if COVID-19 infected him or a family member, if the infection was ongoing and what was the degree of impact of COVID-19 on health (e.g., mild with treatment at home, severe with hospital admission, and severe with intensive care unit admission), was collected.

Monetary-Choice Questionnaire: 27-item version (MCQ-27) – The MCQ-27 consists of 27 fictitious binary monetary choices in which participants choose between a Smaller Immediate Reward (SIR) and a Late Delayed Reward (LDR). The monetary magnitudes and the timeframes for receiving the rewards vary across choice scenarios, which are grouped according to the size of the LDR (i.e., small, medium, and large) with 9 scenarios in each group. A larger k value indicates a greater tendency to discount the delayed reward, indicating impulsive behavior, while a smaller *k* value is associated with a greater tendency to wait for delayed rewards, indicating self-controlled behavior. The computerized version of the MCQ-27 was used in this study.

Game of Dice Task (GDT) – The GDT is a computerized task developed to assess decision-making under risky scenarios (Brand et al., 2005). In this task, participants are presented with the choice of selecting a number or a combination of numbers (options with two, three, or four dice) during 18 attempts. After each choice, a die is rolled, and the participant either wins a fictitious amount of money if they chose the drawn number or loses an amount of equal size if they do not. The GDT allows participants to make either riskier or safer choices with high-stakes ($1000 or $500) or low-stakes ($200 or $100), respectively. Participants are instructed to maximize their winnings and begin with a betting capital of $1000. To analyze the results of the GDT, the number of less risky choices (three and four numbers) is subtracted from the number of riskier choices (one and two numbers), forming a net-score.

Iowa Gambling Task (IGT) – The IGT is a computerized task developed by Bechara et al. (1994) to assess decision-making under ambiguous scenarios. In the IGT, participants are presented with four decks (A, B, C, and D) and are instructed to draw cards from them during 100 trials. After each draw, they can either win or lose money. The participants are required to maximize their gains and start the task with $2000 of betting capital. Two decks (C and D) are advantageous, while the other two (A and B) are disadvantageous over time. During the IGT, it is expected that individuals initially explore the decks in a close-random pattern and gradually learn to choose more cards from the advantageous decks, which can be implicit or explicit by the end of the task; Turnbull et al., 2014). To analyze the results of the IGT, a net-score can be calculated by subtracting the disadvantageous decks from the advantageous decks ((C + D) - (A + B)).

2.3. Procedures

The study used a total of four instruments, including a sociodemographic questionnaire with COVID-19 questions and three different decision-making tasks (i.e., risk, ambiguity, and intertemporal). Participants completed the sociodemographic questionnaire first and then the decision-making tasks in a randomized order to avoid biases and fatigue effects. There were no significant differences found between the order of application for these tasks (Greenhouse-Geisser, F (3, 465) = 2.848, $p < 0.059$, $\eta^2 = .006$). The procedure was administered online using the *Gorilla Experiment Builder* (Anwyl-Irvine et al., 2020).

2.4. Data analysis

For this study the sociodemographic and COVID-19 variables was used to create comparison groups. To form groups based on age, education, high and low worry about COVID-19 and news consumption about COVID-19, cutoff by median was used. Net-score were calculated to the IGT and GDT. To calculate output from MCQ-27 the log-natural of discounting rate (*ln k*) was used. To compare the decision-making variables by groups of demographic and COVID-19 characteristics, ANOVAs and t-test were used. The effect size was calculated using Cohen's d for t-tests and partial eta-squared for ANOVAs. The data analysis was performed using SPSS version 26 (SPSS Inc., Chicago, IL). The reduction of the MCQ-27 results to a *ln k* parameter was conducted with the help of the spreadsheet presented by Kaplan et al. (2016).

2.5. Ethical Issues

This study was approved by the Brazilian Ethical Committee (Plataforma Brasil, CAAE: 34702620.3.0000.8066). Prior to data collection, all participants agreed to and signed a consent form. No participant was given any monetary incentive to take part in the study.

3. Results

3.1. COVID-19 data

In relation of COVID-19 variables, most of the sample was from the general population, although a significant portion of it consisted of healthcare professionals (n = 149; 34.0%). During the data collection period, most participants were in home office (n = 172; 39.4%), but a significant number of people were working in-person on a regular schedule (n = 102; 23.3%), followed by those working in-person on a reduced schedule (n = 73; 16.7%). One-fifth of the sample was either in social isolation and not working (n = 50; 11.4%) or unemployed (n = 41; 9.4%). A total of 245 participants (55.9%) reported regularly exercising during the pandemic, with an average of 2.17 (SD = 2.25) days per week. In terms of worry about COVID-19, the sample scored 4.04 (SD = 0.91) on a scale of 1 to 5. For news consumption related to COVID-19, the score was 2.94 (SD = 1.11).

Regarding COVID-19 infection, 113 participants in the sample (25.8%) reported having had the disease, and of these, 110 (97.4%) had recovered, while 3 (2.7%) were suspected cases. No participant reported having COVID-19 during the survey. As for the severity of the disease, 80 subjects (70.8%) reported experiencing mild symptoms, and 33 (29.2%) reported moderate symptoms, both with treatment at home. Regarding a family member having had COVID-19, 271 participants (61.9%) reported that at least one family member had the disease, and of these, 248 (91.5%) reported that the family member had recovered, while 20 (7.4%) said the family member had the disease, and 3 (1.1%) were suspected cases. As for the severity of symptoms, 122 (45%) of participants reported that the most severe case in their family had mild symptoms and received treatment at home, 77 (28.4%) subjects reported moderate symptoms with treatment at home, 19 (7%) reported severe symptoms with hospitalization, 27 (10%) said that the family member had severe symptoms with intensive care hospitalization, and 26 (9.6%) reported that the family member had died.

3.2. Relation between COVID-19 and decision-making

Decision-making score, standard deviation, and range for all sample can be seen in Table 2. Regarding the influence of COVID-19 variables on decision-making, there were no differences in the delay discounting rate of the MCQ-27 among groups: healthcare workers (*t* (436) = -.14, *p* = .888, *d* = .10), work modality (*F* (4, 438) = .96, *p* = .430, η_p^2 = .009), whether they had COVID-19 or not (*t* (436) = 1.26, *p* = .209, *d* = .14), current COVID-19 infection status (i.e., not had, suspected or recovered from COVID-19; (*F* (2, 438) = .62, *p* = .54; η_p^2 = .003), symptom severity (*t* (113) = .17, *p* = .868, *d* = .03), whether a family member had COVID-19 (*t* (436) = .85, *p* = .399, *d* = .08), current COVID-19 infection status of the family member (*F* (3, 438) = .34, *p* = .798, η_p^2 = .002) and severity of the family member's COVID-19 infection (*F* (5, 438) = .54, *p* = .746, η_p^2 = .006). There were also no differences in groups based on level of worry (*t* (436) = -.81, *p* = .420, *d* = .08), consumption of COVID-19 news (*t* (436) = .20, *p* = .841, *d* = .02), and whether they exercised during the pandemic (*t* (436) = -1.35, *p* = .177, *d* = .13).

INSERT TABLE 2 HERE

Regarding the influence of COVID-19 variables on decision-making, there were no differences in the net-score of the IGT between groups: healthcare workers (*t* (436) = .65, *p* = .517, *d* = .07), work modality (*F* (4, 438) = 1.24, *p* = .294, η_p^2 = .011), whether they had COVID-19 or not (*t* (436) = .04, *p* = .965, *d* = .01), current COVID-19 infection status (*F* (2, 438) = .10, *p* = .905, η_p^2 = .000), symptom severity (*t* (113) = .443, *p* = .66, *d* = .09), whether a family member had COVID-19 (*t* (436) = -.15, *p* = .880, *d* = .00), current COVID-19 infection status of the family member (*F* (3, 438) = .19, *p* = .904, η_p^2 = .001) and severity of the family member's COVID-19 infection (*F* (5, 438) = .43, *p* = .829, η_p^2 = .005). There were also no differences in groups based on level of worry (*t* (436) = .1.25, *p* = .212, *d* =

.12), consumption of COVID-19 news (*t* (436) = 1.32, *p* = .187, *d* = .14), and whether they exercised during the pandemic (*t* (436) = .44, *p* = .662, *d* = .04).

Regarding the influence of COVID-19 variables on decision-making, there were no differences in the net-score of the GDT between groups: healthcare workers (*t* (436) = -1.18, *p* = .237, *d* = .12), work modality (*F* (4, 438) = 1.19, *p* = .313; η_p^2 = .011), whether they had COVID-19 or not (*t* (436) = .40, *p* = .686, *d* = .04), current COVID-19 infection status (*F* (2, 438) = 1.37, *p* = .256, η_p^2 = .006), whether a family member had COVID-19 (*t* (436) = .78, *p* = .435, *d* = .05), current COVID-19 infection status of the family member (*F* (3, 438) = .61, *p* = .612, η_p^2 = .004). Groups based on level of worry (*t* (436) = .45, *p* = .653, *d* = .04), consumption of COVID-19 news (*t* (436) = .08, *p* = .934, *d* = .01), and whether they exercised during the pandemic (*t* (436) = .74, *p* = .459, *d* = .07) also did not show differences.

Only the groups separated by severity of the participant's symptoms GDT (*t* (113) = 2.93, *p* = .004; *d* = .610), and severity of the family member's COVID-19 infection (*F* (4, 271) = 2.84, *p* = .025, η_p^2 = .041) showed significant differences, the first have a moderate effect size and the last a small effect size. The analysis showed that participants with mild symptoms of COVID-19 obtained a better score in the GDT than those with moderate symptoms. Regarding the severity of COVID-19 in the family member, the Bonferroni post-hoc showed that family members with moderate symptoms and home treatment obtained worse scores in the GDT than participants with family members in critical condition and hospitalized in a common ward (*p* = .026). Figure 1 presents the difference between GDT scores by severity of the participant's symptoms and Figure 2 presents the difference by severity of the family member's COVID-19 infection.

INSERT FIGURE 1 HERE

INSERT FIGURE 2 HERE

4. Discussion

The present study aimed to investigate the relationships between COVID-19-related variables and decision-making in intertemporal, risk, and ambiguity contexts. To the best of our knowledge, this is the first study focused on the impacts of pandemic-related variables on individuals' decision-making patterns. Our results did not show relationships between most of the COVID-19 variables and decision-making. The GDT was the only decision-making task related to COVID-19 variables. The variables related to the severity of COVID-19 symptoms experienced by the participants and the severity of COVID-19 symptoms occurring in family members were differently associated with the GDT. Individuals who had mild COVID-19 symptoms chose more advantageous and less risky options than those who had moderate symptoms. Regarding the severity of COVID-19 symptoms in family members, participants who had relatives with moderate symptoms being treated at home had riskier and less advantageous decisions than those who had relatives hospitalized in general ward.

A plausible explanation for individuals who self-reported moderate COVID-19 symptoms showing poorer performance in the GDT lies in the association presented by other studies between COVID-19 and cognitive deficits after infection (Ceban et al., 2022; Crivelli et al., 2022; Zhou et al., 2020). It is possible that greater symptom severity was related to greater cognitive deficits, including decision-making deficits. As mentioned earlier, Egeli et al. (2021) found more risky choices in the IGT in COVID-19-recovered than in controls group. Although the IGT is a task of decision-making under ambiguity and the GDT a task under risk, both share the fact of being built under scenarios of uncertainty (Brand et al., 2008). Despite these convergences, the IGT was not related to COVID-19 symptom severity in this study, and no differences in decision-making between groups stratified into participants who had or did not have COVID-19 was found. Further studies exploring decision-making deficits in individuals who had COVID-19 are necessary to solve these questions.

Regarding the relationship between greater COVID-19 severity in a family member and less risky choices in GDT, this may be due to increased risk perception. As presented by Tarantino et al. (2021), higher perceived stress and self-reported vulnerable immune system in young male adults were related to less risky decisions in IGT. A hypothesis for our finding is based on a similar idea: it is possible that having family members with more severe symptoms increases a subject's fear and perceived stress, as well as their risk perception, causing the subject to have a greater aversion to risk and choose safer and conservative responses. However, although this hypothesis was supported by studies that show the relationship between fear, (Lee & Andrade, 2015; Lemer, 2001), anxiety (Mueller et al., 2010) and risk aversion, caution is needed with these results. In this study, only two groups stratified by the severity of family members' symptoms showed significant difference, with a small effect size. It is possible that the small sample size may have influenced the results. Studies with a larger sample size are needed to better understand these relationships.

Despite these positive results between two COVID-19 variables and GDT, most COVID-19 variables did not show relationships with decision-making, particularly with intertemporal and ambiguous decision-making. Studies linking COVID-19 variables to intertemporal decision-making available in the literature have found relationships between participants' delay discounting rates and their tendency towards safety behaviors (DeAngelis et al., 2022; Lloyd et al., 2021); and this may be the most likely causal direction this relation. For decision-making under ambiguity, maybe the COVID-19 variables collected for this study were not ideal for capturing a possible relationship between them. Good performance in decision-making under ambiguity has been associated with emotional processing (Bechara et al., 1994, 2005; Chiu et al., 2018), and perhaps the variables used were not able to capture potential affective triggers of the pandemic. However, studies exploring the influence of other COVID-19 variables on decision-making are recommended.

The present study has some important limitations. The entire data collection process was conducted online, making it impossible to ensure standardized and controlled conditions for task execution. However, due to the limitations imposed by the pandemic, in-person and controlled data collection was not possible. The sample size is another factor that may have limited the findings, especially in variables where there were groups with small representation (e.g., participants suspected of COVID-19 in the COVID-19 status variable). However, despite the modest number of participants, the effect sizes do not suggest significant effects with increasing sample size. The COVID-19 questionnaire used had only general questions, lacking questions about the subject's behaviors during the pandemic (e.g., social activities and compliance with protective measures), or the family environment (e.g., living alone or with family members, size of residence, and whether someone at home is in a risk group), for example, which may have reduced the number of possible links between the pandemic and decision-making. Lastly, our sample was predominantly composed of young adult females with a high level of education and from richer regions of Brazil, which limits the generalization of the results. Future studies, with more representative samples, in other calamity situations, are needed to better understand their impact on decision-making.

Despite its limitations, this study has important merits, such as investigating decision-making not as a predictor of behaviors during the pandemic, but as a cognitive skill that may have been influenced by it. The use of tasks that assess three distinct decision-making scenarios is also a positive aspect of this study. Since intertemporal risk and ambiguity scenarios function as distinct modulators of decision-making (see Levy et al., 2010; Rangel et al., 2008), using tests from more than one category of decision-making may allow for a greater understanding of their similarities and differences in various contexts. Finally, this study was conducted in Brazil, and to the best of our knowledge, no studies relating COVID-19 and decision-making have been conducted in this territory. Studying how the various variables related to COVID-19 have affected cognitive and mental health aspects in developing countries is important not only for a better understanding of the pandemic's impacts in these locations, but also to understand relevant sociocultural and economic differences.

5. Conclusion

This study aimed to investigate the impact of COVID-19-related variables on intertemporal, risk, and ambiguity decision-making. The results showed that COVID-19 variables did not relate to intertemporal and ambiguity, but only for the risk decision-making task. Further studies with larger and diverse samples are needed to confirm and better understand these relationships. This kind of study is important to understand the cognitive impact of COVID-19 and highlights the relevance of tracking possible changes in individuals' decision-making due to the pandemic.

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Table 1. Demographic data

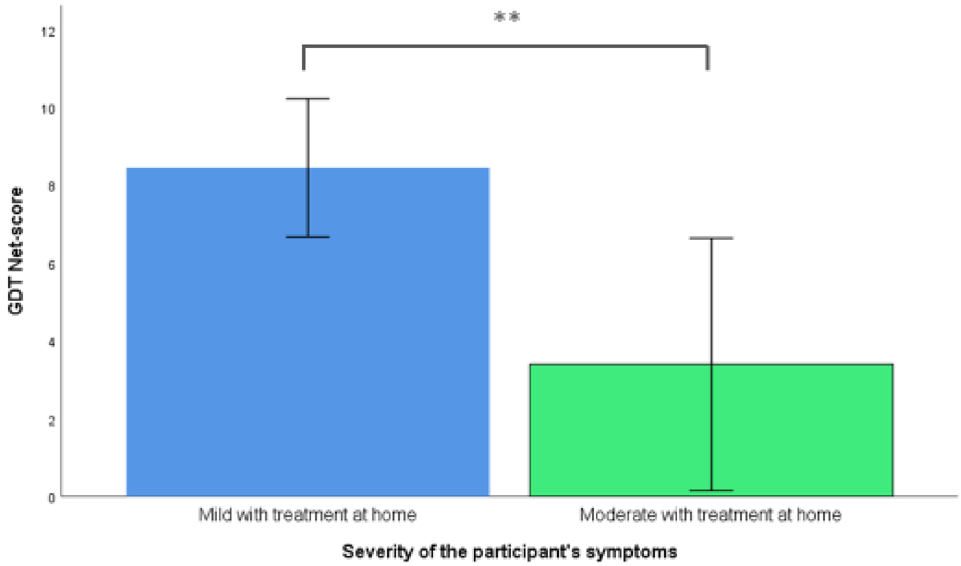
Category		Mean/ N (SD/%)
Age		29.09 (7.80)
Sex		
	Male	141 (32.2%)
	Female	297 (67.8%)
Education (years)		16.79 (3.05)
Maritage status		
	Single	317 (72.4%)
	Maritage	87 (19.9%)
	Divorced	18 (4.1%)
	Others	16 (3.7%)
Family income		
	Less than R$ 2090	50 (11.4%)
	Between R$ 2090 and R$ 4180	137 (31.3%)
	Between R$ 4180 and R$ 10450	145 (33.1%)
	Between R$ 10450 and R$ 20900	64 (14.6%)
	Higher than R$ 20900	42 (9,6%)
Country region		
	South	24 (5.5%)
	Southeast	360 (82.2%)
	Midwest	15 (3.4%)
	North	2 (0.5%)
	Northeast	37 (8.4%)
Mental disorder		
	No	352 (80.4%)
	Yes	86 (19.6%)

Table 2. Decision-making results for all sample.

Variable	Mean	SD	Range
MCQ-27 (Overall *ln k*)	-4.33	1.54	(-8.75) – (-1.39)
IGT (Net-score)	-4.41	33.93	(-.88) – (100)
GDT (Net-score)	7.21	9.00	(-18) – (18)

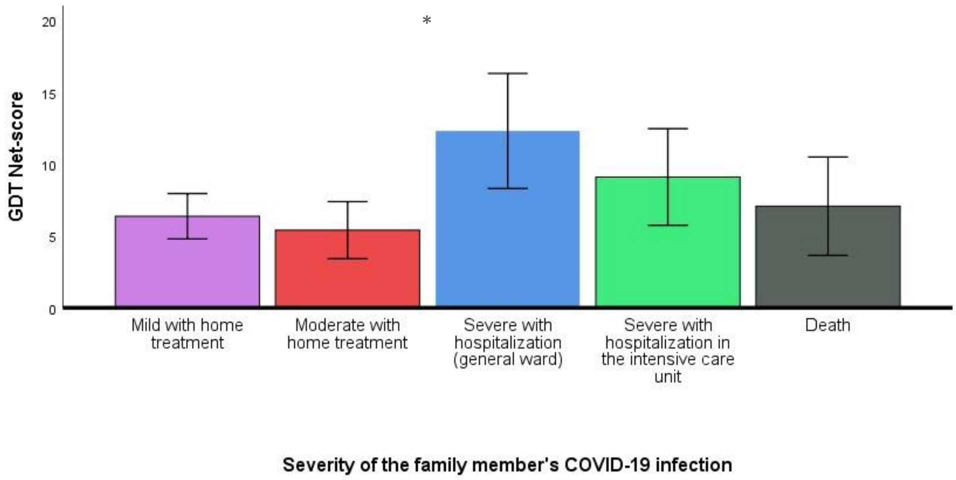
MCQ-27 - Monetary-Choice Questionnaire - 27 Items; IGT - Iowa Gambling Task; GDT - Game of Dice Task

Figure 3. GDT net-score by severity of participant's COVID-19 symptoms.



** < .01; GDT - Game of Dice Task.

Figure 2. Participant's GDT net-score by severity of family member's COVID-19 infection.



* < .05; GDT - Game of Dice Task.

IV. GENERAL DISCUSSION

The main objective of this thesis was explore the relationship between alexithymia and COVID-19-related variables in the decision-making process. To accomplish this, in the article 1, we focused on a brief history of neuroeconomics, presenting some of its main topics, possible applications, and points for future development. The article 2 presented a more technical issue, but important for research in developing countries: the adaptation of measures. In this case an intertemporal decision-making measure was adapted to Brazilian context, and some of its proprieties was studied. The article 3 aimed to understand how traits of alexithymia are related to intertemporal, risky, and ambiguous decision-making. Finally, the fourth study focused on understanding how an incidental context of high emotional impact, the COVID-19 pandemic, influences people's decision-making in risky, ambiguous, and intertemporal contexts.

Article 1 provides a general overview of the development of neuroeconomics and much of its content focused on discussing modulating variables of decision-making, such as time and probabilities related to outcomes. The three empirical articles that followed focused on these variables, studying them in different contexts. Article 2 aimed to evaluate the effects of currency conversion on the MCQ-27, an intertemporal decision-making task that was adapted to the Brazilian context for this research. A significant part of the neuroeconomics literature (e.g., Bakos et al., 2010; Chen et al., 2020; Kim et al., 2012) has been devoted to studying cultural differences in decision-making. These comparisons have great importance for the development of the discipline, as they allow us to know how general or dependent on sociocultural contexts a variable is. A clear point in the decision-making literature is the lack of studies in Latin American samples, especially Brazilian ones. Based on this, we can say that decision-making studies in developing countries can be added to the new challenges and future perspectives presented in article 1. Therefore, article 2 is important to help fill this gap.

The article 2 played a crucial role for the realization of articles 3 and 4. The MCQ-27 is one of the most well-known instruments for assessing delay discounting (Kaplan et al., 2016), however, we not found any articles using this measure in Brazil. Given that the original instrument was created in dollar and the values between the dollar and the Brazilian real are quite disparate, a study was necessary to identify possible effects of currency conversion. The magnitude effect (Kirby & Maraković, 1996) shows that the delay discounting rate tends to be higher for smaller rewards than for larger rewards, which could influence the discounting rate of the converted MCQ-27, since all values would be multiplied by the exchange rate (i.e., 5.65 times greater). The results of this study showed no differences between the version converted by the exchange rate and the one that maintained a value in Brazilian real equal to the dollar (1 to 1). These results brought up questions about the magnitude effect, as presented in article 2. In general, these results show the irrelevance of currency conversion for the task, providing a basis for new studies with the measure in Brazilian territory.

As we have seen in article 1, decision-making is a cognitive activity closely related to emotional processing. The somatic marker hypothesis (Bechara et al., 2005; Bechara et al., 1994; Poppa & Bechara, 2018) and the dual system theory (Mcclure & Bickel, 2014; Mcclure & Cohen, 2004), for instance, demonstrate the relationship between affective processes and decision-making under ambiguity and intertemporal conditions, respectively. Consistent with this literature, article 3, which aimed to investigate the relationship between alexithymia and decision-making, found deficits in decision-making in participants with higher alexithymia scores. The interesting point of this work was to identify those difficulties in analyzing emotions, rather than difficulties in identifying or expressing emotions, were related to decision-making problems. In other words, not recognizing emotional markers as important was more relevant for decision-making than difficulties in identifying and expressing emotions.

Article 4 focused on studying the influence of the COVID-19 pandemic on individuals' decision-making. Given that the pandemic is a stressful event with effects on mental health (e.g., Bueno-notivol et al., 2021; Pashazadeh et al., 2021), mood (e.g., Terry et al., 2020), and emotional processing (Mariani et al., 2021), changes in individuals' decision-making patterns was a plausible hypothesis. The results showed more disadvantageous decision-making in the context of risk in participants who had moderate COVID-19 symptoms compared to those who had mild symptoms. The opposite pattern was found regarding the severity of COVID-19 symptoms in family members, with the risky decision-making pattern being more advantageous in participants who had family members with severe symptoms and hospitalization in a common ward than in participants who had family members with moderate symptoms treated at home. It is possible that having family members in a severe state generates a greater perception of risk for COVID-19, and perhaps this contextual alteration generalizes to other decision-making processes, making the participant more risk averse overall.

Unlike the results of article 3, which found relationships between alexithymia and intertemporal and ambiguous decision-making, article 4 found relationships between COVID-19 pandemic variables and decision-making under risk. These findings demonstrate a different decision-making pattern for external stressors such as the COVID-19 pandemic and emotional processing deficits, as in the case of alexithymia. A plausible explanation is that for ambiguous decisions (unlike those under risk, which have explicit probabilities), somatic markers linked to emotional processing become responsible for guiding the individual during the task (Bechara et al., 2005; Bechara et al., 1997). Regarding intertemporal decision-making, it is plausible that individuals with high traits of alexithymia experience affective markers linked to short-term rewards. However, due to their deficit in the ability to analyze the nature of emotional triggers (related with the analyzing factor of the BVAQ; Vorst & Bermond, 2001), it is possible that they are driven by these markers without realizing it. Regarding decision-making under risk, it is likely that it is not affected by alexithymia because it has explicit probabilities, allowing the participant to act advantageously using only cognition. On the other hand, incidental factors such as the severity of COVID-19 symptoms in a family member may alter the perception of explicit information, emphasizing risk.

The three studies share some limitations that are worth highlighting. Firstly, they have small sample size, which may limit the generalizability of the results. Secondly, the studies relied on self-reported measures (i.e., sociodemographic questionnaire, COVID-19, and alexithymia variables), which may be subject to response biases or social desirability biases. Third, the sample used in all empirical studies was predominantly composed of women from the Southeast region of Brazil with high income and high education, which limits the external validity of the findings, particularly in terms of cross-cultural generalizability. Finally, due to the COVID-19 pandemic, the study had to be conducted online, making it impossible to adopt standardized conditions for task execution, which may have introduced variability in the results. Despite these limitations, the studies provide valuable insights into decision-making processes under different contexts and conditions, highlighting the importance of investigating sociodemographic, emotional, and contextual factors that may influence decision-making. Future studies should aim to address these limitations and build on the findings of these studies to further our understanding of decision-making processes.

V. CONCLUSION

This work aimed to explore the relationship between alexithymia and COVID-19-related variables in the decision-making process. To achieve this goal, four works were presented in the present thesis. The first article provided an overview of the field of neuroeconomics and its contributions for understanding decision-making. The second article investigated the effect of currency conversion on delay discounting rates, highlighting the irrelevance of currency conversion in this context. The third article explored the relationships between alexithymia and decision-making in intertemporal, risky, and ambiguous contexts, identifying deficits in intertemporal and ambiguity decision-making in individuals with greater alexithymia. Finally, the fourth article investigated the influence of the COVID-19 pandemic on intertemporal, risk, and ambiguity decision-making, highlighting the impact of COVID-19 on decision-making under risk. Overall, the articles underscore the importance of considering contextual, emotional and stressful variables in decision-making and highlight the need for continued research on the effects of the pandemic on individuals' decision-making processes.

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VI. ATTACHMENTS

Attachment A: Term of Free and Informed Consent

Título do projeto: "Tomada de decisão e processamento emocional durante uma pandemia".

Pesquisadores responsáveis pelo projeto: Daniel C. Mograbi e Wayson Maturana de Souza.

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Você está sendo convidado(a) a participar de um projeto de pesquisa online que pretende investigar a relação entre a pandemia de COVID-19, o processamento emocional e a tomada de decisão das pessoas, ou seja, como elas escolhem frente duas ou mais opções de resposta. A sua participação nesta pesquisa é **VOLUNTÁRIA.**

Caso você concorde em participar deste estudo, você responderá a um questionário sociodemográfico (com perguntas sobre como você está lidando com a COVID-19), uma escala de ansiedade e depressão, uma escala de alexitimia que significa a incapacidade ou dificuldade de verbalizar, reconhecer e/ou expressar sentimentos), uma escala de interocepção que é a capacidade de identificar sinais corporais relacionados a emoção e três tarefas de tomada de decisão (temporal, de risco e de incerteza). As atividades duram em média uma hora, podendo este tempo ser menor ou maior de acordo com seu ritmo de resposta.

Como o presente estudo envolve apenas o preenchimento de questionário, de escalas e o desempenho em tarefas semelhantes a jogos, você não correrá qualquer risco como consequência de sua participação nesta pesquisa. Os procedimentos escolhidos já foram utilizados em outros estudos sem qualquer efeito adverso, exceto possível desconforto leve com alguma pergunta do questionário ou das escalas. Caso você apresente qualquer tipo de desconforto a sua participação poderá ser interrompida a qualquer momento sem prejuízo a você. O projeto não oferece quaisquer custos ou benefícios financeiros. Os ganhos e perdas das tarefas de aposta contidas no teste são apenas de caráter fictício.

Embora o possível desconforto gerado pela pesquisa tenda a ser leve, nossos contatos (e-mail e telefone) estão disponíveis no ínicio deste documento para que você entre em contato conosco caso considere importante. Nossa equipe é composta de psicólogos que oferecerão esclarecimento do conteúdo e dos procedimentos da pesquisa, dando suporte a questões de ordem emocional referentes a esta, caso você precise. De antemão, sugerimos que não autoavalie de forma crítica suas respostas no questionário, nas escalas e nas tarefas desta pesquisa. Este trabalho foi estruturado para estudar questões pontuais a respeito da relação entre o processamento emocional, a tomada de decisão e sintomas de ansiedade e depressão. Não existem respostas certas ou erradas e estes porcedimentos não tem o intuito nem a capacidade de avaliar seu desempenho individualmente.

A sua participação no estudo não trará qualquer benefício individual e imediato a você, porém proporcionará um melhor conhecimento das relações entre a COVID-19, a saúde mental, o processamento emocional e a tomada de decisão. Você terá garantia de acesso aos profissionais responsáveis pela pesquisa, em qualquer momento, para esclarecimento de dúvidas acerca de procedimentos, riscos e benefícios da pesquisa. O conhecimento dos resultados será opção sua. Caso tenha interesse é só adicionar **seu e-mail** no local indicado ou entrar em contato com os pesquisadores responsáveis através dos contatos acima.

Todas as informações coletadas neste estudo serão divulgadas de forma anônima, sem permitir sua identificação. Os dados obtidos serão analisados em conjunto com as informações dos outros voluntários, ou seja, você terá a sua privacidade garantida.

□ Li e concordo com os termos de consentimento livre e esclarecido.
E-mail: ____

Agradecemos sua participação e estamos à disposição para suporte e esclarecimentos de quaisquer dúvidas sobre a pesquisa.

Attachment B: Sociodemographic Questionnaire

Dados Sociodemográficos

Cidade em que reside:.......................... Estado: ....

Idade: ….... Sexo: feminino □ masculino □ Data de Nascimento: ..…../……../……

Trabalha na área da saúde: sim □ não □

Estado civil: solteiro(a) □ casado(a) □ divorciado(a) □ viúvo(a) □ outro: ....

Grau de escolaridade (em anos de estudo): …………………………………………...

Renda Familiar (em reais): ....

Você faz uso continuado de medicamentos, entorpecentes e/ou outras drogas?

sim □ não □ Se sim, qual? ....

Você tem ou teve alguma patologia neurológica ou psiquiátrica diagnosticada por um médico?

sim □ não □ Qual? Está em tratamento?..

Perguntas sobre COVID-19

1) Em uma escala de 1 a 5 (1 = “nada preocupado” e 5 = “muito preocupado”) o quanto você está preocupado(a) com a pandemia? ....

2) Em uma escala de 1 a 5 (1 = “não acompanho” e 5 = “o tempo todo”) você procura por notícias sobre COVID-19? ....

3) Você está: □ Em isolamento social, sem trabalhar
□ Em isolamento social, trabalhando de casa (*home office*)
□ Trabalhando presencialmente em turno reduzido
□ Trabalhando presencialmente em tempo integral
□ Desempregado(a)

4) Têm praticado algum exercício durante o isolamento social? sim □ não □
Quantas vezes por semana? .... Qual exercício? ....

5) Você tem/teve COVID-19? sim □ não □
Se sim: está com COVID-19 □ teve COVID-19 □ está sob suspeita □
Qual é/foi seu grau de debilidade mais grave:

□ Leve, com tratamento em casa
□ Moderado com tratamento em casa
□ Grave, com internação (leito comum)
□ Grave com internação em unidade de terapia intensiva (na UTI)

6) Algum familiar próximo tem/teve COVID-19? (se teve mais de um caso, marque o referente ao caso mais grave):
sim □ não □
Se sim, esta pessoa: está com COVID-19 □ teve COVID-19 □ está sob suspeita □
Quantas pessoas? ....
Quem? (ex: pai, mãe, irmãos etc.) ....
Qual é/foi o grau de debilidade dessa pessoa? (se teve mais de um caso, marque o referente ao caso mais grave):

□ Leve, com tratamento em casa
□ Moderado com tratamento em casa
□ Grave, com internação (leito comum)
□ Grave com internação em unidade de terapia intensiva (na UTI)
□ Óbito

Attachment C: Brazillian Version of Bermond – Vorst Alexithymia Questionnaire (BVAQ-BR)

A seguir, você encontrará uma lista de afirmações sobre como você geralmente reage no dia a dia. Em cada afirmação, há uma escala de 5 pontos que varia de "concordo totalmente" a "discordo totalmente". O objetivo é que você indique na escala em que medida sua maneira pessoal de reagir corresponde à afirmação.

Um exemplo.
"Ver gatinhos desperta sentimentos de ternura"
Concordo totalmente | _ | _ | _ | _ | _ | Discordo totalmente

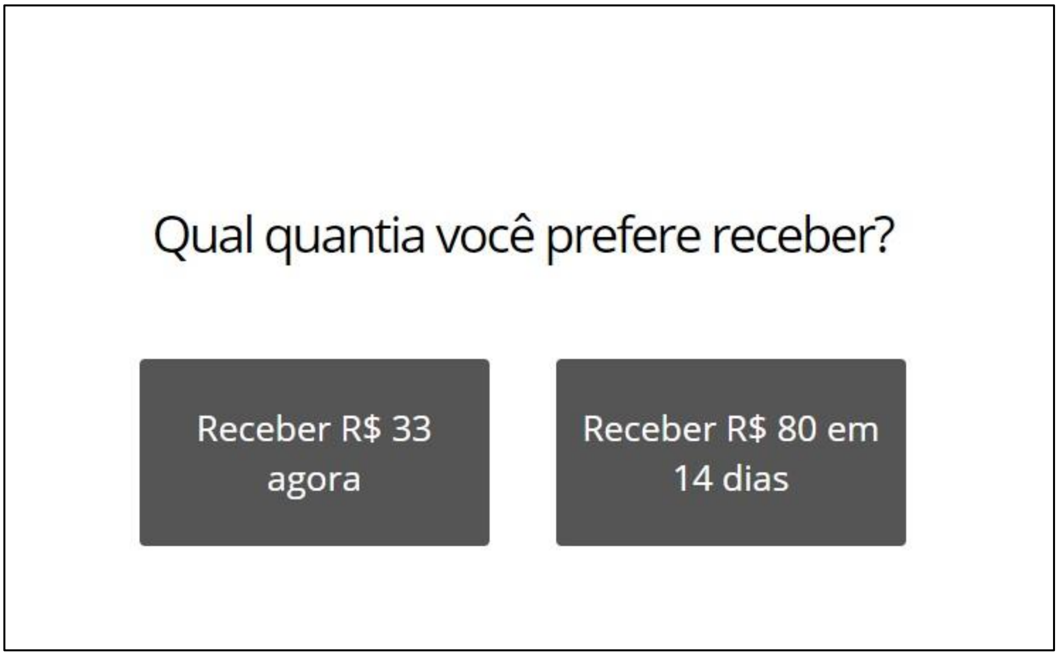
Se você acha que essa afirmação corresponde totalmente à maneira como você reage, marque uma opção mais à esquerda. Se você acha que essa afirmação não corresponde à maneira como você reage, marque uma opção mais à direita. Se você acha que a maneira pela qual você reage é menos clara do que o descrito acima, marque uma opção um pouco mais ao meio. Apenas marque a opção do meio quando for impossível dar uma resposta para a afirmação. Agora você pode começar a preencher o questionário.

Itens	**5**	**4**	**3**	**2**	**1**
1. Eu acho difícil expressar meus sentimentos verbalmente.					
2. Antes de cair no sono, eu imagino vários tipos de eventos, encontros e conversas.					
3. Quando estou abalado, eu sei se estou com medo, triste ou com raiva.					
4. Quando algo inesperado acontece, me mantenho calmo e inalterado.					
5. Eu quase nunca levo em consideração meus sentimentos.					
6. Eu gosto de contar para os outros como me sinto.					
7. Eu tenho poucos devaneios e fantasias.					
8. Quando estou tenso, não fica claro de que sentimentos meus isso vem.					
9. Quando vejo alguém chorando de maneira incontrolável, permaneço inalterado.					
10. Você deveria tentar entender sentimentos.					

Itens	5	4	3	2	1
11. Mesmo com um amigo, eu acho difícil falar sobre meus sentimentos.					
12. Eu uso minha imaginação com frequência.					
13. Quando as coisas ficam um tanto insuportáveis, eu geralmente entendo o porquê.					
14. Quando amigos em volta de mim discutem violentamente, eu fico impactado.					
15. Quando me sinto desconfortável, não vou me incomodar ainda mais me perguntando o porquê disso.					
16. Quando quero expressar o quanto infeliz eu me sinto, eu acho fácil achar as palavras certas					
17. Eu tenho pouco interesse em fantasias e histórias estranhas.					
18. Quando me sinto bem, não fica claro se estou alegre, ou entusiasmado, ou feliz.					
19. Frequentemente emoções crescem dentro de mim de forma inesperada.					
20. Quando me sinto desconfortável, tento descobrir por que me sinto assim.					
21. As pessoas frequentemente dizem que devo falar mais sobre meus sentimentos					
22. Eu quase nunca fantasio.					
23. Eu não sei o que se passa na minha mente.					
24. Mesmo quando os outros estão incrivelmente entusiasmados com alguma coisa, continuo inalterado.					
25. Não há muito o que entender no que se refere às emoções.					
26. Quando estou abalado com algo, eu falo com os outros sobre meus sentimentos.					
27. Eu gosto de inventar histórias incomuns imaginárias.					
28. Quando me sinto infeliz, sei se estou com medo, deprimido ou triste.					
29. Eventos inesperados frequentemente me tomam de emoção.					
30. Eu acho que você deve se manter em sintonia com seus sentimentos.					
31. Eu posso expressar meus sentimentos verbalmente.					
32. Eu acho que fantasiar sobre coisas ou eventos imaginários é uma perda de tempo.					

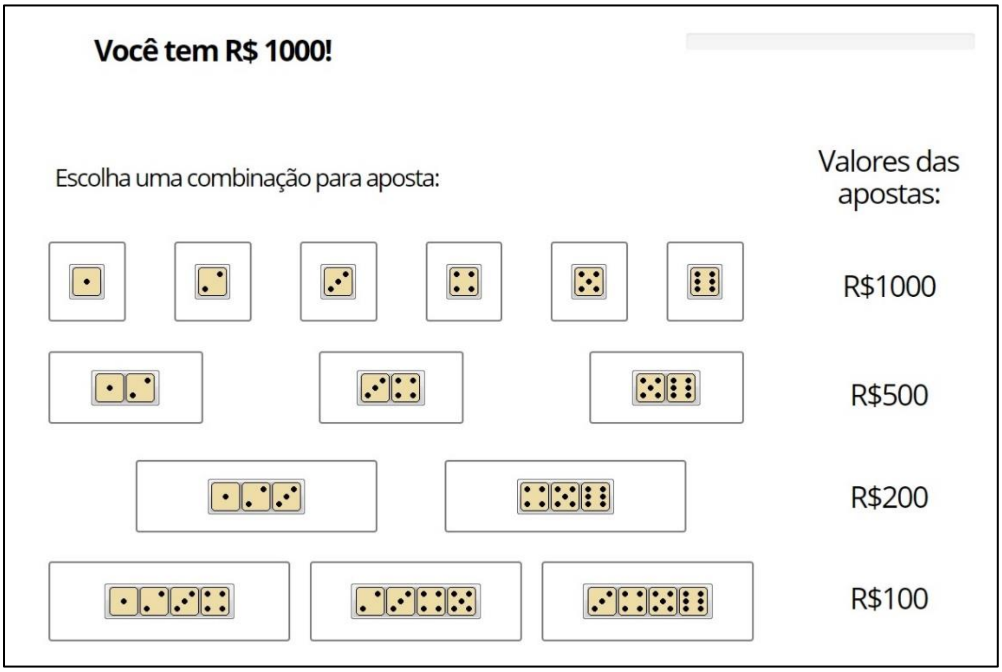
Itens	5	4	3	2	1
33. Quando sou duro comigo mesmo, não fica claro para mim se estou triste, com medo ou infeliz.					
34. Eu aceito desapontamentos sem emoção.					
35. Eu acho estranho que os outros analisem suas emoções com tanta frequência.					
36. Quando converso com as pessoas, prefiro falar sobre atividades diárias do que sobre minhas emoções.					
37. Quando não tenho muito o que fazer, eu devaneio.					
38. Quando estou de bom humor, sei se estou entusiasmado, alegre ou eufórico.					
39. Quando vejo alguém soluçando de tanto chorar, sinto uma tristeza crescer dentro de mim.					
40. Quando estou nervoso, quero saber exatamente de onde vem esse sentimento.					

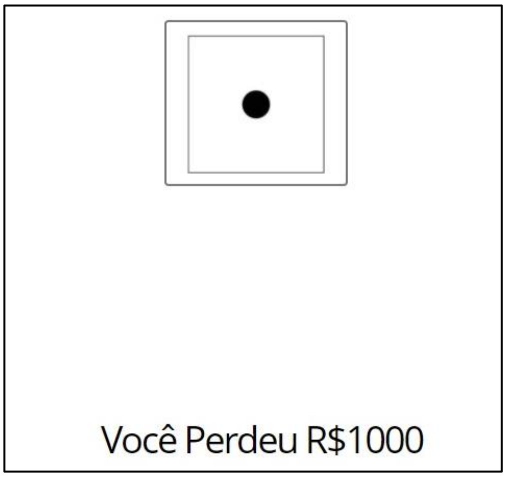
Attachment D: Computerized Version of Monetary Choice Questionnaire (MCQ-27)



Note: In this test, the participant is presented to questions about preference for fictional monetary gains in two different reward scenarios. In the left panel, the option of immediate gratification is presented, and in the right panel, the option of delayed gratification is presented. The individual must choose their preference regarding these two options of fictional gains. The procedure occurred during 27 rounds.

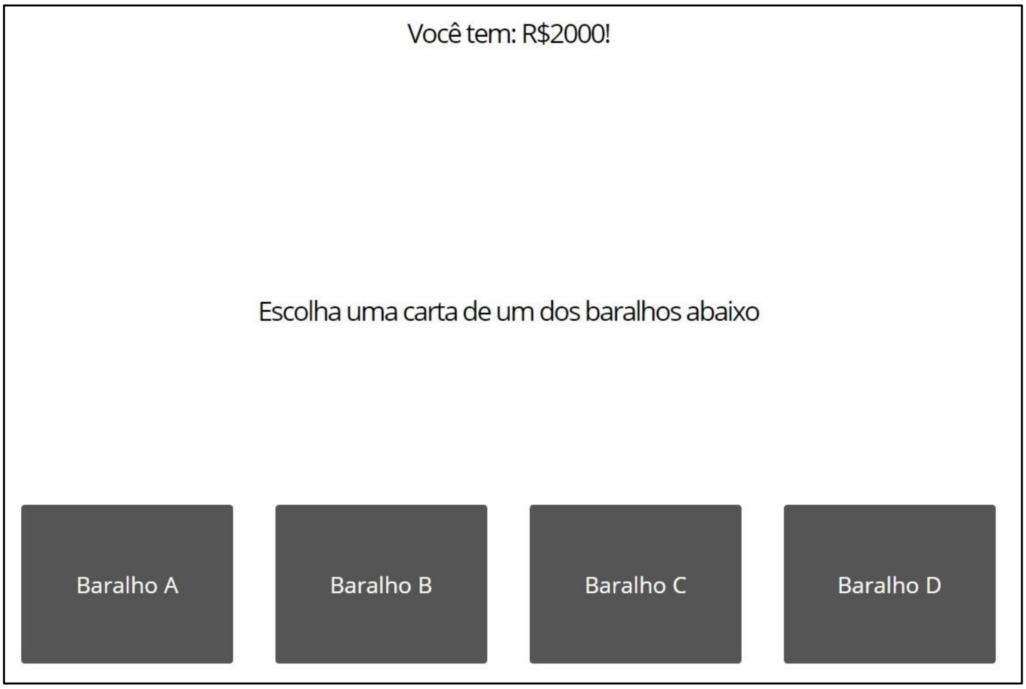
Attachment E: Game of Dice Task (GDT)





Note: The first screen presents the decision-making scenario of the task, where participants must bet on one of the 14 response options, which offer risky options (betting on one or two numbers) and conservative options (betting on three or four numbers). Each available option type has its own bet value (e.g., choosing three numbers is equivalent to betting R$ 200). The first line of text corresponds to the total amount of fictitious money that a participant has. The bar in the top right corner corresponds to the progress of the 18 rounds of the test. The second screen presents an example of outcome of a bet, in this case, a bet on one number with an unfavorable outcome (error and loss of R$ 1000).

Attachment F: Iowa Gambling Task (IGT)



Note: In the IGT, four decks of cards are presented to the participant, where they must choose one to draw a card from (first screen). After choosing one of the four decks (second screen), the participant can either win or lose a specific amount of fictitious money (in this example, win $100), which is added to or subtracted from a cumulative cash (described in the top of the first screen). The participant makes choices like this for 100 rounds.