Nijmegen School of Management
Department of Economics and Business Economics
Master's Thesis Economics (MAN-MTHEC)

Autism, the Perfect Homo Economicus?

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Nijmegen, 29 June, 2022

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Specialisation: Financial Economics
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Abstract

This thesis analyses the decision making of autistic individuals in decisions involving risk, ambiguity and societal contexts, using a sample with 28 autistic and 42 neurotypical individuals. This research differentiates itself from previous research by providing many first-ever insights and using more detailed measurements of risk aversion.

Risk aversion is measured using Prospect Theory in a non-linear regression analysis. The results indicate a more-linear utility function for the autistic individuals, no significant difference within the weighting domain, and a higher degree of loss aversion for the autism group. Furthermore, a negative interaction effect is found between IQ and the loss aversion parameter for autistic individuals. Considering ambiguity aversion - measured using Ellsberg's two-urn task - the findings indicate no significant difference between the autism and neurotypical groups in the gain domain. No significant difference can be found in the loss domain, but the evidence is not strong enough to support the alternative hypothesis of no difference. The Ultimatum and Dictator games are used to test risk in social situations. The findings reveal no significant difference for the Ultimatum game proposer's side, a significantly lower minimum acceptable offer for autistic individuals, and no significant difference with the Dictator game.

Keywords: autism, economic research, prospect theory, ambiguity aversion, Ellsberg's urn, decision under risk, Ultimatum game, Dictator game, behavioural economics, neuroeconomics.

Preface

In front of you is the 'final product' of my master's study, my master thesis about the economic decision-making of autistic individuals. This might seem a 'strange' topic for an economics master's paper. But actually, this topic does make perfect sense to me. Not only because I'm highly interested in autistic individuals, since I believe that we need to know much more about these people, who still have to cope with an inaccurate stereotype picture within today's society, leading to an improper understanding and a lack of good support. But also, because I believe that sciences should be much more integrated than they already are. Thus, I think a better understanding of the economic domain would tremendously help autism research within other sciences. Furthermore, when considering autism, quite a lot is already known about it from a psychological perspective, and also more and more from the neurological perspective. However, autistic people, just like others, also live in a society which is highly dependent on the economy. But it is barely known how autistic individuals differ from others when making economic decisions. It is known that they face more difficulty in the social domain, which might give them a disadvantage in a (future) job. However, maybe, autism also helps them when making economic decisions, or perhaps it causes other difficulties in the financial domain which are yet unknown. Thus, my research not only helps to understand the economic perspective of autism better, but the increase in understanding gained by this study also aids in understanding autism better across many scientific domains. In practice, this helps to comprehend how autistic people might function better in some jobs/tasks, and also to identify how autistic individuals might function in society, and what support they need to better integrate into today's society.

Furthermore, this research allowed me to perfectly combine my knowledge of economics with my urgent feeling for a needed change in today's lack of understanding about autism. And at the same time, it also allowed me to learn a lot more about autism, neurology, and the rising field of neuroeconomics. Moreover, I also consider my research as a valuable contribution in economic & autistic research and hopefully show the economic research community that much more research is needed for our entire population, including under-lighted groups such as autistic individuals and other types of disorders. Besides, my research hopefully supports the change of the inaccurate stereotype picture of autistic individuals.

Hereby, I would like to thank all the professors at Radboud University, who enabled me to gain the knowledge to write this master thesis. I would also like to give special thanks to Dr. Jianying Qiu for his valuable recommendations, which enabled me to improve my thesis. And, of course, I would like to thank Dr. Anita Kopányi-Peuker for her feedback, continuous support, and dedication in helping me write this thesis.

Dennis van Helvert,
Lith, 29th of June 2022

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1 Introduction

We currently live in a world that is increasingly becoming aware of diversity and embraces it more and more (Poushter, Fettterolf, & Tamir, 2019). This not only displays itself in societal changes but also in science. Within economics, there is not only a clear transition from its ‘old’ paradigm of entirely rational behaviour to a new paradigm, which incorporates real-world behaviour, but also a rise in pluralism (Brue & Grant, 2013; Sent, 2018). New schools of thought, such as feminist economics, recognise and embrace diversity within economics (Becchio, 2020). Those changes in economics have tremendously increased progress, with better models that move away from the *homo economicus* assumption and take human biases, system one and two thinking, etc., into account (Brue & Grant, 2013). However, currently, economics as a science still has many shortcomings. A vital shortcoming is its failure to include an essential 1-2% of the world population in its research, those diagnosed with autism spectrum disorders (ASD) (Joon, Kumar, & Parle, 2021). While classical economists might argue that those people were included in ‘old’ models that were based on full rationality, other researchers, like behavioural economists, psychologists, and neurologists, argue that people diagnosed with ASD are neither the perfect *homo economicus*, as they are neither perfectly rational (Brue & Grant, 2013; Fujino et al. 2019; Gosling & Moutler, 2018; Rozenkrantz, D’Mello, & Gabrieli, 2021). Therefore, new research is needed to understand how people diagnosed with ASD might make different decisions when facing economic decision-making situations. This new research not only helps to improve economics as a science but understanding their behaviour also helps to design interventions, coaching courses and regulation, which can aid in the equal treatment and improve the quality of life of those individuals. Consequently, within this thesis, it is researched if autistic individuals behave more like a homo economicus and how their decisions differ from their neurotypical counterparts in typical economic situations that involve risk, ambiguity and self-interested behaviour possibilities.

Generally, studies have found significant differences in behaviour between people diagnosed with ASD and others (Fujino et al., 2017; Gosling & Moutler, 2018; Rozenkrantz, D’Mello, & Gabrieli, 2021). This is likely caused by the key symptoms of their disorder, the impairment of social communication and interaction, and repetitive patterns of behaviour, interests, and/or activities (APA, 2013; World Health Organization, 2019). Those symptoms are present from their early childhood and affect their everyday functioning, but the severity differs among the level of autism (APA, 2013). With around forty-five per cent only having a mild form (level 1), who can live a (relatively) everyday life, and can likely go to an ordinary high school, college, or university and have a regular job (Autism speaks, 2017). Nevertheless, there are also those with more substantial forms (levels 2 and 3) who need far more help and, unfortunately, will not be able to live independent lives without help from others (APA, 2013).

When considering high-functioning autistic individuals (level 1) - which are the subjects of this study, as they will be likely to also make economic choices within their lives - much is still unknown about their decision-making. Studies generally suggest that anomalies within their brain make them more rational but at the same time also more anxious (Baron-Cohen S. et al., 2000; De Martino, Harrison, Knafo, Bird, & Dolan, 2008; Fujino et al., 2019; Gosling & Moutier, 2018; Trepel, Fox, & Poldrack, 2005). However, it has been little studied how their unique behavioural anomalies affect their everyday economic decision-making. So, are they the perfect homo economicus, an entirely rational economic agent who is self-interested and pursues a maximisation of their utility? Within everyday life, the level of rationality can be tested within three types of everyday situations. Situations with known risk provide a baseline for their preferences and show their general behaviour under risky conditions. Situations with ambiguity display how they react differently compared to their neurotypical counterparts when the degree of risk is unknown. Moreover, as it is known that autistic individuals face difficulties in societal situations, the influence of social interaction on their decision outcomes can also be measured (Happe et al., 1996; Wu, Balliet, Kou, Lange, & A.M., 2019).

Considering decision-making under risk, existing research is found to be highly lacking in quantity, with only a few studies that have yet researched it (Fujino et al., 2017; Gosling & Moutier, 2018). However, the problem with those studies is that they used a 'simple' (expected utility) model of choice-making, which lacks external validity and does not consider low probabilities (Kahneman & Tversky, 1979). The results would have been more helpful if they had used a more sophisticated model, like the Prospect Theory of Kahneman & Tversky (1979, 1992). This model is still seen as the best model to describe people's choice-making under risk and as the foundation of behavioural economics, as it includes human biases and thereby can accurately predict and describe real-world behaviour (Fox, 2015; Pan, 2019). As a result of this, it can explain a wide variety of people's real-life choices, such as taking insurance, participating in a lottery, spreading consumption over their life (intertemporal consumption), investor's behaviour in stock markets, the endowment effect, etc. (Barberis, 2013). Furthermore, an additional problem with the existing research is that the results of the neurotypical control group are contradictory to most other research (a considerable risk aversion in the gain domain but only a minimal level of risk-seeking behaviour in the loss domain), which raises doubts about the external validity (Fujino et al., 2017).

Next to that, in everyday life, people often have to make decisions in situations with unknown risks, known as ambiguity (Ellsberg, 1961). While neurotypical people typically show an aversion to this type of risk, the effect is yet unclear for autistic individuals. Based on a higher degree of rationality, it is less likely that autistic individuals will violate the sure-thing principle. Furthermore, suppose autistic individuals are indeed a better *homo economicus* and care less about the feelings of others. In that case, they should be less affected by the 'fear of negative evaluation' – another commonly provided explanation of ambiguity aversion that entails that people dislike ambiguity, as such a decision can be hard to explain to others (Trautmann, Vieider, & Wakker, 2008). However, at the same time, existing research also predicts a higher degree of risk aversion for autistic individuals, which is expected to be even stronger in situations with ambiguity and in loss-domain contexts (Camerer, Bhatt, & Hsu, 2007; Dziobek, Fleck, Rogers, Wolf, & Convit, 2006; Trepel, Fox, & Poldrack, 2005). Thus, the effects of autism on ambiguous situations are yet unclear. Furthermore, they have only yet been studied in one study, the study of Fujino et al. (2017), which was conducted in Japan. This raises doubts about the external validity of those results, as there can be significant differences in behaviour between countries (Oosterbeek, Sloof, & Kuilen, 2003).

Furthermore, the third important part of real-life economic decision-making involves decisions in a societal context. Because decisions are often made in a societal context, and thus the outcome of decisions also affects others. For example, in situations where an individual chooses to donate money to charity, has to split a bill with their friend, or is offered an 'unfair' offer by someone else. When considering the perfect homo economicus, an individual should only behave entirely in their self-interest and thus not care about the feelings, emotions and utility of others. Within a dictator game[1], this would result therein that a perfect homo economicus would offer the lowest possible amount to the fully anonymous other party, as the only reason to offer any money to the other party is caused by a 'feeling of fairness' (Forsythe, Horowitz, Savin, & Sefton, 1991; Thaler, 1988). As a result of this, this experiment is a perfect test to measure if autistic people are a 'better' homo economicus and indeed lack empathy in an economical domain (Jones, Happé, Gilbert, Burnett, & Viding, 2010). Furthermore, when combining this with an ultimatum game[2] from the responder's side, it becomes possible to measure the reaction of autistic people to 'unfair' economic situations. With this, it enables research on whether autistic people care less about others in the economic domain and if they are willing to 'punish' others when they are offered unfair offers. Within the real world, this combination of experiments can, for example, explain if autistic people are less likely to donate to charity, would be willing to accept 'unfair' offers, and thus also if it makes them vulnerable to opportunistic behaviour of others.

Additionally, combining this with a proposer's side ultimatum game differentiates between the 'empathy' and 'fear of rejection' factors. Because the ultimatum game has not only the empathy factor but also the 'fear of rejection' factor that explains people's willingness to give money to the other party (Thaler, 1988). Moreover, this factor is crucial in accurately describing the economical choice behaviour of autistic individuals, as this involves mentalising[3], a process in which autistic individuals typically

[1] A 'game' wherein a person has to split a certain sum of money between himself and an anonymous other person, who cannot deny the offer.

[2] A 'game' wherein a person has to split a sum of money between himself and an anonymous other party. If the other party refuses the offer, neither of them will be paid.

[3] Mentalising is about about predicting and explaining what others do, and why they do so.

face difficulties (Bachevalier & Loveland, 2006; Baron-Cohen S. et al., 2000; Happe et al., 1996). Thus, combining these experiments allows for an analysis of autistic choice behaviour, compared to their neurotypical counterparts, in real-life situations that do and do not incorporate the ability to reject their offer. Thus, are autistic individuals only willing to think about others' welfare because it can also affect their welfare (rejection), or do they genuinely show empathy and care for others' welfare?

When considering the previous studies in this domain, those are also found to be lacking. A few studies have researched autistic adults within the ultimatum game, but some failed to incorporate the proposers' perspective (Jin et al., 2020; Ikuse et al., 2018; Tei et al., 2018). Additionally, some studies only considered children, who are expected to behave differently in such situations (Hartley & Fisher, 2018; Jin et al., 2020). Furthermore, most of the existing research is from Japan and the US. However, due to cultural differences and differences in 'training' techniques, subjects in those countries might behave differently (De Martino, Kumaran, Seymour, & Dolan, 2006; Jin et al., 2020; Luke, Clare, Ring, Redley, & Watson, 2012; Tei et al., 2018). Besides that, none of those studies combined the dictator game with the ultimatum game. They therefore could not distinguish between the effect of 'empathy' and the effect of 'fear of rejection'.

Concludingly, the problem with existing research is that it lacks in quantity, which has a detrimental effect on worldwide external validity. Furthermore, research within the key domain of behaviour economics – choices under risk – is incomplete in accurately explaining choice-making differences under risk within real-life situations. Another problem is that most of the existing research is from Japan and the US, which makes research skewed. They are the countries with some of the highest diagnoses percentages worldwide, which raises questions about how those results would extrapolate to countries with a lower diagnosis percentage (and thereby generally are more skewed towards stronger forms of autism) (De Martino, Kumaran, Seymour, & Dolan, 2006; GDHx, 2017; Jin et al., 2020; Luke, Clare, Ring, Redley, & Watson, 2012; Tei et al., 2018). Additionally, some researchers only considered children, who are unlikely to make economic decisions in real life. This research solves all of these problems by focusing on high-functioning autistic adults, who are likely to make decisions in real life. Furthermore, this study uses the knowledge of prospect theory to predict behavioural differences of autistic people far more accurately. Next to that, this study also combines this with an ambiguity study. Hereby, the results of the ambiguity study become closer to reality, as the utility function from prospect theory can be used to serve as a baseline for both the autism and neurotypical group. Additionally, this study combines this with a dictator game, and an ultimatum game from both the proposer and responder sides. This unique combination of experiments allows this study, for the first time within autism research, to separate the effect of 'empathy' in both the giving and receiving domain and the effect of 'fear of rejection'.

Furthermore, this combination of experiments allows this study to predict how autistic individuals will differ in economic decision-making in multiple real-life situations, with and without social involvement.

Therefore, this research answers the following question: do autistic individuals behave more like a homo economicus? Herefore, because of the lack of currently available knowledge, hypotheses are generated using a triangulated approach, combining existing research about economic decision-making under ASD with research about the psychology of autism, the neurology of autism, and neuroeconomics. The generated hypotheses are tested in an online experiment, using a carefully selected sample consisting of 28 persons of the ASD group and 42 persons of the neurotypical group, matched on age, home country, gender and level of education.

Decision-making under risk is tested using a shortened version of Kahneman & Tversky's experiment out of 1992. The results indicate no significant difference for the weighting parameter in both the gain and loss domain. Regarding the value function, the results support the hypothesis of a more linear function in both the gain and loss domain for the ASD group. When considering the loss aversion parameter, the results indicate a higher degree of loss aversion for the ASD group, contrary to the hypothesis.

Ambiguity aversion is determined with the alpha maxmin parameter, using Ellsberg's (1961) two-urn task. Herein, no significant difference is found within both the gain and loss domain. However, the evidence is not strong enough to state that the two groups are equal within the loss domain.

Considering the ultimatum and dictator game, no difference is found for the proposer's side of the ultimatum game, and for the dictator game. Thus, indicating no significant difference between the 'fear of rejection' and 'empathy' factor between the ASD and neurotypical group. However, when considering the 'minimum acceptable offer' of the ultimatum game, it is found to be significantly lower for autistic individuals.

The structure of this paper is as follows. Chapter two provides an overview of the existing literature and the hypotheses. Hereafter, the third chapter offers an overview of the research design. Following this chapter, the fourth chapter presents an overview of the results. After that, the fifth chapter provides a conclusion and a discussion on the findings of chapter four, combined with possibilities for future research.

2 Literature Review

This chapter starts with a brief introduction to autism, followed by the expected influence of autism in prospect theory, ambiguous situations and the ultimatum and dictator game.

2.1 What is ASD?

This subsection provides a brief introduction to autism. A far more complete description of autism and the neurology of autism can be found in appendix one and two, respectively.

Autism Spectrum Disorder is a form of a developmental disability which already reveals its symptoms in early childhood (APA, 2013). Based on the latest definitions – WHO's ICD[4]-11 guideline, which is favoured, for example, in Europe, and the US's DSM[5]-5 – it is characterised by difficulties in social communication & interaction, restricted interests and repetitive behaviour (APA, 2013; World Health Organization, 2019). Previously, in earlier versions of those norms, distinctions were made between 'types' of autism, such as Asperger's syndrome, PDD-NOS, etc., which is not the case anymore. Nowadays, everyone with autistic symptoms receives the diagnosis of autism and can receive additional diagnoses for additional symptoms (such as lingual development disorders) (APA, 2013). Furthermore, within the latest definition of APA (2013), there is also a distinction between three levels of autism in both key symptoms, 'social communication' and 'restricted, repetitive behaviour'. Individuals are diagnosed on levels one to three for both of those symptoms. Where one entails that the individual needs some support, two entails that the individual does need support, and level three entails that the individual needs extensive support (see appx. 1).

2.2 Prospect Theory

Individuals often must make financial decisions involving risk within the real world. This can include decisions such as choosing to partake in a lottery, taking insurance, or accepting a gamble. Previous theories, such as the expected utility theory, were not able to accurately explain those choices, as they did not take the behavioural biases of individuals into account, such as loss aversion, the framing effect, the certainty effect, the reflection effect and the isolation effect (Barberis, 2013). Therefore, Kahneman and Tversky designed the prospect theory in 1979 to describe how people often make such decisions in real life, which is still one of the most used theories today (Barberis, 2013). This section explores how people diagnosed with autism would make different choices within risky situations, based on the foundation of prospect theory.

[4] International Classification of Diseases, 11th edition
[5] Diagnostic and Statistical Manual, 5th edition

2.2.1 A Brief Introduction to Prospect Theory

Prospect theory is modelled after Kahneman and Tversky's research (1979), which discovered that in real life, people make economic decisions compared to a reference point, wherein they see better outcomes as gains and lower outcomes as losses. Furthermore, their research indicated that two functions explain humans' decision-making: a weighting function and a value function. The weighting function illustrates how people weigh outcomes in reality, based on their subjective probabilities. The value function explains how people value outcomes in real life based on their risk preferences and loss aversion (see appx. 3 for a more detailed description).

Combining all of this leads to a fourfold risk preference function. Within the gain domain, there is risk aversion for higher probabilities and risk-seeking behaviour for very low probabilities (such as a lottery). Within the loss domain, there is risk-seeking behaviour for higher probabilities and risk aversion for very low probabilities (such as insurances).

2.2.2 ASD Behaviour Within Prospect Theory

Value function within the gain domain

when considering the value function, its form is mainly explained by diminishing sensitivity (Kahneman & Tversky, 1992). And within the gain domain, it is also explained by diminishing utility of money, which is as well expected to be present for autistic individuals. This effect is caused by people using money to buy goods ranked from high to low importance for them. So, as money increases, the utility per amount of money decreases (Caplin & Glimcher, 2014). However, for a perfect homo economicus, under a concave utility function, the effect of diminishing sensitivity should mainly hold for large gains. As, within small gains (such as an additional gain of two euros when being twenty euros in the gain domain), there is no significant effect of decreasing utility of money, when considering the individual's total amount of money. However, prospect theory indicates that this effect as well holds for such small amounts of money, which only has a negligible effect on the absolute total utility of the individual (Kahneman & Tversky, 1992). Moreover, there is the concept of 'diminishing sensitivity' (Caplin & Glimcher, 2014; Kahneman & Tversky, 1992). This is caused by people acting compared to a reference point, under an effect known as the Weber-Fechner law, which means that people become less sensitive to changes, the further they are away from the reference point (Weber, 1975). However, rational people should not consider each decision individually, but instead, consider their total utility and the effect the individual decision has on their overall utility (Kahneman & Tversky, 1992). Therefore, based on this evidence, autistic people, who are perceived as being more rational, should be less influenced by these psychological effects (Rozenkrantz, D'Mello, & Gabrieli, 2021). This will lead to a more linear gain-domain value function.

When considering the neurological evidence, the effects are found to be unclear. Within a gain-domain situation, the medial prefrontal cortex (mPFC)[6] and orbitofrontal cortex (OFC)[7] are likely to be triggered (Levin et al., 2012). However, the reduction in FCs between the amygdala[8] and mPFC – as witnessed in autistic individuals – is likely to reduce the individuals' risk tolerance (Hoon Jung, Lee, Lerman, & Kable, 2018). Furthermore, although the amygdala usually is not functioning in autistic individuals, situations with risk can trigger a – small – fear response, which can thus still make the decision emotion-driven (Trepel, Fox, & Poldrack, 2005). This therefore presumes that the utility function will become less linear and more risk averse. However, within the gain domain, only a small trigger of the amygdala is expected, as gain domain situations typically trigger only a tiny fear response (Gosling & Moutier, 2018). Moreover, reduced FCs between the amygdala and the OFC will likely make the decision-making less emotion-based (Trepel, Fox, & Poldrack, 2005). Furthermore, due to the correct functioning of the OFC and hippocampus within high-functioning autistic individuals, they are still likely to apply the marginal utility of money and diminishing sensitivity correctly. Thus, generally, some factors make the decision-making of autistic individuals somewhat risk-averse. However, generally, due to the smaller involvement of emotions, the gain-domain utility function is expected to be more linear than that of neurotypical individuals.

Value function within the loss domain

When considering the loss domain, there is only the factor of diminishing marginal utility, which explains the convexity of the loss domain function. As described above, this effect is caused by people acting compared to the reference point under an effect known as the Weber-Fechner law. Without considering the loss-aversion parameter, this effect leads to an under-sensitivity to losses (Kahneman & Tversky, 1992). However, autistic individuals, who are expected to be less influenced by psychological biases are less likely to be affected by this effect (Brue & Grant, 2013; Fujino et al., 2019; Gosling & Moutler, 2018; Rozenkrantz, D'Mello, & Gabrieli, 2021; Trepel, Fox, & Poldrack, 2005). When considering the neurological evidence, a loss situation is expected to trigger the orbitofrontal cortex, insula[9], medial prefrontal cortex, anterior cingulate cortex (ACC)[10] and amygdala (De Martino, Kumaran, Seymour, & Dolan, 2006; Levin et al., 2012; Trepel, Fox, & Poldrack, 2005). As described in appx. two, the reduction in functional connections between those various brain parts and the amygdala, combined with a largely inactive amygdala, results in less emotion-driven decision making. However, situations of risk, especially within the loss domain, can also result in the feeling of fear, which might even hyperactivate the amygdala (Barak & Feng, 2016; Baron-Cohen S. et al., 2000; Dziobek et al.,

[6] mPFC is involved in situations that involve retrieving long-term memory. See appx. 2 for details.
[7] OFC is responsible for adapting human behaviour based on emotions and stimuli-based decision making. See appx. 2 for details.
[8] Amygdala is seen as the central component of the 'social brain'. See appx. 2 for details.
[9] Insula is responsible for the awareness of one's own emotions and understanding and empathizing for other's emotions. See appx. 2 for details.
[10] ACC weights the social and economic cost of decision options. See appx. 2 for details.

2006; Herrington et al., 2017). Thus, autistic individuals are likely to be less influenced by biases and emotions within the loss-domain decision-making, making the loss function more linear than that of neurotypical individuals. But, the feeling of fear is also expected somewhat to influence the loss domain value function, resulting in neither an entirely linear value function.

Loss aversion parameter/framing

When considering the loss aversion parameter, the results are puzzling. On the one hand, an increase in rationality would result in a decrease in loss-aversion. However, on the other hand, the increased levels of anxiety – which plays a significant role in loss-aversion – would predict a higher loss-aversion parameter (Baron-Cohen S. et al., 2000; De Martino, Camerer, & Adolphs, 2010; Trepel, Fox, & Poldrack, 2005). But, as Kahneman & Tversky (1979 & 1992) explained, this loss aversion parameter also depends significantly on framing. Because, depending on how the information is framed, people perceive it as a loss or gain. For example, a situation can be framed in a gain context by stating a chance of winning a certain amount or framed in a loss context by stating a chance of losing a certain amount.

When considering the autistic brain, it is generally expected to make more use of System two thinking – slow, logical, conscious thinking – instead of system one thinking, which results in autistic people better considering the situation and thereby being less susceptible to the framing effect (De Martino, Harrison, Knafo, Bird, & Dolan, 2008; Trepel, Fox, & Poldrack, 2005). Furthermore, framing is generally seen as being caused by emotional biases within the human brain (De Martino, Kumaran, Seymour, & Dolan, 2006). However, due to the anomalies in the amygdala and the FCs to it, those emotional biases are likely to be smaller in autistic individuals. This will result in the autistic brain making more rational decisions. When considering empirical evidence, there is some discrepancy, but it generally also supports a reduction in framing effects and loss aversion sensitivity within autistic brains (De Martino, Harrison, Knafo, Bird, & Dolan, 2008; De Martino, Camerer, & Adolphs, 2010; Fujino et al., 2019; Gosling & Moutler, 2018).

However, despite the reduced framing effect, the autistic brain is also known to (hyper)activate the amygdala when feelings of anxiety arise, which are triggered by the possibility of loss (Baron-Cohen S. et al., 2000; Trepel Fox, & Poldrack, 2005). This will lead to the decision-making to become somewhat emotion-based – depending on the FCs between the amygdala and the mPFC, OFC & ACC and the functioning of the amygdala itself – resulting in autistic people preferring a 'safe' choice over a 'risky' choice. Therefore, based on the lower susceptibility to the framing effect, the loss aversion parameter is expected to be lower. However, due to the feeling of fear, driven by the potential to lose money, it is likely that the loss aversion remains, although likely smaller than within neurotypical individuals.

Overall loss-domain function

When combining the evidence, the loss domain value function will likely still have a loss aversion parameter, combined with a more linear value function, compared to neurotypical individuals. This results in autistic individuals being loss averse, but less risk-seeking when already in the loss domain. This is also supported by the minimal available research, that reveals an increase in risk aversion in the loss domain within autistic individuals (Fujino et al., 2017; Gosling & Moutier, 2018). However, it should be noted that those studies cannot be directly compared to prospect theory, as they did not consider extremely low probabilities or use any non-linear utility function. Furthermore, the results of the neurotypical control group also show results that significantly differ from most of the risky domain based research, with a considerable risk aversion in the gain domain, but only a minimal level of risk-seeking behaviour in the loss domain.

Weighting function

The other important parameter of cumulative prospect theory is the weighting function, which is as well explained by diminishing sensitivity (Kahneman & Tversky, 1992). As illustrated in previous chapters, autistic individuals are expected to be less influenced by emotions and biases, thus less susceptible to this effect. However, the study by Trepel, Fox, & Poldrack (2005) suggests that the overweighting of low-probability losses and underweighting of high-probability gains is also caused by fear and the overweighting of low-probability gains and underweighting of high-probability losses by a feeling of hope. Moreover, it is known from the neurological evidence that those feelings, especially the feeling of ‘fear’, are typically mainly triggered within the amygdala, thus influencing decision making (see appx. 2). However, neurological evidence suggests that a feeling of hope would be unlikely to trigger the amygdala and other emotion-controlling areas within the brain of autistic individuals, thereby making it unlikely that those emotions affect the decision-making (see appx. 2). When considering the feeling of fear, this is expected to trigger the amygdala within autistic individuals, especially in the case of a loss (Dziobek, Fleck, Rogers, Wolf, & Convit, 2006). Thus, based on neurological evidence, it is likely that autistic individuals have a more linear gain-domain weighting function. Within the loss domain, the weighting function is also expected to be more linear but still somewhat overweight low-probability losses due to increased fear. However, because of the mathematical distribution of the weighting function, it will not be able to fully capture increases in low-probability loss weights without displaying a relative underweighting of higher-probability losses. Thus, based on the mathematical interaction between the weighting and value function, an overweighting of low-probability high-monetary-value losses, without underweighting high probability losses, might show itself as an increase in the value function parameter instead of the weighting function parameter (see appx. 4).

Based on the above-described evidence, the following hypotheses are derived:

H1: high-functioning autistic people have a more linear cumulative weighting function, compared to neurotypical individuals, within the gain domain.

H2: high-functioning autistic people have a more linear cumulative weighting function, compared to neurotypical individuals, within the loss domain.

H3: the prospect theory value function of high-functioning autistic individuals is more linear than that of neurotypical individuals, in the gain domain.

H4: the prospect theory value function of high-functioning autistic individuals is more linear than that of neurotypical individuals, in the loss domain.

H5: high-functioning autistic people have a loss aversion parameter lower than that of neurotypical individuals.

2.3 Ambiguity

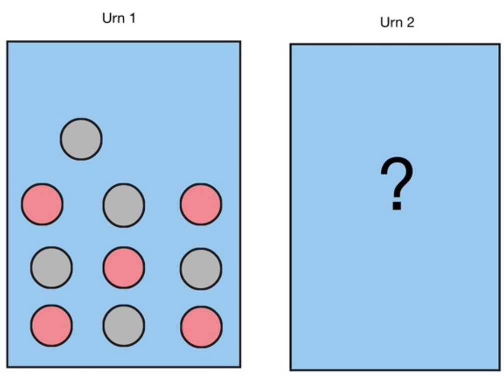
In real life, people also often face decisions of unknown risk, known as ambiguity. For example, compared to domestic stock markets, people often underinvest in international stock markets due to a home bias; people prefer to order online products with higher ratings, even if the median rating is lower; etc. All those situations have in common that the individuals do not know the exact risk and would rather choose a situation with known risk over a situation of unknown risk. One of the most used experiments to test this ambiguity aversion is Ellsberg's two-urn and one-urn experiments (Ellsberg, 1961).

Two-urn experiment

Ellsberg's two-urn experiment

Within the two-urn experiment, the respondent is shown two urns, one with a known distribution of red and black balls (urn_{known}), and one with an unknown distribution of red and black balls ($urn_{unknown}$). The respondent can choose if he earns money if the red ball is drawn, or if he wants to earn money when the black ball is drawn. Furthermore, the respondent can also choose if he prefers urn_{known} or $urn_{unknown}$.

Figure 1: Ellsberg's urn



The outcomes of this experiment, which has been repeated many times over the last 60 years, indicate no general preference for red or black but do indicate a preference for urn one over urn two. This is a strict violation of the expected utility theory. Because an individual knows that the chance of winning with urn 1 is 50%, thus if the individual believes that urn 1 provides a higher utility than urn 2, he believes that his chance of winning with urn 2 is below 50%. However, then he could have chosen the other colour and thus have a belief of over 50% for winning in urn 2.

However, these violations can be explained by the ambiguity aversion of individuals. As in all those situations, people prefer the choice that gives a known risk over the option that gives an unknown risk. The leading cause hereof lies in the 'fear of negative evaluation' (Curley, Yates, & Abrams, 1986; Trautmann, Vieider, & Wakker, 2008). This means that people want to rather take a decision with known risk instead of a decision with unknown risk, as a negative outcome can be hard to explain to others. People can call it bad luck in a known risk situation because they had all the available information. However, when a person chooses for the unknown risk, he deliberately chooses for a position in which he does not have as much available information; losing, when selecting for the situation of unknown instead of known risk, can be hard to explain to others.

When considering the neurological evidence, a situation of ambiguity activates both the orbitofrontal cortex and the amygdala (Camerer, Bhatt, & Hsu, 2007). Herein, the orbitofrontal cortex is mainly responsible for making the decision, and weighting between the emotions (as received from the amygdala) and the monetary gains/losses. Furthermore, the situation of uncertainty is likely to create a fear response, which triggers the amygdala (Dziobek, Fleck, Rogers, Wolf, & Convit, 2006; Trepel, Fox, & Poldrack, 2005). However, even though autistic people are known to be more afraid, caused by an amygdala that can be oversensitive to an anxiety trigger, there also is a reduction in the functional connections between the amygdala and OFC (see appx. 2). Within the gain domain, the amygdala will probably only be mildly triggered because the risks are relatively low within most gain-domain Ellsberg urn experiments. Moreover, the decreased functional connections between the OFC and the amygdala will likely result in a lower degree of ambiguity aversion compared to neurotypical individuals. But, when considering the loss-domain context, the possibility of losing might trigger the amygdala stronger compared to a gain-domain situation (Dziobek, Fleck, Rogers, Wolf, & Convit, 2006; Trepel, Fox, & Poldrack, 2005). This stronger amygdala activation might make the decision more emotionally driven. However, the degree of emotion-drivenness also depends on the degree of fear and the FC between the amygdala and the OFC & ACC (see appx. 2). Thus, based on these facts, the influence of autism on such decisions is unclear and likely minor.

However, newer evidence also reveals that autistic people have an elevated ‘fear of negative evaluation’ (Davidson, Vanegas, & Hilvert, 2017; White, Bray, & Ollendick, 2012); contrary to many older studies that paint a picture of autistic individuals being more selfish and lacking empathy (Baron-Cohen S., 2005; Kanner, 1943) This elevation is correlated with their social anxiety, and results therein that they are more afraid than neurotypical individuals in social situations, and thereby also the negative evaluation by others (Davidson, Vanegas, & Hilvert, 2017). Thus, depending on the type of experiment, the outcome can significantly differ. Experiments with a high possibility of the ‘fear of negative evaluation’, such as a field and especially a natural experiment, might display a greater degree of ambiguity aversion within autistic individuals. However, a lab experiment, which involves a limited degree of ‘fear of negative evaluation’, is likely to result in a decreased ambiguity aversion, especially within the gain domain, compared to neurotypical individuals. Fujino et al. (2017) also confirmed this in a lab experiment. They found significantly less ambiguity aversion in the high-functioning ASD group, within the gain domain but no clear difference within the loss domain.

Based on the above-described facts, the following hypotheses can be derived:
H6: high-functioning autistic individuals are less ambiguity averse, in a gain domain Ellsberg's urn task, compared to neurotypical individuals.
H7: high-functioning autistic individuals are just as ambiguity averse, in a loss domain Ellsberg's urn task, compared to neurotypical individuals.

2.4 Rationality in the Social Domain

This section explores how autistic people might behave differently in situations that involve economic decisions which also influence others. Hereby, this section explores how far the rationality of an autistic individual goes in cases that involve fairness – such as in the ultimatum game. This is essential to understanding and predicting real-world economic behaviour, as people in the real world often reject unfair offers, even though accepting them would make both of them better off. For example, countries fail to make peace, leading to a costly war for both parties; and businesses & consumers go to court for minor conflicts, which has high costs for both parties.

2.4.1 Ultimatum Game

the ultimatum game (UG) is one of the most used economic experiments to test the boundaries of rationality in economic decision-making.

How does the ultimatum game work?

There are two parties within the ultimatum game, the proposer and the responder, which are anonymous to another and cannot negotiate.

Step 1: The proposer receives a given sum of money ($€_{received}$), to share with the responder.
Step 2: the proposer offers a certain amount of money to the responder ($0 \leq €_{offer} \leq €_{received}$).
Step 3: the responder can choose to accept or deny the offer:

- If he accepts: both parties receive their part ($Proposer = €_{received} - €_{offered}\,; responder = €_{offered}$.
- If he denies, neither one receives anything.

Responder

When considering perfect rationality, an individual would accept any offer above zero, as this makes him better off. However, when considering neurotypical respondents, the lowest percentage typically accepted ranges between 30-40%, depending on the money at stake (Cameron, 2007; Novakova & Flegr, 2013). This thus reveals two main findings. First of all, it reveals that people value fairness and reject offers that seem unfair to them; therefore, it seems to be the case that unfairness has a decreasing effect on an individual's utility. Furthermore, it indicates that the monetary amount people are willing to lose by rejecting an unfair offer decrease relatively when the stakes increase. However, absolutely, people are willing to lose vast amounts of money just because of unfairness. In an experiment run by Cameron (2007), where they even went as far as using a real monetary amount of three times the monthly wage, some people would still reject a likely very high offer ($offer\ \bar{X} = 42\%, \sigma = 12\%, acceptance\ rate = 90\%$). Moreover, regarding geographical differences, there are also some differences to be expected caused by cultural differences. In some cultures, individuals value fairness more, while in other cultures – like the Netherlands – people behave more rationally (Oosterbeek, Sloof, & Kuilen, 2003).

However, when considering autistic individuals, the outcomes are expected to be vastly different, as autistic individuals are regarded as being more rational and making less emotion-driven decisions (Baron-Cohen S., 2005; Rozenkrantz, D'Mello, & Gabrieli, 2021). When considering neurological research, it shows that 'unfairness' in the ultimatum game activates two brain regions, the anterior insula – which is primarily responsible for emotions – and the dorsolateral prefrontal cortex – which is in such tasks used for the suppression of unwanted emotions (the feeling of unfairness) (Kenning & Plassmann, 2005; Sanfey, Loewenstein, McClure, & Cohen, 2006). Herefore, those brain areas are also connected to the amygdala - the brain's region mainly responsible for the individuals' emotions. However (as stated in appx. 2), those brain areas are under-activated in autistic individuals, and the FCs to the amygdala are also reduced. This will result in the brain being less influenced by emotions, thus in more rational decision-making, which involves accepting more unfair offers. However, even though those brain areas are found to be less functioning, especially the amygdala and anterior insula, a high-functioning autistic person is still not likely to accept a very unfair offer, as those brain areas are still somewhat activated. This higher acceptance rate, but no full acceptance of unfair offers, is as well confirmed by Tei et al. (2018), who found a roughly two times higher acceptance rate (20% vs 40%) among autistic individuals for unfair offers.

Proposer
When considering the proposer's perspective, the optimal strategy is more puzzling. It not only depends on what the individual sees as fair but also the fear of the other one rejecting the offer (Thaler, 1988). Within neurotypical experiments, the average offer is around 40% (Oosterbeek, Sloof, & Kuilen, 2003). This offer is based on the following three elements (Thaler, 1988).

Self-interest: when considering self-interested behaviour, an entirely rational individual would allocate 100% of the money to themselves.

Fairness: when considering fairness, neurotypical respondents are shown to value fairness, and they thus derive a certain utility from altruism and a fair spread. However, as already described, high-functioning autistic individuals are expected to place less value on fairness and more on their own utility than neurotypical individuals.

Fear of rejection: in an ultimatum game, there is also the risk of rejection. As a result of this, it involves a process known as mentalising, whereby an individual has to understand how others are likely to feel and react to their offer (Happe et al., 1996). As explained in appx. 2, autistic people are found to be worse at mentalising due to the anomalies in the medial temporal lobe. However, even though they find it hard to mentalise how others would feel, they can still use other information – such as past experiences and watched tv-shows with similar experiments/situations – to determine that neurotypical people typically favour fairness more and take this into account. And furthermore, autistic people are also known to be more anxious, which might make them spread more fairly, as they might be afraid that the other party would not accept their offer (Baron-Cohen S. et al., 2000).

So, even though autistic individuals are more rational, and thus place less value on fairness, and are expected to have a more linear utility function (see §3), their fear of rejection, partially caused by difficulties in mentalising, will still likely result in autistic people giving a higher share of money to the responder, compared to neurotypical individuals. An experiment by Ikuse et al. (2018) also confirms this, revealing that high-functioning Japanese autistic people generally propose a higher share to the responder than neurotypical individuals.

2.4.2 Dictator Game

The dictator game (DG) is an experiment, quite like the UG, with two parties, the proposer and the responder, which are anonymous to each other. However, there is one key difference; within the DG, the responder cannot deny the offer (Forsythe, Horowitz, Savin, & Sefton, 1991). And this exact difference can have major consequences for autistic individuals proposing an offer, as the 'fear of rejection' disappears. Because, with this change, entirely rational behaviour would imply offering the lowest possible amount to the responder. This change also has considerable effects on neurotypical individuals, where the offer is typically around twenty-five per cent, compared to approximately forty percent in the ultimatum game (Gneezy & Charness, 2008; Novakova & Flegr, 2013).

When considering the neurological side, no current evidence accurately describes the used brain areas within DG decisions. However, based on evidence about the functioning of the brain (see appx. 2) and the evidence on UG type decisions (see 2.4.1), it is likely that multiple brain areas will be activated: the anterior insula, dorsolateral prefrontal cortex, orbitofrontal cortex, and amygdala. These are the key areas in the brain involved in decision-making processes that involve feelings and monetary aspects. Based on the neurological evidence, as presented in appx. 2, multiple brain areas within high-functioning autistic people are not fully operational, and functional connections to multiple brain areas are also weaker, of which the amygdala is generally seen as the most important. Therefore, this results therein that the decision will still be partially driven by feelings and emotions, but considerably less than in neurotypical individuals. Thus, this likely results in high-functioning autistic individuals still offering some amount to the anonymous other party, although it is likely considerably less than neurotypical individuals.

Based on the evidence as provided above about the social domain decisions, the following hypotheses are derived:

H8: high-functioning autistic individuals have a lower minimal acceptable offer, in the ultimatum game, than neurotypical individuals.

H9: high-functioning autistic individuals propose a higher amount than neurotypical individuals, in the ultimatum game.

H10: high-functioning autistic individuals propose a lower amount than neurotypical individuals, in the dictator game.

3 Research Design

3.1 Participants

Participants

In total, there are 42 responses belonging to the neurotypical group and 28 to the autism group. This amount is comparable to previous studies, which as well used 20-30 responses (Fujino et al., 2017; Gosling & Moutier, 2018; Ikuse et al., 2018; Tei et al., 2018). Furthermore, additional effort was taken to ensure a good matching of gender, age and level of education between the two groups.

Selection criteria

In order to reach the proper respondents, strict selection criteria are used. Given that the goal of this study is to explain the decision-making behaviour of high-functioning autistic individuals compared to neurotypical others. Therefore, it also has to be ensured that other medical conditions and/or medicinal treatments do not explain some of the differences. An overview of the selection criteria, which are checked by self-reporting, is presented below.

For both groups the criteria are: (1) a minimum age of 18 years; (2) have not had significant head trauma; (3) have not been diagnosed with ADHD and/or other psychiatric disorders (schizophrenia, anxiety disorder, etc.); (4), only Dutch residents[11]; (5) have completed high-school.

And, for the autistic group, the following additional criteria are applied: (1) only high-functioning autism / level 1 autism; (2) no combination with another psychiatric disorder; (3) have not taken medicine to treat the symptoms of autism in the last 12 months.

Recruitment

Participants were recruited via a variety of methods in order to reach a diverse subject group. The survey is spread to both groups using online forums, LinkedIn, my personal network, autism coaching centres, surveycircle, surveyswap, and academia prolific.

Due to the strict selection criteria, much effort was taken to reach sufficient autistic subjects. This involved contacting a variety of training facilities (of whom the most, unfortunately, could not co-operate), contacting the 'Nederlandse Vereniging Voor Autisme' (who unfortunately could not spread it) and spreading it on a paid survey platform, which allows filtering for autistic subjects (academia prolific).

[11] This study selected only Dutch respondents to prevent cultural biases.

Furthermore, the relatively long time (around 20 minutes to complete the survey), and the storage of sensitive medical information, combined with the heightened level of anxiety typically found in autistic individuals, have likely been additional barriers to participation.

Payment structure

All the subjects could choose whether they will be paid. Depending on the choices they made during the experiment, their payment is between 3-7 euros. Furthermore, the subjects are informed about the precise payment structure and how full anonymity is ensured.

Ethics and Data protection

As this experiment includes sensitive medical data, several measures are taken to reach full GDPR compliance and prevent the leakage of possible medical data. The measures include full anonymity in the online experiment, an enabled anonymity mode within Qualtrics, optional payment, etc.

Furthermore, as this study also involves autistic subjects, a representative of the ethical board of the Radboud University was contacted, who deemed that no approval was necessary.

3.2 Statistical Analysis

All the regressions are run in the latest version of IBM SPSS at this time, version 28. Furthermore, data preparation and some calculations are run in Microsoft Excel. R is used to run the TOST test of equivalence of hypothesis seven, and for creating the graphs. The data is collected using Qualtrics XM in anonimity mode.

3.3 Experimental Design

3.3.1 Cumulative Prospect Theory

CPT functions

The cumulative prospect theory (CPT) is used in this experiment to test the behaviour under risk of autistic individuals. The CPT's certainty equivalent – a monetary amount with the same subjective utility – is calculated using two formulas:

- The exponential value function (equation 1) is used to determine the utility of a certain monetary amount. Within the gain domain, it has a power of α; in the loss domain, it has the loss aversion parameter λ and a power of β.
- The weighting function (equation 2) is used to determine the overweighting of extreme outcomes and the underweighting of middle outcomes (see §2.3). This function also has another

parameter in the gain domain (γ), compared to the loss domain (δ), to compensate for differences in weighting between the loss and gain domains. Furthermore, within the cumulative prospect theory, this function includes cumulative weighting. This consists of the following steps:

1. The monetary outcomes are ordered from most to least extreme, in both domains.
2. The cumulative probability is calculated from most to least extreme.
3. The 'weighting function' is applied to the cumulative probability.
4. The 'decision weights' (DW) are calculated. This equals the outcome of step 3 minus the decision weights of the more extreme outcomes.

After both the decision weights and the values of the possible outcomes are calculated, the CPT-value can be calculated. This equals the value of outcome one, times the DW of outcome one, plus the value of outcome two, times the DW of outcome two, … (equation 3). And then, the certainty equivalent (CE) is just a fixed monetary amount, which delivers the same utility as the risky choice (CPT-value) (equation 4).

$$V^{\pm}(x): \begin{cases} x^{\alpha} \; if \; x \geq 0 \\ -\lambda(-x)^{\beta} \; if \; x < 0 \end{cases} \tag{1}$$

$$W^{\pm}(p) \begin{cases} \dfrac{p^{\gamma}}{(p^{\gamma} + (1-p)^{\gamma})^{\frac{1}{\gamma}}} \; if \; V^{\pm}(x) \geq 0 \\ \dfrac{p^{\delta}}{(p^{\delta} + (1-p)^{\delta})^{\frac{1}{\delta}}} \; if \; V^{\pm}(x) < 0 \end{cases} \tag{2}$$

$$CPT - value = positive \; outcomes + negative \; outcomes$$
$$\rightarrow \sum_{i=0}^{n} \big(V^{+}(x_i) * W^{+}(p_i)\big) + \sum_{i=-m}^{0} \big(V^{-}(x_i) * W^{-}(p_i)\big) \tag{3}$$

$$CPT - value = V^{\pm}(CE) \tag{4}$$

Experiment

In order to test the cumulative prospect theory, this experiment uses a shortened version of Kahneman and Tversky's experiment out of 1992. Within this experiment, there are two types of questions:

- Gain/loss domain questions: the subjects are displayed a risky lottery with two possible outcomes and are asked how much they are willing to pay for the lottery (= the certainty equivalent). Within both the gain and loss domain, 10 questions were asked, involving 2 different lotteries and 5 different probability distributions (see table 1).
- Mixed domain questions: the subjects are shown two different lotteries with a 50% chance to lose 'c' and 50% to win 'x'. Herein, subjects are asked for the minimum amount of x that makes them accept the lottery (see table 1).

Furthermore, the questions are in random order to prevent potential biases leading to overly consistent behaviour. Additionally, an attention check is also built-in (a question states that they have to answer 50). Answers that indicate a lack of understanding (a CE unmistakeably below/above the lowest/highest possible outcome) are allowed within the answer field to analyse a lack of understanding. As explained within the assumption tests, significant outliers and cases of lack of understanding/attention are removed (see appx. 7).

Alterations of this experiment

Instead of letting subjects choose between several amounts, subjects can fill the answer in freely. This reduces the possible effect of a 'response bias', especially the extreme/neutral response bias. Furthermore, the number of questions is also reduced (see table 1). This is done to shorten the experiment, preventing the decline of attention. Based on other studies, which also reduced the number of questions, the outcomes are still expected to be robust (l'Haridon & Vieider, 2016; Peon, Calvo, & Antelo, 2014; Rieger, Wang, & Hens, 2017). Nevertheless, of course, the outcomes will be less accurate than within the complete experiment, and some parameter deviations are expected compared to Kahneman and Tversky's experiment out of 1992. However, the goal of this study is not to predict the most accurate parameters for autistic individuals but only to study if the parameters significantly differ between autistic and neurotypical individuals.

Table 1: Prospect theory experimental setup

	Kahneman & Tversky (1992)	*This experiment*
Gain domain outcomes (v1, v2)	(0,50) (0,100) (0,200) (0,400) (50,100) (50,150) (100,200)	(50,0) (150,50)
Gain domain probabilities (p1)	(0.01, 0.05, 0.1, 0.25, 0.5, 0.75, 0.9, 0,95, 0.99)	(0.05, 0.25, 0.5, 0.75, 0,95)
Loss domain outcomes (v1, v2)	(0,-50) (0,-100) (0,-200) (0,-400) (-50,-100) (-50,-150) (-100,-200)	(-50,-0) (-150,-50)
Loss domain probabilities (p1)	(0.01, 0.05, 0.1, 0.25, 0.5, 0.75, 0.9, 0,95, 0.99)	(0.05, 0.1, 0.25, 0.5, 0.75, 0.9, 0,95)
Mixed domain outcomes (50/50 probability)	a b c 0 0 -25 0 0 -50 0 0 -100	a b c 0 0 -25 0 0 -150

0	0	-150
-20	50	-50
-50	150	-125
50	120	20
100	300	25

Parameter estimations

In order to estimate the parameters, this experiment uses a two-step approach, based on Kahneman & Tversky's (1992) approach. The first step consists of estimating both the median gain and loss domain parameters of the value and weighting functions, for both subject groups (equation (eq.) 5, 6 and 7). As these are strictly loss/gain domain questions, the loss aversion parameter (λ) is not relevant for the estimation of the other parameters ($\alpha, \beta, \gamma, \delta$). After the estimation of these parameters, the median loss aversion parameter is calculated for both subject groups, using the calculated parameters of step 1 (eq. 8 and 9).

The used regression method for estimating the gain and loss-domain prospect theory questions, is a two-step non-linear regression approach. The first step involves estimating the approximated parameters, using the Levenberg-Marquardt (LM) algorithm. Within the second step, those estimated parameters serve as the starting point, and also serve to determine the boundaries for the Sequential Quadratic Programming (SQP) algorithm, with 500 bootstraps (see appendix 7 for more details). Equation 7 indicates the regression formula for these estimations. In order to reduce the length, the control variables are summarized in the variable 'cv'. Furthermore, the outcomes are always ordered from most extreme to least extreme, as required within prospect theory.

The mixed domain prospect theory parameter is estimated in an OLS regression, with the proper gain and loss domain prospect theory value and weighting function, for both the ASD and neurotypical group, as calculated in the previous step (see eq. 9).

$$CPT - value = risky\ lottery \rightarrow V^{+}(€_{s}) = (W^{+}(p_{1}) * V^{+}(€_{o1}) + (1 - (W^{+}(p_{1})) * V^{+}(€_{o2}) \quad (5)$$

$$CPT - value = risky\ lottery \rightarrow V^{-}(€_{s}) = (W^{-}(p_{1}) * V^{-}(€_{o1}) + (1 - (W^{-}(p_{1})) * V^{-}(€_{o2}) \quad (6)$$

$$€_s = (\left(\left(\left(\frac{p_1^{(\gamma+\beta 1*autism+\beta_n*cv)}}{\left(p_1^{(\gamma+\beta 1*autism+\beta_n*cv)} + (1-p_1)^{(\gamma+\beta 1*autism+\beta_n*cv)}\right)^{\frac{1}{(\gamma+\beta 1*autism+\beta_n*cv)}}}\right) * \left(€_1^{(\alpha+\beta 1*autism+\beta_n*cv)}\right)\right) + \left(\left(1-\left(\frac{p_1^{(\gamma+\beta 1*autism+\beta_n*cv)}}{\left(p_1^{(\gamma+\beta 1*autism+\beta_n*cv)} + (1-p_1)^{(\gamma+\beta 1*autism+\beta_n*cv)}\right)^{\frac{1}{(\gamma+\beta 1*autism+\beta_n*cv)}}}\right)\right) * \left(€_2^{(\alpha+\beta 1*autism+\beta_n*cv)}\right)\right)\right)^{\frac{1}{(alpha+\beta 1*autism+\beta_n*cv)}} + \epsilon \quad (7)$$

$$0 = lottery\ [(W^-(0.5) * V^-(c) + W^+(0.5) * V^+(x)] \quad (8)$$

$$[W^+(0.5) * V^+(x)] = \beta 0(= constant) + [W^-(0.5) * V^-(c)] * (\beta_1(=\lambda) + \beta 2 * \text{autism} + \beta_n * cv) + \epsilon \quad (9)$$

Incentive structure

Following the study of Kahneman & Tversky (1992), this study does make use of a fixed incentive structure within this experiment.

Robustness check

As a robustness check, the outcomes of this experiment are compared to previous experiments by other authors.

3.3.2 Ellsberg's Two-Urn Task

In order to study differences in ambiguity aversion between the ASD and neurotypical group, this study uses Ellsberg's two-urn task within both the gain and the loss domain. The two-urn task is chosen as it makes it easier to compare the results to a previous study by Fujino et al. (2017). However, it should be noted that this study uses a somewhat shorter approach to reduce the needed time (Fujino et al.'s study used 320 trails in total).

Experiment

this experiment uses a shortened version of Gneezy, Imas, & List's (2015) experimental setup. Instead of the twenty possible choices, ranging from strong ambiguity loving to strong ambiguity aversion, the most extreme outcomes are removed, as they are highly unlikely to be chosen, based on previous experiments (Fujino et al., 2017; Gneezy, Imas, & List, 2015). Furthermore, in order to determine the baseline utility function for both the ASD and neurotypical groups - which are needed to estimate the alpha maxmin parameter accurately and to prevent overestimation - this study uses the outcome of the prospect theory utility function instead of the Expected Utility (EU) theory (Gneezy, Imas, & List, 2015). Additionally, within this experiment, the subject must choose a colour and choose if he wants to win if this colour is drawn from urn_{known} or if drawn from $urn_{unknown}$; to prevent a bias due to a colour preference. Furthermore, this experiment is played in both the gain and loss domain. Within the gain domain, the payment structure is as follows: if the chosen colour is drawn from the chosen urn, the payment equals: 1: if the chosen urn is URN_{known}, it equals 200 tokens, 2: If the chosen urn is $URN_{unknown}$, it depends on the round{180, 190, 195, 200, 205, 210, 215, 225, 235, 250, 290}. Every round, the payment of $URN_{unknown}$, is increased to determine the switching point. Within the loss domain, a similar approach is used. The loss of URN_{known} equals 200, and the loss of $URN_{unknown}$ increases every round {100, 120, 140, 160, 180, 200, 220, 240, 260, 280, 300}. So, within the experiment, the respondent will switch from URN_{known} to $URN_{unknown}$ within the gain domain at some point and switch from $URN_{unknown}$ to URN_{known} in the loss domain. This switching point is used to determine the ambiguity aversion parameter.

Statistical tests

First of all, all responses with unstable preferences are removed (multiple switches). After that, on the remaining sample, the ambiguity aversion is measured. This is done for each subject individually, based on the switching point between urn_{known} and $urn_{unknown}$. With those switching points, the alpha-maxmin parameter is calculated (eq. 10 & 11 for the gain domain, and eq. 12 & 13 for the loss domain), of which the average parameter is used within the analyses. This is all measured under the assumption of a utility-maximizing individual (see equation 1, prospect theory).

$$\begin{cases} 0.5 * U(200) > \alpha_a * 0 + (1-\alpha_a) * u(tokens_{unknown})\ if\ subject\ prefers\ urn_{known} > urn_{uknown} \\ 0.5 * U(200) < \alpha_b * 0 + (1-\alpha_b) * u(tokens_{unknown})\ if\ subject\ prefers\ urn_{known} < urn_{uknown} \end{cases} \tag{10}$$

$$\alpha_{maxmin} = a_a \bigcap \alpha_b \tag{11}$$

$$\begin{cases} 0.5 * U(-200) > \alpha_a * u(tokens_{unknown}) + (1-\alpha_a) * 0\ if\ subject\ prefers\ urn_{known} > urn_{uknown} \\ 0.5 * U(-200) < \alpha_b * u(tokens_{unknown}) + (1-\alpha_b) * 0\ if\ subject\ prefers\ urn_{known} < urn_{uknown} \end{cases} \tag{12}$$

$$\alpha_{maxmin} = a_a \bigcap \alpha_b \tag{13}$$

In order to measure the differences between the two groups (ASD and Neurotypical), while also taking the various control variables into account, an OLS regression analysis is used (equation 14). And, furthermore, in order to test the hypothesis of equivalent (H7) within the loss domain, the TOST test of equivalence is used. This test is run within the 'TOSTER' package of 'R'.

$$\alpha = \beta 0 + \beta 1 * autism + \beta n * control\ variables + \epsilon \tag{14}$$

Incentive structure

The effect of incentives on the choices is not exactly clear, some studies suggest no significant effect, while other studies suggest some effect (Abdellaoui, Baillon, Platido, & Wakker, 2011; Gneezy, Imas, & List, 2015). Due to the limited budget, this experiment has chosen to not use a variable incentive. But instead, the respondent is also paid from the fixed minimal payment of 3 euros.

Robustness check

As a robustness check, the outcomes of this experiment are compared to previous experiments by other authors. Furthermore, as an additional robustness check of the influence of the utility function, the regression is also run with the outcome of the 'EU' utility function instead of prospect theory, and with the same utility function for both the ASD and neurotypical group.

3.3.3 Ultimatum Game

As explained in chapter two, this experiment uses the ultimatum game from the proposer's and the responder's perspectives. All players play the game from both perspectives. Furthermore, the players are randomly matched to each other and do not know whether the other player is neurotypical or autistic (to avoid a bias).

Proposer

The proposer first receives an explanation of the 'rules of the game'. After that, he receives a fixed sum of money, ten euros, and has to state how much he is willing to offer to the responder (offer).

Responder

The responder also starts by receiving an explanation of the 'rules of the game'. After that, it is explained that the proposer is given a fixed sum of money and that he has to state the minimum amount he will accept (min).

Incentive structure

Existing research is still inconclusive about the reliability of hypothetical payments within ultimatum game experiments, and the effects on autistic individuals are yet unknown (Forsythe, Horowitz, Savin, & Sefton, 1991; Gillis & Hettler, 2007). Therefore, in order to make the experiment as close as possible to real life, this experiment uses a real payment:

- If the amount proposed by the proposer (offer) is higher than or equal to the minimum amount the responder will accept, both parties will be paid out, according to the proposer's offer. This pay-out equals 1/10 of the proposed amount in real money.

- If the amount proposed by the proposer (offer) is lower than the minimum amount that the responder will accept, neither party will be paid out.

Statistical test

To test for significant differences between the ASD and neurotypical group, this part uses a regression analysis with ASD as a dummy variable.

$$Ultimatum\ Propose = \beta 0 + \beta 1 * \text{autism} + \beta_n * control\ variables + \epsilon \tag{15}$$

$$Ultimatum\ Minimal\ Acceptable\ Offer = \beta 0 + \beta 1 * \text{autism} + \beta_n * control\ variables + \epsilon \tag{16}$$

Robustness check

As a robustness check, the outcomes of this experiment are compared to previous experiments by other authors.

3.3.4 Dictator Game

Within the dictator game, the proposer starts by receiving an explanation of the 'rules of the game'. Thereafter, he receives a fixed sum of money, 10 euros, and has to state how much he is willing to offer to the other party (offer).

Incentive structure

This experiment also uses a real payment, following the ultimatum game. The offer, divided by ten, is paid out to the random-matched 'receiver'. The remaining amount (10-offer) divided by ten, is paid out to the proposer.

Statistical test

To test for significant differences between the ASD and neurotypical group, this part uses a regression analysis with ASD as a dummy variable.

$$Dictator\ Propose = \beta 0 + \beta 1 * \text{autism} + \beta_n * control\ variables + \epsilon \tag{17}$$

Robustness check

As a robustness check, the outcomes of this experiment are compared to previous experiments by other authors.

3.4 Control Variables

In order to accurately research the effects of autism on the decisions within the different domains, this research also includes control variables to ensure that differences are not caused by any other effects.

IQ

This research includes a simple measurement of IQ in order to control for differences in choices between higher and lower IQ. IQ is measured using the Matrix Reasoning test of the public-domain ICAR project, which contains 11 stimuli similar to Raven's progressive matrices (International Cognitive Ability Resource Team, 2022). A non-weighted measure is used to determine the final IQ, wherein each correct answer is given a weight of one. Thus, the possible range of IQ is 0-11. In order to make the results easier to interpret, to reduce multicollinearity, and to make the estimates more valid, the variable IQ is centred with a mean of seven.

Interaction between autism and IQ

There is also an interaction term added between autism and the IQ dummy. According to some researchers, within autistic individuals, IQ is closely related to autism severity, where a higher IQ indicates a lower severity (Freitag et al., 2009; Kanne et al., 2011; Mayes & Calhoun, 2011). Thus, in order to control for the effect of autism severity, without including the time-consuming direct measure of symptom severity (of which the AQ test with 50 questions is the most used variant), this variable is used. Furthermore, this variable is based on the centred version of IQ, with a mean of seven.

Education

The level of education is also measured, as it can be expected that people with a lower degree of education might make other choices, for example, due to them having less knowledge about economics and maybe being more sensitive to biases (Sajid & Bhardwaj, 2021). This measure is included within the regressions as a dummy variable 'higher educated', which is valid for all respondents with an education of one of the following types (according to the Dutch system): HBO[12] bachelor & master, University bachelor & master, PhD, a doctorate degree.

Gender

Gender is also included to control for possible genderial differences. This is added within the regression as a double dummy variable, with 'male' and 'non-binary' being the dummies and female being the reference group.

[12] Hoger BeroepsOnderwijs / University of Applied Sciences. Is roughly similar to a College in the US.

Age

Age in years is included as a control variable. Age differences can explain differences between groups, for example, due to past life experiences, differences in education, etc. The used variable is the centred version of age, with a mean of 30.

Received training

A dummy variable was added to indicate whether the autistic individual has received training, for example, training like ‘theory of mind’. Those training programmes aim to help autistic individuals function better in society, which might result therein that those autistic individuals will also behave more like their neurotypical counterparts. However, the high correlation coefficient with the autism dummy, combined with the relatively low number of observations within this study, unfortunately, made the removal of this dummy variable necessary.

Level of financial literacy

The individual’s financial literacy level was measured using three questions, ranging from very simple to more complicated, based on the ‘Big Three’ questions from Lusardi and Mitchell (2011) (see appendix 5).

Duration

The total duration (in seconds) is included as a control variable for two main reasons. First of all, a longer duration might indicate that the individual more thoroughly reads the question and thinks about it (thus potentially using more system two thinking). However, a longer duration might also indicate a lack of understanding.

3.5 Assumption Tests

The assumption tests for all three domains (prospect theory, Ellsberg's urn and the social domain) are summarized in this chapter. A complete overview of the assumption tests is available in appendix seven.

3.5.1 Significant Outliers

All the regressions have been tested for significant outliers, manually and using cook's distance. Only significant outliers that indicate a lack of understanding, a lack of attention and/or a likely typographical error are removed. Other influential outliers are not removed, as they are likely to possess 'real' data and thus should not be removed (Field, 2018).

3.5.2 Multicollinearity

The data is tested for multicollinearity using the VIF statistic and collinearity table within SPSS. Given the high degree of correlation between the 'autism training dummy' and the 'autism dummy' (correlation coefficient >0.8) within the various regressions, it has been decided to remove the variable from all the analyses. All other variables are well below the critical level across the regressions.

3.5.3 Heteroscedasticity

All regressions are tested for heteroscedasticity using scatterplots, and the Breusch-Pagan test where possible. Based on this analysis, a correction was deemed necessary within all three domains of prospect theory. Within the gain and loss domain, it was corrected by using bootstrapping with 500 iterations. Within the OLS regression of the mixed domain, it was corrected by bootstrapping with 1000 iterations and a Bias-Corrected accelerated confidence interval. Those methods are seen as the best available methods today within SPSS (Field, 2018; IBM, 2022).

3.5.4 Normal Distribution of Residuals

Although not an essential parameter within a regression with a larger sample (N>50), it has also been tested if the residuals are normally distributed using the P-P plot function of SPSS and the histogram (Field, 2018; Lumley, Diehr, Emerson, & Chen, 2002). Based on this analysis, all variables are found to be reasonably normally distributed within all domains except the mixed-domain prospect theory. However, this does not cause a problem within the mixed-domain prospect theory, as that regression already uses a form of robust standard errors (bootstrapping) and has a large enough sample.

3.5.5 Independent Residuals

Within all the OLS regressions, it has been tested if the residuals are independent using the Durbin-Watson test. As expected within a cross-section dataset, the residuals are independent. Within the non-linear regressions of prospect theory, this cannot be tested. However, based on the evidence in the other domains, it is very unlikely that the residuals are correlated within this domain.

3.5.6 Linearity Between the Independent Variables and the Dependent Variable

Within all the regressions, it has been tested if the relationship between the independent variables and the dependent variable is linear. Only within the ultimatum and dictator game there was one correction necessary, namely adding IQ as a squared term.

3.6 Descriptive Statistics

In total, there are 150 responses. After controlling for completeness, the built-in attention check and the screening criteria, 70 responses remain. Hereof, 42 belong to the neurotypical group and 28 to the autism group. Of those 70 responses, 13 are not fully complete (due to the user not fully finishing the experiment and/or improper understanding of prospect theory). An overview of the main descriptive statistics is provided in table two.

Table 2: Descriptive statistics

	Autism group	*Neurotypical group*
Gender distribution	14 males, 1 non-binary and 13 females	19 males and 23 females
Age distribution	Mean = 26 years (kurtosis = 1.7, skewness = 1.2)	Mean = 31 years (kurtosis = -0.1, skewness = 1.0)
Intelligence distribution (0-11)	Mean = 6.8612 (kurtosis = -1.1, skewness = 0.1)	Mean = 7.1 (kurtosis = -1, skewness = -0.3)
Higher Educated (HBO and higher)	79%	76%
Financial literacy (0-3)	Mean = 2.64/3	Mean = 2.69/3

3.7 Imputation

There are some cases of missing data of the dependent variable, namely: 13 missing responses in the prospect theory experiment, of which 11 belong to the neurotypical group; within the gain-domain ambiguity task there are 17 cases of missing data (4 of the asd group), due to users not finishing the experiment, inconsistent behaviour and a too high/low ambiguity aversion; within the loss-domain ambiguity task, there are 18 cases of missing data (4 of the asd group), due to the same reasons; within the dictator game, there are 10 cases of missing data; within the ultimatum game proposer side, there are 10 cases of missing data; within the responder's side of the ultimatum game, there are also 10 cases of missing data (in all those 3 cases, 2 responses belong to the ASD group). In order to prevent a possible bias, those missing variables within both Ellsberg's urn as within the ultimatum and dictator game are imputated, using multiple imputations with ten iterations, with Predictive Mean Matching, which is seen as the best method available today (IBM, 2022). Within prospect theory, missing data is not imputated; since those questions were at the beginning of the experiment, imputation would prove to be difficult as there is fewer data of those subjects to ensure an accurate imputation. When considering the missing data, it is not missing completely at random, as they are mostly missing within the neurotypical group, primarily due to respondents not fully finishing the experiment. However, this does not cause any problem, as the neurotypical group has fourteen more responses in total. Furthermore, a possible bias is also mitigated since autism is a dummy variable within the regression. Any other relationship between the missing data and other variables could not be discovered.

4 Results

This chapter delivers an overview of the results of this research. Therefore, this chapter is split into the three main research topics. Within each topic, the results and the tests of the hypotheses are presented. To provide a quick overview, the header of the rejected hypotheses are highlighted in red.

4.1 Prospect Theory

Below, the results of the non-linear regression predictions of the alpha, beta, delta and gamma parameters, are shown in table three. The prediction of the lambda parameter (loss aversion) is provided in table four. Within the gain and loss domain – thus not within the mixed domain – the variable age is made non-centred due to the unique nature of a non-linear SQP regression. Furthermore, the variable duration and higher education are removed, due to a low explanatory power combined with an 'abnormal' effect within the SQP-based regression and high correlation coefficients, respectively (see appx. 7 for more details).

Table 3

Panel A: Regression Coefficients for Predicting the Alpha and Gamma Parameters of Prospect Theory (eq.7)
R^2=.886, DF of the regression = 15, DF of the residual = 596, 252 observations in ASD group, 360 observations in neurotypical group

Parameter	Unstandardized coefficients B	Std. Error	95.0% Confidence Interval for B Lower Bound	Upper Bound
Alpha	0.890***	0.000	0.890	0.890
Gamma	0.613***	0.088	0.440	0.785
Alpha Autism	0.100***’’’	0.000	0.100	0.100
Alpha Autism IQ Interaction	-0.019	0.044	-0.105	0.067
Alpha Age	0.001***	0.000	0.001	0.001
Alpha Male	0.050***	0.000	0.050	0.050
Alpha Non-Binary Gender	0.072	0.140	-0.203	0.348
Alpha IQ	0.005	0.014	-0.023	0.034
Alpha Financial Literacy	0.010***	0.000	0.010	0.010
Gamma Autism	0.028	0.031	-0.034	0.089
Gamma Autism IQ Interaction	0.020	0.023	-0.026	0.065
Gamma Age	0.001	0.003	-0.004	0.006
Gamma Male	0.050	0.046	-0.039	0.140
Gamma Non-Binary Gender	-0.065	0.129	-0.318	0.187
Gamma IQ	0.011	0.007	-0.004	0.025
Gamma Financial Literacy	0.030***	0.000	0.030	0.030

Panel B: Regression Coefficients for Predicting the Beta and Delta Parameters of Prospect Theory (eq.7)
R^2=.893, DF of the regression = 15, DF of the residual = 413, 203 observations in ASD group, 336 in neurotypical group

Parameter	B	Std. Error	Lower Bound	Upper Bound
Beta	0.840***	0.000	0.840	0.840
Delta	0.552***	0.059	0.436	0.667
Beta Autism	0.110***’’’	0.001	0.108	0.112
Beta Autism IQ Interaction	-0.050***	0.001	-0.053	-0.047
Beta Age	0.001***	0.000	0.001	0.001
Beta Male	0.050***	0.000	0.050	0.050
Beta Non-Binary Gender	-0.010	1.055	-2.083	2.063
Beta IQ	0.000	0.001	-0.001	0.001
Beta Financial Literacy	0.009	0.072	-0.132	0.151
Delta Autism	-0.016	0.032	-0.080	0.047
Delta Autism IQ Interaction	0.009	0.012	-0.014	0.032
Delta Age	-0.001	0.002	-0.005	0.003
Delta Male	0.081**	0.037	0.008	0.154
Delta Non-Binary Gender	-0.015	1.573	-3.105	3.075
Delta IQ	0.023***	0.008	0.007	0.039
Delta Financial Literacy	0.026	0.040	-0.053	0.105

*, **, *** indicates 90%, 95%, 99% two-sided confidence, respectively. `. ``. ```. indicates 90%, 95%, 99% one-sided confidence, in the hypothesized direction, respectively. B = unstandardized beta.

Hypothesis 1

H0: high-functioning autistic people do not have a more linear cumulative weighting function, compared to neurotypical individuals, within the gain domain.
Ha: high-functioning autistic people have a more linear cumulative weighting function, compared to neurotypical individuals, within the gain domain.

The null hypothesis of h1 cannot be rejected. The outcomes of this study do not reveal a significant influence of autism on the weighting parameter of prospect theory ('Gamma Autism' parameter in table 3, $\beta = 0.028; 95\%\ CI\ [-0.034, 0.089]$).

Hypothesis 2

H0: high-functioning autistic people do not have a more linear cumulative weighting function, compared to neurotypical individuals, within the loss domain.
Ha: high-functioning autistic people have a more linear cumulative weighting function, compared to neurotypical individuals, within the loss domain.

The null hypothesis of h1 cannot be rejected, as this study does not find a significant influence of autism on the delta parameter of prospect theory ('Delta Autism' parameter in table 3, $\beta = -0.016; 95\%\ CI\ [-0.080, 0.047]$),. A possible reason can lie therein that autistic individuals do indeed overweight small probability losses more, due to a feeling of fear, but do otherwise have a weighting function quite alike neurotypical others. Due to the relationship between the weighting and value function, this excess CE only for low probability outcomes can show itself within an increase of the value function parameter, instead of within the weighting parameter (see appx. 4).

Hypothesis 3

H0: the prospect theory value function of high-functioning autistic individuals is not more linear than that of neurotypical individuals, in the gain domain.
Ha: the prospect theory value function of high-functioning autistic individuals is more linear than that of neurotypical individuals, in the gain domain.

Based on the results of the non-linear regression, the null-hypothesis of h3 must be rejected ('Alpha Autism' parameter in table 3, $\beta = 0.100; 95\%\ CI\ [0.100{,}0.100]$), as the evidence predicts a more linear gain-domain value function for autistic individuals, represented by an increased alpha parameter.

Hypothesis 4

H0: the prospect theory value function of high-functioning autistic individuals is not more linear than that of neurotypical individuals, in the loss domain.
Ha: the prospect theory value function of high-functioning autistic individuals is more linear than that of neurotypical individuals, in the loss domain.

The results of the analysis indicate that the null hypothesis of h4 must be rejected ('Beta Autism' parameter in table 3, $\beta = 0.110, 95\%\ CI\ [0.108, 0.112]$). Thus, the evidence predicts that autistic individuals have a more linear loss-domain value function than the neurotypical individuals.

Additionally, there is also tested for large differences in the Alpha/Beta and Gamma/Delta parameters for autism, with the (50,0) prospect compared to the (150,50) prospect. As the Alpha/Beta has a much higher effect on the CE within the (50,0) domain compared to the (150,50) domain, it has been tested to ensure that the Alpha/Beta would not have been overpredicted in the (50,0) domain and/or underpredicted in the (150,50) domain (see appx. 8). Based on the evidence, no significant degree of over and/or under predicting between those domains can be detected.

Table 4

Regression Coefficients for Estimating the Lambda Parameter of Prospect Theory (eq.9)
R^2=.379, DF of the regression = 10, DF of the residual = 105, 51 observations in ASD group, 65 observations in neurotypical group

	Unstandardized Coefficients			95,0% Confidence Interval for B	
	B	Std. Error	Sig.	Lower Bound	Upper Bound
Constant	2.361***	0.438	<.001	1.503	3.220
Lambda	3.359***	0.033	.000	3.295	3.424
Interaction variables with loss-domain CPT value:					
Age	-0.009***	0.002	<.001	-0.013	-0.006
Higher Educated	-0.973***	0.028	<.001	-1.028	-0.918
Male Dummy	0.837***	0.022	.000	0.794	0.880
Non-Binary Dummy	3.924***	0.064	.000	3.798	4.050
Autism Dummy	0.770***	0.023	<.001	0.726	0.815
Autism IQ Interaction	-0.291***	0.008	<.001	-0.307	-0.275
IQ	0.006	0.006	.363	-0.007	0.018
Financial Literacy	-0.148***	0.020	<.001	-0.188	-0.109
Duration (in seconds)	0.000***	0.000	<.001	0.000	0.000

*, **, *** indicates 90%, 95%, 99% two-sided confidence, respectively. \`. \`\`. \`\`\`. indicates 90%, 95%, 99% one-sided confidence, in the hypothesized direction, respectively. B = unstandardized beta. Sig. = two-sided p-value.

Hypothesis 5

H0: high-functioning autistic people have a loss aversion parameter not lower than that of neurotypical individuals.

Ha: high-functioning autistic people have a loss aversion parameter lower than that of neurotypical individuals.

The results of this study indicate that the null hypothesis of h5 cannot be rejected (‘Autism Dummy’ in table 4, $\beta = 0.770, two - sided\ p < .001$). Based on this evidence, autistic individuals are more loss-averse, contrary to the prediction. However, a significant two-way interaction effect on lambda with autism and IQ is also found (‘Autism IQ Interaction’ in table 4, $\beta = -0.291, two - sided\ p < .001$). Given that IQ is strongly related to autism severity (see 3.4), autism severity has a significant effect on the loss aversion parameter. For the average autistic individual within this study (as IQ is centered), the loss aversion is thus higher than for the average neurotypical individual. However, autistic individuals with a lower IQ – thus a more severe degree of autism – have a much higher loss aversion. This higher degree of loss aversion, and the significance of this interaction effect, can have various reasons. It was predicted that autistic individuals were less vulnerable to this framing effect. However, it can very well be that this lower degree of vulnerability only comes into play for autistic individuals with lower symptom severity. Given that IQ, by itself, is not a significant variable, it does not seem likely that IQ predicts the general ability of all respondents to recognize the ‘framing effect’.

Graphically, the outcomes of the prospect theory regressions lead to the following value (figure 2) and weighting function (figure 3 and 4), of both the asd group (red) and neurotypical group (blue). Thus, as also shown within those graphs, autistic individuals are not more rational within the weighting function, but do show a higher degree of rationality within the value function, and are also more loss averse.

Figure 2: Value function

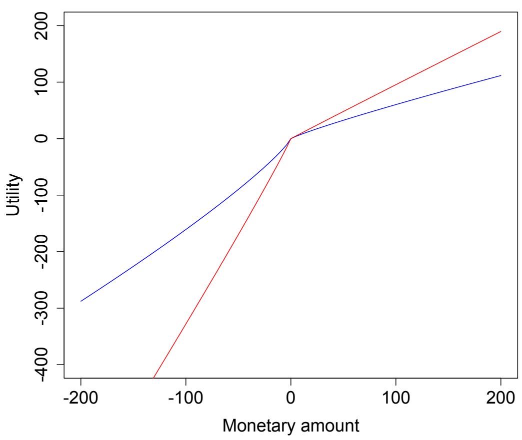


Figure 3: Gain-domain weighting function

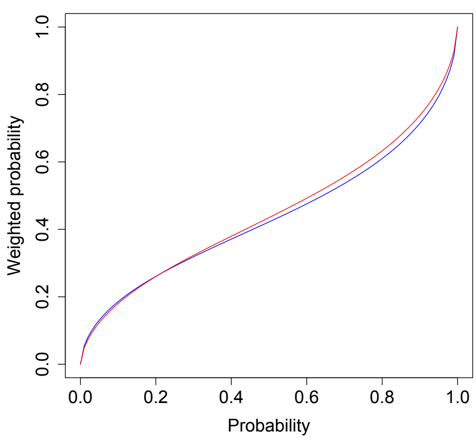
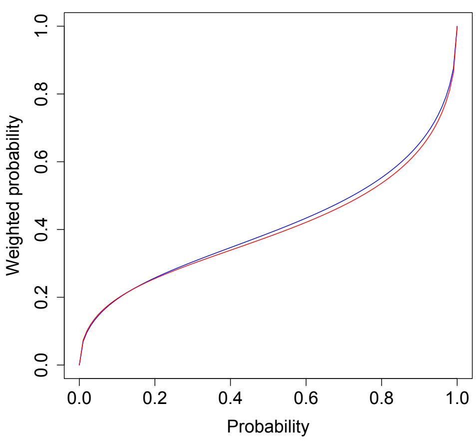


Figure 4: Loss-domain weighting function



ASD group

Neurotypical group

4.2 Ellsberg's URN

Table five provides the outputs of the OLS prediction of Ellsberg's urn α-maxmin parameters of the gain and loss domain, respectively.

Table 5

Panel A: Regression Coefficients for Predicting the Ellsberg's Urn Gain-Domain Parameters (eq. 14)
R^2=.196, Adj. R^2=.071, DF of the regression = 9, DF of the residual = 60, 28 observations in ASD group, 42 observations in neurotypical group

	Unstandardized Coefficients			95,0% Confidence Interval for B	
Variable	B	Std. Error	Sig.	Lower Bound	Upper Bound
Constant (alpha)	0.508***	0.014	.000	0.480	0.535
Autism Dummy	0.003	0.010	.799	-0.017	0.022
Higher Educated Dummy	0.022	0.016	.168	-0.010	0.054
Male Gender Dummy	0.002	0.011	.888	-0.020	0.024
Non-Binary Gender Dummy	0.005	0.042	.897	-0.076	0.087
Age Centered	0.000	0.001	.792	-0.001	0.002
Financial Literacy Centered	-0.006	0.011	.597	-0.027	0.015
Autism <> IQ Interaction Centered	0.002	0.004	.580	-0.006	0.011
IQ Centered	0.002	0.003	.448	-0.003	0.007
Duration in Seconds	0.000	0.000	.213	-0.000	0.000

Panel B: Regression Coefficients for Predicting the Ellsberg's Urn Loss-Domain Parameters (eq. 14)
R^2=.118, Adj. R^2=-.020, DF of the regression = 9, DF of the residual = 60, 28 observations in ASD group, 42 observations in neurotypical group

Variable	B	Std. Error	Sig.	Lower Bound	Upper Bound
Constant (alpha)	0.539***	0.033	.000	0.474	0.604
Autism Dummy	0.025	0.027	.361	-0.029	0.078
Higher Educated Dummy	-0.003	0.044	.950	-0.090	0.085
Male Gender Dummy	-0.001	0.029	.971	-0.059	0.057
Non-Binary Gender Dummy	-0.104	0.107	.331	-0.314	0.106
Age Centered	-0.001	0.002	.412	-0.005	0.002
Financial Literacy Centered	0.025	0.028	.367	-0.030	0.081
Autism <> IQ Interaction Centered	-0.006	0.012	.613	-0.029	0.017
IQ Centered	-0.002	0.007	.829	-0.016	0.013
Duration in Seconds	0.000	0.000	.771	-0.000	0.000

*, **, *** indicates 90%, 95%, 99% two-sided confidence, respectively. `. ``. ```. indicates 90%, 95%, 99% one-sided confidence, in the hypothesized direction, respectively. B = unstandardized beta. Sig. = two-sided p-value.

Hypothesis 6

H0: high-functioning autistic individuals are not less ambiguity averse, in a gain domain Ellsberg's urn task, compared to neurotypical individuals.
Ha: high-functioning autistic individuals are less ambiguity averse, in a gain domain Ellsberg's urn task, compared to neurotypical individuals.

The null-hypothesis of h6 cannot be rejected ('Autism Dummy' in table 5 Panel A, $\beta = 0.003; two - sided\ p = .799$). Based on this evidence, autistic people do not appear the have a lower degree of ambiguity aversion, than that of the neurotypical individuals. A likely reason is that ambiguity aversion is mainly caused by a "fear of negative evaluation", as stated in chapter 2.4. However, given that this is an online experiment, which is fully anonymous, there is (almost) no negative evaluation possible. Thus, this causes both the neurotypical and the autism group to behave almost completely rational, thereby disallowing this analysis to find differences between those two groups.

Hypothesis 7

H0: high-functioning autistic individuals have a different ambiguity aversion, in a loss domain Ellsberg's urn task, than neurotypical individuals.
Ha: high-functioning autistic individuals are just as ambiguity averse, in a loss domain Ellsberg's urn task, compared to neurotypical individuals.

The null-hypothesis of h7 cannot be rejected. Based on a TOST test of equivalence, with a lower and upper bound of 0.03 for equality, the groups are not equivalent ($two - sided\ p = .427; \beta \leq -0.03\ p = .021; B \geq 0.03\ p = .427$). Thus, even though the regression analysis does not find a significant p-value for the autism dummy, the outcomes neither indicate a 95% confidence of no significant difference between the groups.

Concludingly, within the ambiguity gain domain, the evidence does not support a higher degree of rationality for autistic individuals. A likely cause for this inability to find differences, was the high degree of rationality also present within neurotypical individuals.

4.3 Ultimatum and Dictator Game

Table six, seven and eight provide the OLS prediction of the ultimatum game and dictator game, respectively.

Table 6

Regression Coefficients for Predicting the Ultimatum Game Proposed Amount (eq. 15)
R^2=.328, Adj. R^2=.211, DF of the regression = 10, DF of the residual = 57, 28 observations in ASD group, 40 observations in neurotypical group

	Unstandardized Coefficients			95,0% Confidence Interval for B	
Variable	B	Std. Error	Sig.	Lower Bound	Upper Bound
Constant	5.041***	0.439	.000	4.395	5.596
Autism Dummy	-0.176	0.273	.520	-0.706	0.358
Higher Educated Dummy	0.398	0.368	.273	-0.319	1.122
Male Gender Dummy	-0.467*	0.287	.097	-1.030	0.086
Non-Binary Gender Dummy	-3.547***	1.022	.000	-5.540	-1.568
Age Centered	0.004	0.017	.826	-0.030	0.037
Financial Literacy Centered	0.109	0.252	.669	-0.384	0.598
Autism <> IQ Interaction Centered	0.163	0.119	.173	-0.070	0.387
IQ Centered	-0.045	0.071	.507	-0.185	0.092
IQ Squared	-0.026	0.022	.227	-0.069	0.016
Duration in Seconds	-0.000	.000	.150	0.000	0.000

*, **, *** indicates 90%, 95%, 99% two-sided confidence, respectively. `. ``. ```. indicates 90%, 95%, 99% one-sided confidence, in the hypothesized direction, respectively. B = unstandardized beta. Sig. = two-sided p-value.

Table 7

Regression Coefficients for Predicting the Ultimatum Game Minimum Acceptable Offer (eq. 16)
R^2=.208, Adj. R^2=.062, DF of the regression = 10, DF of the residual = 56, 28 observations in ASD group, 39 observations in neurotypical group

	Unstandardized Coefficients			95,0% Confidence Interval for B	
Variable	B	Std. Error	Sig.	Lower Bound	Upper Bound
Constant	3.967***	0.703	.000	2.585	5.349
Autism Dummy	-0.738*``	0.387	.057	-1.498	0.022
Higher Educated Dummy	0.144	0.565	.799	-0.966	1.254
Male Gender Dummy	0.168	0.454	.711	-0.723	1.060
Non-Binary Gender Dummy	-2.263	1.569	.149	-5.338	0.812
Age Centered	0.047	0.027	.082	-0.006	0.099
Financial Literacy Centered	0.140	0.398	.725	-0.641	0.920
Autism <> IQ Interaction Centered	0.178	0.173	.303	-0.161	0.517
IQ Centered	-0.174	0.103	.090	-0.376	0.027
IQ Squared	-0.012	0.038	.748	-0.086	0.062
Duration in Seconds	0.000	0.000	.637	-0.001	0.000

*, **, *** indicates 90%, 95%, 99% two-sided confidence, respectively. `. ``. ```. indicates 90%, 95%, 99% one-sided confidence, in the hypothesized direction, respectively. B = unstandardized beta. Sig. = two-sided p-value.

Table 8

Regression Coefficients for Predicting the Dictator Game Proposed Amount (eq. 17)
R^2=.224, Adj. R^2=.082, DF of the regression = 10, DF of the residual = 56, 28 observations in ASD group, 39 observations in neurotypical group

	Unstandardized Coefficients			95,0% Confidence Interval for B	
Variable	B	Std. Error	Sig.	Lower Bound	Upper Bound
Constant	4.050***	0.817	.000	2.437	5.664
Autism Dummy	0.271	0.433	.531	-0.577	1.120
Higher Educated Dummy	0.057	0.594	.924	-1.110	1.224
Male Gender Dummy	-0.917*	0.503	.069	-1.906	0.073
Non-Binary Gender Dummy	-3.854**	1.703	.024	-7.192	-0.517
Age Centered	0.004	0.028	.882	-0.051	0.060
Financial Literacy Centered	-0.564	0.431	.191	-1.410	0.282
Autism <> IQ Interaction Centered	-0.158	0.197	.421	-0.545	0.228
IQ Centered	-0.028	0.112	.807	-0.249	0.193
IQ Squared	0.000	0.039	.997	-0.078	0.078
Duration in Seconds	0.000	0.000	.450	0.000	0.001

*, **, *** indicates 90%, 95%, 99% two-sided confidence, respectively. \`. \`\`. \`\`\`. indicates 90%, 95%, 99% one-sided confidence, in the hypothesized direction, respectively. B = unstandardized beta. Sig. = two-sided p-value.

Hypothesis 8

H0: high-functioning autistic individuals do not have a lower minimal acceptable offer, in the ultimatum game, than neurotypical individuals.
H8: high-functioning autistic individuals have a lower minimal acceptable offer, in the ultimatum game, than neurotypical individuals.

Based on the results, the null hypothesis of h8 must be rejected ('Autism Dummy' in table 7, $\beta = -0.738; one - sided\ p = .029$). The results do thus indicate that autistic individuals indeed accept lower offers than their neurotypical counterparts.

Hypothesis 9

H0: high-functioning autistic individuals do not propose a higher amount than neurotypical individuals, in the ultimatum game.
Ha: high-functioning autistic individuals propose a higher amount than neurotypical individuals, in the ultimatum game.

The results do not indicate that autistic individuals propose a higher amount than neurotypical individuals in the ultimatum game (‘Autism Dummy in Table 6, $\beta = -0.176; two - sided\ p = .520$), thus the null hypothesis cannot be rejected.

Hypothesis 10

H0: high-functioning autistic individuals do not propose a lower amount than neurotypical individuals, in the dictator game.
Ha: high-functioning autistic individuals propose a lower amount than neurotypical individuals, in the dictator game.

The results do not indicate that autistic individuals propose a lower amount than neurotypical individuals, within the dictator game (‘Autism Dummy’ in Table 8, $\beta = 0.271; two - sided\ p = .531$). The null-hypothesis thus cannot be rejected. Based on the results of H9 and H10, it does not seem likely that autistic individuals act more rational, at the cost of other parties, within these types of tasks. Neither does it seem likely, that the ‘fear of rejection’ is significantly higher within autistic individuals. As the fear of rejection indicates the difference between the ultimatum game and dictator game, which is not significantly greater for autistic individuals (also see appx. 10).

Concludingly, the results indicate that autistic individuals are not willing to offer less money to other parties, both in situations that allow ‘punishment’ and in situations that do not. However, autistic individuals are more willing to accept unfair offers. Thus, autistic individuals can be somewhat more rational, depending on the situation.

5 Conclusion & Discussion

This research analysed if autistic individuals differ in their economic behaviour, compared to a neurotypical control group, in situations with risk, ambiguity, and social risk/factors. This is analysed using an online experiment with twenty-eight autistic and forty-two neurotypical respondents from the Netherlands, matched on age, gender and level of education. Hereby, this study contributes to the existing literature by gaining many first-ever insights into the economic decision-making of autistic individuals.

Prospect theory

Concludingly, this research reveals that autistic people follow a more linear value function and thus are likely more rational from a homo-economicus point of view, when making economic decisions. However, contrary to the prediction, this research's outcomes also indicate that autistic people behave according to a non-linear weighting function, roughly similar to that of their neurotypical counterparts. Furthermore, when considering the loss aversion parameter, it is found to be higher for autistic individuals, contrary to the prediction. However, a strong negative interaction effect with IQ is also found for the ASD group, but only within this loss aversion parameter. Given that IQ is negatively correlated with ASD severity, it indirectly demonstrates that more severe cases of ASD are much more loss averse than the less severe cases (see 3.4).

Combining the prospect theory functions reveals that autistic people are likely to follow a more linear utility function and are less driven by diminishing sensitivity within the value-function domain. However, it also indicates that high-functioning autistic people, just like their neurotypical counterparts, are likely to overweight low and underweight high probabilities. Though, it is not yet fully known why autistic people as well show this non-linear weighting function. As described in chapter 2.2, the main two reasons for the non-linearity of this function are the feeling of 'fear' and 'hope', and the effect of diminishing sensitivity (Kahneman & Tversky, 1992; Trepel, Fox, & Poldrack, 2005). But, neither of those two reasons can justify it. As stated in chapter 2.2, diminishing sensitivity should be less within autistic individuals, as they are likely to be less emotion-biased in making decisions. Furthermore, considering the feeling of hope and fear, based on the functioning of the amygdala and other parts of the Medial Temporal Lobe, they should be mainly affected by the feeling of fear (see chapter 2.2). However, only the combination of hope and fear can explain this weighting function (Trepel, Fox, & Poldrack, 2005). A likely cause could thus be that autistic individuals are more influenced by emotions and biases, as previously thought.

When comparing these results to the previous study of Fujino et al. (2017) and of Gosling & Moutier (2018) – whom both used the Expected Utility (EU) function instead of prospect theory -, it leads to the following findings. Fujino et al. (2017) did not find significant differences within the gain domain, and

Gosling & Moutier (2018) saw a higher degree of risk aversion for autistic individuals in the gain domain. This is thus contrary to the findings of this study. Within the loss domain, both Fujino et al. (2017) and Gosling & Moutier (2018) found significantly lower risk-seeking behaviour in ASD individuals. Thus, within the loss domain, the results are comparable, but within the gain domain, the results of this study are contradictory to the results of Golsing & Moutier (2018). Regarding the found differences, it has been tested using an additional regression analysis, if the cause might be the use of EU instead of prospect theory within those studies. The lack of finding differences might be caused hereby, but not the reversed behaviour within the gain domain (see appendix 9). Furthermore, the age, IQ, and selection criteria of the selected sample are comparable to this study, which shows that the selected individuals are relatively similar on those control variables and are likely to have a similar gradation of autism (Freitag et al., 2009; Kanne et al., 2011; Mayes & Calhoun, 2011). However, it should be noted that both the study of Gosling & Moutier (2018) and Fujino, et al. (2017) mainly included males (19% and 12.5% female, respectively) and did not control for gender differences. Another possible reason for the differences might be the design of those studies and questions, as both of those studies let the subjects choose between a risky vs sure lottery instead of letting subjects fill in a Certainty Equivalent (CE). Other possible differences could be cultural differences or other undefined differences between the studies.

As an additional robustness check, the determined parameters of the neurotypical group are also compared to previous studies. The value and weighting function are found to be comparable to previous studies, both within the loss and gain domain. Off those four parameters, the loss-domain weighting parameter (delta) displays, by far, the largest deviation compared to Kahneman & Tversky's study (1992) (0.552 in this study, compared to their parameter of 0.69). However, even this deviation lies well within the expected range, as previous studies indicated that these parameters can have large deviations - delta, for example, mostly lies between 0.45-0.85 - due to multiple differences within the sample, such as culture, gender and age, and differences between parameter estimation methods (Glöckner & Pachur, 2012; Nilsson, Rieskamp, & Wagenmakers, 2011; Rieger, Wang, & Hens, 2017). When considering the loss aversion parameter (lambda), it is found to be somewhat higher than in most studies (3.34 instead of Kahneman & Tverksy's 2.25), but not alarmingly so, as it lies well within the range of previous studies (Abdellaoui, Bleichrodt, & Paraschiv, 2007; Kahneman & Tverksy, 1992; Nilsson, Rieskamp, & Wagenmakers, 2011). The exact reason for this difference is unknown, but it could well be due to cultural reasons. But, nevertheless, based on those robustness checks, the outcomes are expected to be very robust.

In practice, these results thus indicate that autistic individuals are more likely to purchase products that are based on the overweighting and underweighting of outcomes, such as lotteries and insurances; given that they estimate the probability roughly similar, but their utility function results therein that they apply a higher certainty equivalent to the low-probability high-monetary-amount outcomes. Furthermore, their higher degree of loss aversion would result therein that autistic subjects are more ‘afraid’ of losses and thus are more likely to buy products that prevent losses (e.g., insurance) and are likely less willing to invest money in stock markets. However, the more linear utility function found within this experiment, associated with a reduction in diminishing sensitivity and Weber-Fechner law sensitivity, would result therein that in real-life autistic individuals are also more likely to look at their overall wealth, instead of only the wealth of a decision. This would thus result in autistic individuals being better able to assess the influence of their decisions on their entire wealth and hereby being likely less influenced by behavioural biases.

But, to examine the behaviour of autistic individuals more accurately within the risky domain, more research is needed. For example, to understand why autistic people behave quite similarly to neurotypical individuals only within the value and not within the weighting function, and to understand the differences between this study’s findings and Gosling & Moutier’s (2018) within the gain domain. This new research would preferably use neuroimaging techniques, such as MRIs, to determine the involved brain areas more accurately within prospect theory’s weighting and value functions. Because if the amygdala and other parts of the Medial Temporal Lobe are indeed involved in the weighting function, it might be the case that these areas perform better in some ways within high-functioning autistic individuals than what is currently known. However, it can also reveal that other brain areas may be involved in such decisions. Moreover, such possible new evidence would not only help within the analysis of autism but also within the analysis of the effect of other brain anomalies (e.g., Alzheimer’s, ADHD, Parkinson’s, epilepsy, etc.) on human decision-making. Furthermore, to better determine the precise behaviour within prospect theory, and not face a too high risk of diminishing attention, it would be useful to run a prospect theory experiment with more questions, without the other experiments and the relatively lengthy IQ test. Other possibilities would be to take a closer look at how the found differences will affect their investment behaviour. With this, a helpful addition would also be to measure if there are differences between myopia sensitivity between autistic and neurotypical individuals. Another possibility would be to take a closer look at the effects of loss aversion and its associated biases, such as the endowment effect.

Ambiguity domain

When considering decision-making under ambiguity, this research does not find a significant difference in the gain domain, with barely any ambiguity aversion for both the ASD and neurotypical groups. This contradicts the findings of Fujino et al. (2017), who discovered that the ASD group was significantly less ambiguity averse than the neurotypical group, within the gain domain. A likely reason for the inability to find intergroup differences within this research, lies therein that within this study, the neurotypical group is almost ambiguity neutral as well. This could be due to cultural differences, between the Dutch respondents of this study, compared to the Japanese respondents of the study of Fujino et al. (Adachi et al., 2013), and, given the differences in the experimental design, the design of this study might appear more anonymous thereby reducing the 'fear of negative evaluation', which is seen as the main reason of ambiguity aversion (see chapter 2.3). When considering the loss domain, this study's outcomes do not show a significant difference between the ASD and neurotypical group (supporting the prediction). However, the results are not strong enough to accept the alternative hypothesis of no difference between the ASD and neurotypical groups. Those findings are in line with the finding of Fujino, et al. (2017). Thus, it seems that ambiguity aversion is almost similarly present in autistic and neurotypical respondents, in both the gain and loss domain, in situations without social interaction, with Dutch respondents. In practice, this results therein that autistic individuals will not behave differently compared to their neurotypical counterparts, in cases with unknown risk (e.g., when accepting a lottery, when making investment decisions).

Furthermore, as an additional robustness check, the results of the neurotypical group are also compared to previous studies. When considering the study that used the exact same approach within the gain domain, the study of Gneezy, Imas & List (2015), that study found a slightly higher ambiguity aversion (0.54, compared to the parameter of 0.51 in this study). This slightly higher degree of ambiguity aversion within their study, could be due to the less anonymous design of their study (pencil and paper, resulting in a higher 'fear of negative evaluation') or due to cultural differences. But also when considering other studies that used alpha maxmin within a lab experiment, both within the gain and loss domain, the results are found to be comparable (Dimmock, Kouwenberg, Mitchell, & Peijnenburg, 2015; Liu & Onculer, 2017). Thus, based on these robustness checks, the outcomes are expected to be robust.

When considering possibilities for future research, it would be useful to research ambiguity aversion within a field and/or natural experiment, or a lab experiment that allows a 'fear of negative evaluation', as real-life economic decisions are often made in situations involving social interaction. Especially as the 'fear of negative evaluation' is seen as the main reason for ambiguity aversion, and is expected to come into play in situations whereby there is social interaction and/or the outcome of the decision can be judged by others. Researching this would help to gain a deeper understanding of how autistic people are likely to make different choices in real-life situations with unknown risk, both in cases where they can act in the way they prefer (as researched in this experiment) and in situations whereby their behaviour is altered due to social evaluation of their decisions. Furthermore, an additional direction for future research would be incorporating neuroimaging (e.g., MRIs, CTs, PETs, etc.). This would allow gaining a deeper understanding of the involved brain areas within such types of decisions, both in situations that would allow a 'fear of negative evaluation' and situations that do not. This helps to better comprehend the autistic brain and the effect of a social context on the involved brain areas, both of ASD and neurotypical respondents. In practice, this would support in understanding the impacts different situations might have on autistic individuals, and if certain conditions might make autistic individuals more/less vulnerable. For example, if autistic people would be more/less vulnerable to ambiguous offers, both in situations where they are in a social context (e.g., on the street, with friends, etc.), and in circumstances where they are not in a social context (such as online without others). Furthermore, it helps to gain a deeper understanding of the 'social brain' of autistic individuals. And additionally, this increase in neurological and neuroeconomic knowledge would also help predict the effects of other brain anomalies (e.g., Alzheimer's, etc.) on decision-making under ambiguity. Another possible direction for future research is to research the impact of real variable monetary incentives on the outcomes, both of neurotypical and autistic respondents.

Ultimatum & Dictator game

When considering the proposer's side of the ultimatum and dictator game, no significant differences are found between the ASD and neurotypical groups. Furthermore, when considering the difference in the offered amount between the dictator and ultimatum game (see appx. 10), no significant difference is found either. In practice, this results therein that autistic individuals are similarly influenced by the feeling of 'altruism' (as measured in the dictator game), and the 'fear of rejection' (as measured by the difference between the ultimatum and dictator game) as their neurotypical counterparts. This is thus contrary to the dominant stereotype view of the self-interested autistic person, who is less interested in others' welfare (Baron-Cohen S., 2005; Draaisma, 2009). Furthermore, this also contradicts the findings of Ikuse, et al. (2018), who discovered that neurotypical respondents gave less within the UG. The exact reason for the difference between that experiment and this is unknown. Possible causes include cultural differences (Dutch vs Japanese respondents) and that they did not include control variables within the regression. Another striking difference is the study design. Within the study of Ikuse et al. (2018), the respondents did not have a free-to-choose amount; instead, the respondents could only choose between five possible amounts (0-100% evenly distributed). It could well be that autistic individuals have a different response bias, making them more likely to choose the middle option.

Furthermore, contrary to other studies, no significant difference is found between dictator and ultimatum game, both for the ASD and neurotypical groups (see appx. 10) (Forsythe, Horowitz, Savin, & Sefton, 1991; Novakova & Flegr, 2013). It could be that due to cultural differences, Dutch respondents offer more due to a feeling of 'altruism' (Chai, Dorj, Kim, Liu, & Sherstyuk, 2018; Oosterbeek, Sloof, & Kuilen, 2003). This higher offered amount would decrease the chance of rejection, thereby reducing the difference between the dictator and the ultimatum game. Furthermore, as all three of these experiments used a real monetary incentive, it could also be the case that this reduced the feeling of anonymity and thereby increased the 'fear of negative evaluation'. This would likely lead to a higher offered amount, and even (slightly) more so for the autistic individuals, within both the UG and DG proposals (Davidson, Vanegas, & Hilvert, 2017; White, Bray, & Ollendick, 2012).

When considering the responder's side of the UG, differences are found between the ASD and neurotypical groups. In support of the hypothesis, this research found, just like Tei et al. (2018), that autistic individuals do accept lower offers. There are multiple reasons why they might do so. A possible explanation, supporting the outcome of the other experiments and the neurological views, could be that autistic individuals want to act more rationally, when it affects their own welfare and it does not directly hurt other's welfare, but do not want to act selfish, at the direct cost of other parties. Another possible reason, also in support of the neurological views and the outcomes of the other experiments, is that the 'fear of negative evaluation' influences autistic individuals more, and thus they are afraid that rejecting another's offer is negatively evaluated. However, the outcomes also show that autistic individuals still are willing to reject very low offers. Thus, even though they are less likely to reject offers, they would still somewhat be willing to punish others for selfish behaviour.

In order to ensure the robustness of the results, the robustness of the neurotypical control group is also tested. The offered share within the UG for the neurotypical group is somewhat higher than the average amount worldwide (50% in this study, compared to around 40% worldwide), but lies well within the deviation found between existing studies (Chuah, Hoffmann, Jones, & Williams, 2007; Oosterbeek, Sloof, & Kuilen, 2003). When considering the difference between the ultimatum and dictator game for an average respondent, it is found to be positive, albeit somewhat smaller than in previous studies (around 20% difference, compared to ±35% in previous studies) (Novakova & Flegr, 2013; Gneezy & Charness, 2008). Thus, this sample might be somewhat more driven by the feeling of altruism. When considering the responder's side of the ultimatum game, the minimum accepted percentage is around 47%, thus comparable to previous studies with a low-monetary amount, albeit also slightly above average (Cameron, 2007; Novakova & Flegr, 2013). Consequently, the results are expected to be robust, but it should be noted that the neurotypical group appears to be driven slighly more by the feeling of 'fairness' than within most studies.

Concludingly, this combination of findings has numerous implications. Because it illustrates that high-functioning autistic individuals would mostly behave just like their neurotypical counterparts, and thus not act more selfishly. In practice, this would result therein that autistic individuals would not give lower amounts of money to others in anonymous settings, and hence not behave opportunistically. But furthermore, it also shows that autistic individuals would accept lower offers. This makes them more rational, but if the others are aware thereof, it as well makes them more vulnerable to opportunistic behaviour. Additionally, it demonstrates that autistic individuals are social human beings who also care about the feeling of others.

For future research, there exists a wide degree of possibilities. A possible research direction would be to research the ultimatum and dictator game, in situations with less anonymity to predict how autistic individuals would behave in such conditions. It could well be that autistic individuals would behave differently in such situations due to the increase of the 'fear of negative evaluation'. Hereby, three possible situations can be tested: semi-anonymous online matching with a known other party (e.g., a friend, family, etc.), real-life matching with an unknown other party, and real-life matching with a known other party. This would aid in understanding how the increased level of social anxiety might influence their decisions in situations with more and less social interaction. This would help to predict better how autistic individuals would behave towards individuals with a small and large social distance, both in anonymous and non-anonymous settings. Would they, for example, act more/less altruistic when the situation is in real life, and how does it affect their decisions if they know the other party? It could be that they want to be more altruistic to people they know, but it could also well be that they are more 'afraid' of strangers.

Future research

Another possible direction would include 'scaling' to measure if the autistic group behaves differently than the neurotypical group, when the money at stake increases. Furthermore, it could also be worthwhile to include a direct measure of autism symptom severity (such as the autism quotient). This aids in examining the effect of symptom severity on made choices and in reviewing how good IQ is as a predictor for autism severity. For example, an increase in brain anomalies within more severe cases, could lead to more severe cases being worse at mentalising others and maybe caring less about others, which might make them behave differently.

Altering the 'pairing' would be another possibility for future research, which can also be combined with the abovementioned options. This involves letting both the ASD and neurotypical subjects know if they are paired against a neurotypical or ASD counterparty. From the neurotypical domain, this would help to examine if a neurotypical individual would behave differently towards autistic individuals, which can help with understanding if it makes autistic individuals vulnerable to opportunistic behaviour when others are aware of their autism. From the autism perspective, it aids in understanding if autistic individuals would want to behave differently towards neurotypical individuals compared to autistic individuals. This would, for example, aid in understanding if autistic individuals behave in a certain way, only due to a 'fear of negative evaluation' of their neurotypical counterparts. With this, this experiment could also involve other types of 'games' to examine how the society might treat autistic individuals differently in various situations. And, furthermore, this experiment can be broadened even furthermore, by also adding some 'qualitative' questions, in order to discover the reasons for why the subjects make certain choices.

Other directions for future research could include, a more thorough investigation of why there exists a strong correlation between IQ in autistic individuals, with risk aversion in prospect theory (mixed domain), but not in other domains and experiments. Given these outcomes, it seems that IQ within autistic individuals is strongly correlated with specific behavioural anomalies, which only shows itself in certain decisions. Research on this phenomenon would help to better comprehend the relationship between IQ and the autistic brain, and how this relationship could affect the decisions and everyday life of both high and low-IQ autistic individuals. Other directions for future research would be to take a closer look at the practical implications of these experiments. For example, how does the increased degree of rationality found within the prospect theory's value function affect the investment behaviour of autistic individuals; does this make them better investors? And what the effects are from a personal finance perspective. Do autistic individuals behave differently with their budgeting; are they less or more driven by short-term buying decisions, which might affect their ability to chase their long-term (saving) goals? Do autistic individuals face more difficulty when making decisions under time pressure[13]? Do autistic individuals manage their own budgeting more rationally? Etc. Alternatively, research on how autistic individuals are less/more influenced by cognitive biases (e.g., anchoring effects, the illusion of control, base rate fallacy, hyperbolic discounting, decoy effect, etc.) is also a valuable direction for future research. All these types of research can also be built upon the foundation built within this study; given that, for example, prospect theory is highly related to a wide degree of behavioural biases.

[13] Some studies show that autistic individuals need more time to make decisions and face difficulties when making quick decisions, which can lead to the feeling of anxiety (triggering the amygdala). However, in real-life, decisions often have to be made under time pressure.

Limitations

This study has some limitations. First of all, it only used Dutch respondents to better control for cultural differences. For future studies, with a larger budget, it is advisable to use a more worldwide sample in order to examine the effect of regional differences. Another limitation of this study is that it used a shortened approach of Prospect Theory. The goal hereof was to detect if there are differences between the ASD and neurotypical group, which can be explored in greater detail within future research, using a far broader question set. Another constraint of this study is that it is based on an online experiment. This can lead to a variety of problems, such as the lack of attention, the too large difference with real-life situations, etc. and response biases, such as: answering conforming to the social norms (social desirability bias), respondents might fill in the answer that they think the researcher wants (demand characteristics), and extreme/middle responding (only filling in middle outcomes or extreme outcomes). Various measures are taken to reduce those effects, such as build-in attention checks, open questions (to prevent extreme/middle responding), outlier tests, lack-of-understanding tests, variable payment structures, and reducing the number of similar questions to avoid a decrease in attention. Nevertheless, biases remain a problem for online & lab experiments. For future research, combining an online/lab experiment with a field or natural experiment would thus be beneficial.

Furthermore, although the sample size is relatively small, it is comparable to previous studies (see chapter 3 for more details). Nevertheless, for future studies, it would be helpful to use a larger sample size, by seeking co-operations with autism training facilities, hospitals, diagnosis centres, etc. Besides, although the regressions did control herefore, both the ASD and the neurotypical sample are skewed towards a higher educated group with a lower average age than the typical Dutch population. Another limitation of this study is that it only indirectly controlled for autism severity through the correlation between IQ and autism severity. Given that the most used test for autism severity – autism quotient – consists of fifty questions, and previous studies did not find a significant correlation, it has been decided not to include a direct test. However, it could be a useful addition to a future study, especially since this can also be used to ensure that subjects do not falsely report to which group they belong (ASD or neurotypical).

However, even though some improvements are possible, the outcomes are still expected to be robust, especially for Dutch respondents and countries with a similar culture. Besides, for other cultures, the intergroup differences are also expected to be fairly robust, as both the neurotypical group and autism group are affected by the cultural differences.

General conclusion

This research has widespread implications from an economic and a social perspective. It illustrates that the stereotype picture of a rational autistic person, who mainly cares about himself, is untrue. Based on these experiments, there is no evidence that autistic people care more about themselves at the (economic) cost of others. They may lack some social skills and face difficulties processing (other's) emotions and mental states, which might give others the feeling of a lower degree of altruism. But based on their economic choices, these anomalies do not make the decision-making of high-functioning autistic adults more selfish. As a result, this supports an urgent need to change the dominant stereotype picture of autistic individuals, as it is incorrect and can result in a lack of proper societal support. Changing this picture is a complicated process, as this involves changing the stereotypical view there still exists worldwide. Moreover, the movement from different 'forms' of autism (e.g., Asperger's, PDD-NOS, etc.) towards only one form of autism in the newest versions of DSM and ICD, might make this process even harder. Nevertheless, governments and international institutions should have a clear role herein, given that a proper understanding of those people would result in better societal support for this important group, which is still poorly understood today. Another critical role lies at the (international) media, filmmakers, and writers, which should provide a more accurate and less stereotypical description of autistic individuals. Furthermore, the findings indicate that autistic individuals might be more vulnerable to opportunistic offers from other parties. This creates a role for the coaching facilities, which should adequately train autistic individuals to deal with such situations.

From an economic perspective, this experiment shows that high-functioning autistic people are slightly more rational than neurotypical others but are far from the perfect *homo economicus*. They have a more linear utility function and are less likely to reject offers from others at the cost of their own welfare. However, autistic individuals are also more loss-averse at the same time, especially those with a lower IQ. Furthermore, based on the evidence provided in this study, it seems as if autistic individuals only behave more rational when their decision primarily affects their own welfare and not so when it negatively affects others. So, based on this, autistic individuals are not likely to be far different within everyday decisions and thus also not incapable of making such decisions. But, given their choices under risk, they might be somewhat 'better' at making everyday economic decisions under risk but also be more willing to avoid the possibility of losses. Nevertheless, most of all, this research is a foundation for future research. Given that there is yet so much unknown about autism from an economic perspective, this research mainly aimed to explore how autistic individuals make different everyday economic decisions, due to their behavioural and neurological anomalies. Future research should explore all individual findings in much greater detail, preferably while also using neuroimaging, to fully understand how and why autistic individuals differ from others and what the implications thereof are.

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Appendix 1: A Detailed Overview of Autism

The History of ASD Diagnosis Over Time

The diagnosis of autism started with Kanner's (1943) article in 1943, which discovered autistic disturbances in eleven cases within children below eleven years old (Kanner, 1943). According to this article, there are multiple key phenomena. The children have all shown an extreme demand for aloneness from the early beginning of life. When in a room with other people/children, they avoid contact as much as possible and prefer to play alone. When asked a question, they typically do not respond, and when asked multiple times, they just respond to 'get over with it and go back to what they were doing'. Next to that, the children can have an excellent relationship with objects that do not interfere with their aloneness and whereover they have control. They can also be very caring or even angry, towards those objects.

Another critical phenomenon is their excessive desire for sameness and rigidness (Kanner, 1943). Those children face difficulties when routines change, when everyday patterns change, and even when furniture moves. Those children like routines even in playing, for example, arranging blocks by colour and jumping up and down twice after they finish. In a linguistic context, this desire also causes another critical phenomenon. Namely, the excellent rote memory[14], wherein they remember exact sentences of others, but the inability to use language in any other way than the once remembered (Kanner, 1943). For those children, the remembered sentences/words are more of a memory exercise instead of something for the purpose of communication. So, those children often exactly repeat sentences said by others. This also results in the words having rigid meanings for them, and they thus face difficulty when words have multiple meanings or are used figuratively. Furthermore, this repetition of sentences also causes them to use 'you' to express themselves and the use of 'I' to express others, which gradually declines after the age of six years (Kanner, 1943). However, this continuous memory training by remembering exact sentences might also develop an exceptional rote memory. In later life, they can use this, for example, to reproduce complex mathematical formulas, or to learn for exams wherein they only have to remember exact knowledge without its meaning (Stevens & Bernier, 2013).

According to Kanner (1943), an interesting common denominator was that all those children came from highly intelligent families, with parents who were not warm-hearted and had a busy life. This might have contributed to the condition of these children, as those children have had less social interaction in early life, and thus come into a world without the ability to form the usually provided affective contact with people (Kanner, 1943). However, later studies found that autism is based on neurological anomalies and is thus not caused by the parent's busy life (see appx. 2).

[14] Memory used when recalling (factual) information, be it for example an exact sentence or formula.

But, the real development of autism diagnosis started in the 1980s, as it was added in the 3rd edition of the APA's DSM, within the class of pervasive developmental disorders (PDD) (APA, 1980). However, by then, the focus was still on infantile autism. Fundamental phenomena were: "a lack of responsiveness to other people, gross impairment in communicative skills, and bizarre responses to various aspects of the environment, all developing within the 30 months of age" (APA, 1980). Furthermore, there was still doubt if autism was the earliest form of schizophrenia or if they are two different conditions. Key features were a low IQ (<70), under or over responsiveness to sensory stimuli and rhythmic body movements. Furthermore, it was then still seen as very rare, with 2-4 cases per 10,000 and a ratio of 3:1 between boys and girls (APA, 1980).

In the third revision of DSM - DSM-III-R - there were some significant improvements to better address autism in childhood phases, which also showed itself in the renaming of 'infantile autism' to 'autistic disorder' (APA, 1987; Volkmar & Reichow, 2013). Furthermore, they also introduced 'Pervasive Developmental Disorder Not Otherwise Specified) (PDD-NOS) as a separate subclass of PDD, which, by that time, was seen as a 'milder' form of autism. Criteria of typical autism were also revised to become more extensive and include symptoms from social and communication categories, and resistance to change (APA, 1987). However, the major problem with this new definition, was that it led to overdiagnosis of autism in higher-IQ individuals and underdiagnosis at the lower end (Volkmar & Reichow, 2013).

So, extensive changes were necessary and have been made in DSM-IV. This included large literature reviews, data reanalysis and a global multi-site field trial, with around 1000 cases (Volkmar & Reichow, 2013). The goal hereof was to improve sensitivity and specificity across age and the IQ range, and to increase the convergence with ICD-10 (Volkmar & Reichow, 2013). Those changes also included the addition of three new disorders (next to the two existing, autistic disorder and PDD-NOS):

Rett's disorder

This is mainly found in females and is characterized by regular very early (before ±6 months) development, which then deteriorates into a pattern that includes loss of speech, uncontrolled body movements, respiratory problems and social unresponsiveness (Swedo, 2010).

Childhood disintegrative disorder (Heller's syndrome)

This is characterized by a period of normal development for around the first four years, followed by a large developmental deterioration and the development of typical autistic symptoms (Volkmar & Reichow, 2013).

Asperger's syndrome

This is a mild form of autism and is characterized by major problems in social and nonverbal communication, combined with repetitive behaviour and limited interests. A key distinction between Asperger's and other types of ASD is a near-normal linguistic development, normal intelligence and the lack of verbal communication difficulties (Faridi & Khosrowabadi, 2017). However, this addition caused much controversy, not only because of the ongoing discussion about the name Asperger's syndrome (Asperger's syndrome is named after Hans Asperger, and there is much controversy about if he did or did not 'euthanize' many children, as they did not fit into 'Das Dritte Reich') but also because of an unclear definition that made it difficult to properly diagnose if someone had Asperger's syndrome or PDD-NOS (APA, 1994; Baron-Cohen, Klin, Silberman, & Buxbaum, 2018; Herwig, 2019; Volkmar & Reichow, 2013).

The Current Diagnosis of ASD

After ±80 years of progress after Kramer's study, much progress has been made. Much more is known about autism, especially about less severe cases, and the diagnosis ratio has increased from 2-4 cases per 10,000 in the late 70s to 1-2 cases per 100 people today (APA, 1980; Joon, Kumar, & Parle, 2021). This severe rise is primarily due to heightened awareness in society and improved/changed diagnosis and diagnosis criteria, especially for mild forms. But, partially, also due to environmental factors, generally heightened parental age at birth, and biological factors (Joon, Kumar, & Parle, 2021; Rice et al., 2012; Chiarotti & Venerosi, 2014).

Considering the current diagnosis, the newest global norms are DSM-5 and ICD-11. Key distinctions between the newest and previous versions include an even closer alignment between DSM and ICD, such that diagnoses become more comparable throughout the world, and the removal of 'language problems' as a characteristic of autism (APA, 2013; World Health Organization, 2019). Next to that, they also place a bigger emphasis on unusual sensory sensitivities, which are often found in people with ASD. Furthermore, no distinctions between different types of disorders are made anymore. Nowadays, they all are diagnosed with ASD. Based on other conditions (such as a delay in language development), they receive additional diagnoses, such as developmental language disorder (Lord & Jones, 2012). Rett's was, for example, removed due to ASD behaviours being only noticeable in a brief period during development, and due to the etiological condition of Rett's, compared to the behavioural definition of ASD (Swedo, 2010). PDD-NOS and Asperger's were removed due to the difficulties in distinguishing those two (Volkmar & Reichow, 2013). Therefore, instead, in DSM-5, there is a distinction made between the severity of ASD, ranging from level one to three. Moreover, those levels are diagnosed separately for both key symptoms 'social communication' and 'restricted, repetitive behaviour', so a person can be diagnosed on level 1 for 'social communication' and level 2 for 'restricted, repetitive behaviour', for example. A brief overview of those three levels is described in table 9 (APA, 2013).

Table 9 (APA, 2013)

Level of severity	**Social communication**	**Restricted, repetitive behaviour**
Level 1 "requiring support"	- Without support, they have noticeable social communication impairments. - Can appear to have decreased interest in social interactions. - Attempts to make friends are odd and typically unsuccessful. - Speaks full sentences.	- Extreme difficulty in coping with change. - Restricted/repetitive behaviours markedly interfere with function in all ways. - Great distress/difficulty changing focus/action.

Level 2 "requiring substantial support"	- Deficits in verbal and nonverbal communication. - Limited initiation of social interaction. - Speaks simple sentences.	- Inflexibility/difficulty with change/repetitive behaviours appear frequently enough to be obvious to a casual observer. - Distress/difficulty changing focus or action.
Level 3 "requiring very substantial support"	- Severe deficits in verbal and nonsocial communication skills - Very limited initiation of social interactions. - Few words of intelligible speech.	- Causes significant problems in functioning in one/or more contexts. - Difficulties in switching between activities. - Problems of organization and planning that hinders independence.

However, removing those terms also caused controversy in multiple ways. One problem is that it reduced the diagnosis sensitivity to higher functioning levels of autism (PDD-NOS and Asperger's), with studies expecting that around 20% overall, and an even higher percentage in high-function autism of people diagnosed with ASD under DSM-IV, do not reach today's criteria, which can result in a lack of service eligibility for those people (Hosseini & Molla, 2021; Volkmar & Reichow, 2013). Furthermore, people diagnosed with Asperger's or PDD-NOS might be more reluctant to say that they have autism instead of Asperger's or PDD-NOS, due to the generally more positive social perception of those disorders compared to autism (Martin, 2012).

Nonetheless, despite the growing coherence between ICD-11 and DSM-5, there are still some important differences between those two. A significant difference is that the ICD-11 provides much more detailed guidelines for distinguishing autism with and without an intellectual disability, while, conversely, DSM-5 only states that autism and an intellectual disability can co-occur (APA, 2013; Volkmar & Reichow, 2013; World Health Organization, 2019). Another key distinction is that ICD-11 is designed to work globally, and therefore places less emphasis on the type of play that children partake in, as this can significantly differ between cultures and countries (Volkmar & Reichow, 2013). But instead, it focuses more on whether those kids follow 'strict rules' in playing, which is a typical behaviour of autistic children (World Health Organization, 2019). Furthermore, another minor difference is that DSM-5 is a strict guideline, while ICD-11 is a somewhat 'looser' and focuses more on the clinician's observations.

Conclusion

The diagnosis of ASD has progressed much over time. From the early study and diagnosis of Kanner in 1943 towards the inclusion of ASD in DSM-III and the large changes in DSM-IV. This large change especially led to huge progress due to the far better scientific foundation and the classification of sub-types, which helped diagnose milder forms. However, the introduction of those subtypes also caused some controversy, especially due to the inclusion of Rett's disorder and the difficulty of distinguishing between Asperger's and PDD-NOS. All the research from the past led to today's newest norms, DSM-5 and ICD-11, which are more aligned than ever before and moved away from the subtypes of autism, towards just one diagnosis of ASD, with three levels of severity, and additional diagnoses that are used to explain other conditions (such as lingual development disorders).

Appendix 2: A More Detailed Overview of the Neurological Aspects

Medial Temporal Lobe Anomalies

The medial temporal lobe (MTL) is an essential part of the human brain, as it is responsible for the perception of the world, storing (factual) information (such as remembering people, locations, books), emotions, the understanding of others' emotions and moving information from short to long-term memory. Furthermore, it is also highly involved in Theory of Mind (ToM) - this is about recognizing and understanding others' feelings, emotions and thoughts (mental states), and thereby also understanding how others will likely react to behaviour (Happe et al., 1996). This is also highly correlated - and often confused - with the concept of 'mentalizing', which is about predicting and explaining what others do, and why they do so (McLaren & Sharp, 2020). However, research suggests that multiple areas within the MTL and the interconnectedness of the areas are affected within autistic individuals (Bachevalier & Loveland, 2006). Hereunder, this subparagraph offers an overview of each part of the MTL, and how those parts are affected within autistic individuals.

Amygdala

the amygdala is a small, almond-shaped part of the brain and is part of the limbic system (Barak & Feng, 2016). It consists of thirteen nuclei divided into three clusters: the deep nuclei that are primarily responsible for sensory processing, the superficial regions that play a role in loving and sexual behaviour, and the other nuclei (Baron-Cohen S. et al., 2000). Generally, the amygdala is seen as the central component of the 'social brain'. Its role includes processing emotional reactions, anxiety, recognizing emotions from faces, memory processing and face recognition (Bachevalier & Loveland, 2006; Barak & Feng, 2016).

However, generally, the amygdala is one of the most important anomalies in the autistic brain and is responsible for a significant degree of the less-social behaviour and a higher degree of anxiety, typical for ASD individuals (Baron-Cohen S. et al., 2000). Regarding the cerebral volume (the size of the entire brain) and amygdala size of ASD-diagnosed individuals, which has been extensively researched using fMRIs[15], PETs[16] and post-mortem research, the results are rather remarkable. Studies that focus on young children (between 2-4 years) suggest an increase in cerebral volume, an increase in amygdala size, and an overly large right amygdala; with an even more significant size difference for girls than for boys (Schuman, Barnes, Lord, & Courchesne, 2009; Sparks et al., 2002). However, when considering

[15] Functional Magnetic Resonance Imaging, a way to measure brain activity by measuring changes in blood flow.
[16] Positron Emission Tomography, an imaging technique using radioactivity to indirectly measure blood flow to the brain.

adults, the studies are contradictory. Some studies suggest an increase in the size of the amygdala, some suggest a decreased size, and some studies suggest no significant differences (Herrington et al., 2017).

A more recent study that compared 23 of those studies, with in total 2103 individuals, suggests an average cerebral volume and only an increase in the right amygdala volume (Kovecevic et al., 2021). When considering the number of neurons in the amygdala, such an abnormal growth pattern, with excessive growth in early life, is also seen; the number of neurons in the amygdala is found to be abnormally high in children and abnormally low in adults, according to multiple studies (Baron-Cohen S. et al., 2000; Schumann & Amaral, 2006). However, when taking the IQ into account - which is negatively correlated with severity – this abnormal pattern in both neuron brain size and neuron size seems to be much stronger within low IQ ASD individuals than in individuals with high IQ (Freitag et al., 2009; Mayes & Calhoun, 2011). Moreover, when considering the cell density, evidence suggests that the more severe the case, the larger the portions of the amygdala affected by abnormal cell densities (Bachevalier & Loveland, 2006). So, this evidence suggests that stronger forms of autism have more significant anomalies in the brain's growth pattern, cell density and neuron size.

However, while earlier studies suggest that the size of the amygdala and the number of neurons is mainly responsible for behaviour, this does not seem to be the case within ASD, as this would predict that people with ASD would be abnormally social in early life, and become relatively normal (based on the volume) or less social (based on the number of neurons) in later life (Bickart, Wright, Dautoff, Dickerson, & Barrett, 2011; Dziobek, Fleck, Rogers, Wolf, & Convit, 2006; Wegiel et al., 2014). Except, this is not the case, as the 'typical' autistic behaviour is already observed from early life, and stays so throughout their whole life. Furthermore, individuals diagnosed with Williams syndrome – a syndrome with very social behaviour – show similar anomalies in the amygdala part of the brain, based on fMRI scans (Barak & Feng, 2016). But, within autistic individuals, the study of Dziobek et al. (2006) indicate no relationship between amygdala size and social behaviour & non-verbal communication (Dziobek, Fleck, Rogers, Wolf, & Convit, 2006). This thus suggests that autistic individuals do not use the amygdala for social and emotional tasks.

Nevertheless, studies do reveal a significant negative relationship when considering the other typical phenomena of autism, restricted, repetitive behaviour and narrow interests. The smaller – especially the left - amygdala, the stronger these types of behaviour (Dziobek, Fleck, Rogers, Wolf, & Convit, 2006). Besides, a study by Herrington et al. (2017) also indicated that ASD-diagnosed individuals with a reduction in the size of the right amygdala have an increased level of anxiety.

Furthermore, lower general utilization of the amygdala can neither entirely accurately explain autistic behaviour. Because while the amygdala indeed has reduced activity during emotional processing and typical social tasks, there are also some states which can lead to hyperactivation of the amygdala, such as when autistic subjects look at faces (gazing) or when they show anxiety (Barak & Feng, 2016; Baron-Cohen S. et al., 2000; Dziobek et al., 2006; Herrington et al., 2017). Thus, evidence suggests that the amygdala is partially dysfunctional in autism, with the parts that are responsible for emotional and social behaviours being dysfunctional, but the amygdala stills seem to be able to reduce the restrictive-repetitive behaviours. However, the level of dysfunctionality also depends on the severity of autism, with higher dysfunctioning found in more severe cases (Zalla & Sperduti, 2013).

The amygdala is seen as the central component of the 'social brain', but therefore it is also highly connected with other brain parts which also influence behaviour, such as the hippocampus, prefrontal cortex, orbitofrontal cortex, anterior cingulate cortex and cerebellum (Baron-Cohen S. et al., 2000; Dziobek et al., 2006; Pitskel, Bolling, Kaiser, Pelphrey, & Crowley, 2014). Thus, studies suggest that the connection between the amygdala and those other brain areas might also be impaired, which causes the wide range of social problems associated with autism (Bachevalier & Loveland, 2006; Dziobek, Fleck, Rogers, Wolf, & Convit, 2006). And especially a significant increase in behavioural deficits when the damage is visible within the amygdala and other parts of the MTL.

Hippocampus

This is another vital part of the MTL, which serves two main roles. First of all, it serves for spatial memory/orientation and thus helps people remember where they are, navigate through cities, etc. Furthermore, it is responsible for the consolidation process, which entails storing new memories in the long-term memory (Squire, Stark, & Clark, 2004). However, it also has some other roles, such as influencing emotions, motor and hypothalamic functions[17] (Anand & Dhikav, 2012). Damage to this brain area typically shows itself in Alzheimer-like behaviour, with a loss of spatial orientation and the inability to store memories in long-term memory. Furthermore, it is also used within social interaction to remember others and their typical behaviour (Banker, Gu, Schiller, & Foss-Feig, 2021).

Considering ASD individuals they typically have problems with remembering others, storing/remembering information and navigating through cities. This thus suggests that they also have an anomaly within the hippocampus part of their brain. However, the higher-functioning autistic people generally have far less trouble remembering information and score even remarkably well on tests with rote memory and remembering details (Hill & Frith, 2003). This is also supported by the study of Bachevalier & Loveland (2006), who reported only damage to the hippocampal area and its functional connections in those with 'stronger' forms of autism and lingual problems. Considering a more recent study, the study of Richards et al. (2020) with over 400 ASD-diagnosed individuals, found a significant difference in hippocampus shape, which was even higher for males, but no difference in size. A possible

[17] Functions such as controlling body temperature, hunger, sleep, fatigue, etc.

reason could be that this study did not include the degree of autism, which could affect the size, according to some studies (Bachevalier & Loveland, 2006; Freitag et al., 2009; Hill & Frith, 2003). Furthermore, other reasons for abnormal hippocampus functioning could include legions that were not studied in existing studies, increased cell packing densities, and more severe damage to the interconnectedness of the hippocampus, with the amygdala, and other brain parts (Blatt, 2012).

Entorhinal cortex

This is another brain area within the MTL and serves as the gateway between the hippocampus and the neocortex[18]. As a result of this, it plays an essential role in the consolidation of our memory and our spatial memory. Furthermore, it pre-processes human hearing and seeing. Research also shows a similar growth pattern of the entorhinal cortex as witnessed in the amygdala, with an increase in neurons in early life and a reduction of neurons in adulthood (Baron-Cohen S. et al., 2000; Wegiel et al., 2014). Furthermore, the research of Freitag et al. (2009) also suggests that this growth pattern becomes more abnormal within stronger forms of autism. Thus, the unusual growth pattern of the entorhinal cortex can also partially explain the worse memory typically found in individuals with autism, especially those with a lower IQ (Banker, Gu, Schiller, & Foss-Feig, 2021).

Parahippocampal cortex/gyrus

The parahippocampal cortex/gyrus (PHG) is yet another part affected by the autistic brain. This brain area is responsible for multiple tasks, mostly related to the encodation and retrieval of (spacial) memory, making it closely related to the hippocampus. And more specifically, this particular area is especially evolved in remembering topographical images, such as places, landscapes, rooms, etc.; hereby, it aids in spatial memory and navigation (Squire, Stark, & Clark, 2004). However, later research suggests it is also concerned with contextual associations and emotion processing (Aminoff, Kveraga, & Bar, 2013). Thus it serves people in a wide variety of tasks: navigating through a city because it reminds people to turn left when they see a specific building, but also to understand the emotion of a song/movie scene, and to associate a face to a name.

The PHG also shows a similar growth pattern as other parts of the MTL within ASD-diagnosed individuals (Ting et al., 2020). Thus excessive volume and neuron density in early life, towards an average volume with lower neuron density in adulthood. However, in this brain area, the moderating effects of IQ are not researched. Yet, based on the same growth pattern witnessed in other parts of the MTL and a higher dysfunctioning in stronger cases of ASD, it is likely that IQ also has a modering factor in the PHG. This thus also explains the difficulties autistic people generally have to navigate, remember others, process emotions, etc.

[18] Is responsible for the higher order brain functions, such as language, cognition, abstract thinking, controlling movements and reasoning.

Perirhinal cortex

The perirhinal cortex (PRC) is the other element within the MTL and has two main tasks. The first main task is the connection of visual inputs to the brain, and hereby it helps to store visual information. Moreover, through the interconnectedness with other brain parts – mainly the hippocampus – it is also involved in recognising objects (Brown & Aggleton, 2001). Currently, no evidence suggests that autistic people have any malfunctioning in the PRC.

Prefrontal Cortex

The prefrontal cortex is an integral part of the brain, which lies in the front part of the frontal lobe. This part of the brain is responsible for controlling the executive functions, such as planning, decision making, social behaviour, short-term memory, controlling impulses, initiating new actions, adapting to change, controlling emotions, self-control and acting based on long-term goals (Bachevalier & Loveland, 2006; Hill & Frith, 2003).

Orbitofrontal cortex

The orbitofrontal cortex (OFC) – Brodmann area (BA) 10, 11, 47 – is highly connected to the amygdala and is another important brain area for the processing of emotions. While the amygdala serves to understand/perceive the emotions of others, and the ability to have emotions, the orbital frontal cortex is responsible for adapting human behaviour based on emotions (Bachevalier & Loveland, 2006). Thus, for example, an individual sees that someone else is scared (amygdala) and chooses to comfort (orbital frontal cortex) this person. Furthermore, this brain area is also responsible for reflecting taste and reward; through a process called stimulus-reinforced decision making (Rolls, 2004). This means that people change their behaviour based on the stimuli they receive; for example, people eat food they appreciate and are friendly to others who are nice to them. In an economic situation, this brain area also makes humans accept a gamble or an offer in the ultimatum game, both based on the emotional feeling (which is received through the amygdala) and the monetary reward (which is also a stimulus). Thus, damage to the OFC can have multiple consequences; it can make people more rational but at the same time also more risk-taking due to the decreased ability to react to emotions (Bachevalier & Loveland, 2006; Rolls, 2004). Furthermore, it can also reduce the human's ability to be consistent with subjective preferences, which are also closely related to emotions. However, research finds no evidence of negative effects of OFC damage on purely rational, economic value types of decisions, for the higher-functioning autistic individuals (Bachevalier & Loveland, 2006; Stalnaker, Cooch, & Schoenbaum, 2015). Thus, OFC damage primarily affects choices that rely on the interconnectedness between the OFC and other brain areas, within autistic individuals.

Regarding people diagnosed with autism, research does find anomalies in the orbitofrontal cortex, with a decrease in size of the right lateral OFC in the children and adolescents with autism, but an increase in size in adults (Bachevalier & Loveland, 2006; Hardan et al., 2006). However, newer studies that used an ultrahigh field MRI and post-mortem research did also find other anomalies within the right part of the OFC; namely, increases in grey matter and a reduction in the density of excitatory neurons (Fischi-Gomez, Bonnier, Ward, Granziara, & Hadjikhani, 2021; Liu, Bautista, Liu, & Zikopoulos, 2020). Those anomalies found within the right side of the OFC, combined with the weak connection between the amygdala and orbitofrontal cortex, as found by Bachevalier & Loveland (2006), do likely result in the typical, less emotion-driven, more rational decision-making of ASD individuals (Rolls, 2004). However, there are considerable differences between high- and low-functioning autistic individuals. In high-functioning autistic individuals, the connections to the amygdala are mostly affected, while in the lower-functioning autistic individuals, the OFC is also more affected (Bachevalier & Loveland, 2006).

Medial prefrontal cortex

The medial prefrontal cortex (mPFC) is another area of the prefrontal cortex, which consists of Brodmann areas 9-12 and 25 (Grossmann, 2013). Although there is much unknown about the precise role of the mPFC, the consensus is that it is involved with decision-making using the bigger picture and retrieving long-term memory, for example, in tasks where the brain has to recall the best actions/emotional responses to specific situations (Euston, Gruber, & McNaughton, 2012). Therefore, when the individual has to make a decision for which he needs information about the past (like the outcomes of such decisions in the past), it uses the medial prefrontal cortex. Moreover, the mPFC thereby also relies on the amygdala and hippocampus, which the mPFC uses for emotions and the recalling of recent memories, respectively (Euston, Gruber, & McNaughton, 2012; Grossmann, 2013). So, this brain area is critical in many human decisions and is essential to learn from the past.

However, among individuals diagnosed with autism, studies suggest multiple anomalies within the mPFC. In low-functioning ASD children, low blood flow in the mPFC is detected, which might explain their inability to respond in different situations appropriately (Shalom, 2009). When considering high-functioning adults, the medial prefrontal cortex performs more neurotypical. However, in tasks wherein subjects have to understand others' mental states (theory of mind tasks), a higher activation is seen in the Brodmann area (BA) 9, and a lower activation within the other BA's (Shalom, 2009). Furthermore, a significant positive relationship between the functional connectivity between the mPFC and amygdala, and social functioning is also seen; suggesting that in more severe cases of autism, the ability to integrate emotion in decisions is further reduced (Assaf et al., 2010). Another study, which considered brain activity in judgement making of high-functioning autistic adults using nonverbal content, showed significant lower activation of the mPFC area of the brain (Watanabe et al., 2012). This suggests a reduced ability of ASD individuals to judge others based on nonverbal information.

Dorsolateral prefrontal cortex

The dorsolateral prefrontal cortex (DLPFC), which consists of Brodmann areas 9 and 46, is used for multiple tasks. It is responsible for the suppression of unwanted motion and motoric, planning, executive functions, cognitive flexibility and lying (Ferng, 2022).

Within ASD, research generally finds dysfunctioning in the left part of the DLPFC, which is found to be correlated to the repetitive and restrictive behaviour found in ASD-diagnosed individuals (Fujii, et al., 2010; Gómez, et al., 2017). Furthermore, the DLPFC is closely connected to the hippocampus, which can partially explain a reduction in long-term memory within ASD subjects.

Other Brain Areas

Next to the prefrontal cortex and the medial temporal lobe, some other brain areas are also affected by autism.

Cerebellum

While it was previously thought that the cerebellum is primarily responsible for the motor control of our body, newer evidence indicates that it is also responsible for a variety of other functions, including language, motor function, mental imagination and cognition and executive function (Bauman & Kemper, 2003; Blatt, 2012; Wegiel et al., 2014). The research generally finds a reduction of neurons within the cerebellum in ASD subjects, which explains the language impairments and motoric difficulties typically found in individuals with more severe ASD (Bachevalier & Loveland, 2006; Bauman & Kemper, 2003; Wegiel et al., 2014).

Superior temporal gyrus

the superior temporal gyrus (STG) is a part of the brain responsible for language and perceiving emotions and is also an essential structure between the amygdala and prefrontal cortex (Baron-Cohen S. et al., 1999; Baron-Cohen S. et al., 2000). In neurotypical subjects, the size of the STG is positively correlated to language functions; however, in autistic brains, no significant relationship is found between STG size and language skills (Bigler et al., 2007). When considering tasks involving social behaviour, Baron-Cohen et al. (1999) shows a reduction in STG activity, which is consistent with the typical decision-making of autistic individuals.

Brainstem

According to some studies, there can be abnormalities within the brainstem, which are caused by the ASD risk gene (Wegiel et al., 2014). However, these abnormalities significantly differ between patients, and patients can also have no brainstem damage, all possible depending on genetic variations in the gene (Blatt, 2012).

Anterior Cingulate Cortex

The anterior cingulate cortex (ACC) is a brain area responsible for various tasks, such as error detection and reward-based learning. However, it also plays an important part in decision-making by weighting multiple decision options' costs (especially economic and social) (Lavin et al., 2013). Therefore, in decision-making, this is responsible for the balance between monetary reward and fairness/emotional preferences. Herefore, the ACC is also connected to the amygdala - the part in the human brain responsible for emotions - and the orbitofrontal cortex – responsible for making decisions based on stimuli and incorporating the results of previous decisions. Evidence suggests that these functional connections between the amygdala and ACC are reduced, resulting in reduced emotions in decision making and social dysfunction. Generally, among more socially impaired autistic individuals, this connection is found to be more impaired (Assaf et al., 2010; Velasquez et al., 2017).

Anterior Insula

The anterior insula (AI) is also an important part of the brain, which serves in the emotional and social processing by, making the individual aware of emotions, have empathy for others, and understand the emotions of others (Carla & Falco, 2015; Uddin & Menon, 2009). Therefore, it is also highly connected to other brain parts, especially the amygdala and orbitofrontal cortex, and can send and receive information to/from these brain parts. However, within autistic individuals, the AI is found to be both considerably underreacting and under-connected to other brain parts, which reduces the emotional ability, even of high-functioning autistic individuals (Uddin & Menon, 2009).

Connectivity

Functional brain connectivity (FC) is an important part of a correct functioning human brain. The human brain needs both short/local range connections (to nearby brain parts) for tasks like sensory perception, attention and memory. At the same time, the brain also needs long-range connections for tasks that involve multiple distant brain parts, and which is also positively correlated to general intelligence (Crespi, 2016).

Many previous studies suggest that autistic people have increased short-range connections but decreased long-range connections. This explains oversensitivity, better auditory perceptions and restricted interest, and the generally lower level of general intelligence (Barak & Feng, 2016; Crespi, 2016).

However, while many of the previous studies only considered the general level of high/low-range FCs, and only considered 20-30 subjects, some new studies took a much deeper look at the FCs between multiple parts of the brain, and even used over 600 ASD diagnosed subjects (Long, Duan, Mantini, & Chen, 2016; Tomasi & Volkow, 2017). Based on this new evidence, the outcomes are vastly different, and far more subtle outcome. According to new research, there seems to be a decrease in short, medium and long-range FCs in some areas, such as the cerebellum, and between some areas, such as the amygdala and the medial prefrontal cortex (Assaf et al., 2010; Long, Duan, Mantini, & Chen, 2016; Tomasa & Volkow, 2017). However, at the same time, some areas also have higher functional connections compared to neurotypical individuals. This decrease in FCs can explain the difficulty autistic individuals typically face in various tasks, especially those involving the 'social brain'. But, the increase in FCs between some other areas, can also explain why people with autism generally have a better memory for details and an excellent rote memory.

Moreover, the cause of these abnormalities in brain connections of adults with autism, is likely related to the abnormal growth pattern witnessed in autistic individuals. As described in section one, autistic individuals typically have abnormally high growth in early life, followed by slow growth. Furthermore, a positive correlation is found between this growth pattern and the severity of autism. This unique growth pattern can, in later life, result in the reduced ability to form long and short-range connections of those respective brain areas, which further explain the puzzling brain behaviour of autistic individuals (Lewis, Theilmann, Townsend, & Evans, 2013).

So, the connectivity within the autistic brain vastly differs from what was previously thought. Previous research believed in increased short-range connections and decreased long-range connections. In contrast, newer research paints a far more nuanced picture, with both in- and decreases in long- and short-range brain connections, which partially causes autistic behaviour.

Conclusion

The autistic brain is found to be unique, both in functioning and development. The two most affected areas are the amygdala and the orbitofrontal cortex, responsible for having/understanding emotions and adjusting individuals' behaviour based on these emotions, respectively. Furthermore, research also suggests a reduced functioning of the amygdala within social and emotional tasks, but an overreaction when faced with anxiety.

When considering the growth pattern, most affected brain areas show a unique growth pattern, with increased growth in early life, followed by a reduced growth later on. The larger this amount of unusual growth, the more those brain areas are dysfunctional in adulthood. Furthermore, the positive relationships, that typically exists between the size of a brain area and its functioning, do not hold for a considerable amount of the affected brain areas. Additionally, the functional connection between various brain areas to the areas responsible for emotions/feeling are also affected, resulting in reduced emotional abilities.

When considering lower-functioning autistic people, the functional connections and the key brain areas seem to be affected more. Furthermore, in the high-functioning autistic people, only the areas responsible for emotion are affected. But, in lower-functioning autistic people, other brain areas are also more affected. This results in even worse control over emotion, strengthening repetitive behaviour, a decrease in long-term memory, a further decrease in the ability to cope with change, a worsening of spatial memory and a decrease in linguistic ability.

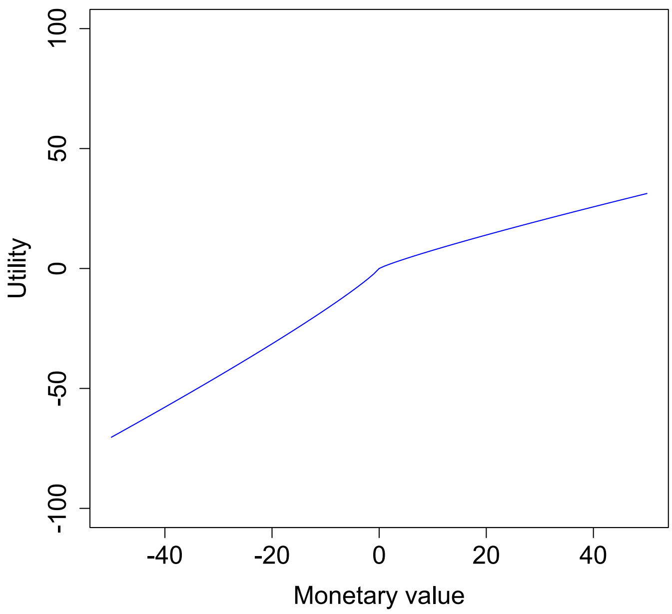
Appendix 3 – Prospect Theory Value and Weighting Function

Value function

The value function shows how people make a decision in real-life, based on the subjective utility of an outcome and compared to a reference point (Kahneman & Tversky, 1979). This function is normally concave within the gain domain and convex within the loss domain. Furthermore, this function is also much steeper for losses than gains, which is due to overweighting losses by roughly 2.25 times (Kahneman & Tversky, 1979). The form of this function is explained by the following two causes (Kahneman & Tversky, 1992):

- Diminishing sensitivity: this is the main explanation according to Kahneman & Tversky (1992) and explains both the concaveness in the gain domain and the convexity in the loss domain. Diminishing sensitivity entails that the sensitivity to money decreases further away from the reference point. So, an additional loss of one hundred euros has a more significant effect for someone that has just lost ten euros compared to someone that has just lost 100,000 euros. Alternatively, if someone buys two products separately, one of one hundred euros and one of 100,000 euros, a discount of twenty euros would more positively affect his utility if it is given on the lower-priced product.
- Decreasing utility: this only explains the concaveness in the gain domain, as it explains that the utility of each additional euro decreases. For example, people gain more for utility from their first one million euros than their second one million euros.

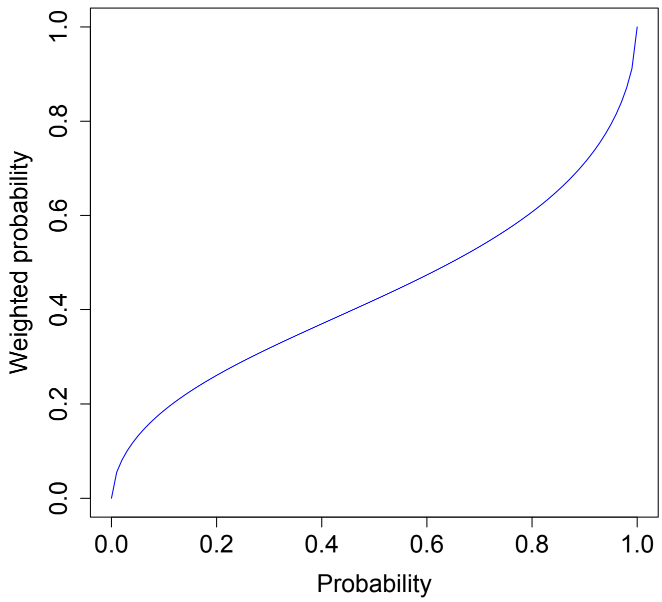
Figure 5: value function



Weighting function

The weighting function explains how people weigh outcomes in reality. As demonstrated by the research of Kahneman & Tversky (1979; 1992), people often overweight extreme outcomes (like the chance of winning a lottery) but underweight outcomes with high probabilities. Within cumulative prospect theory, this weighting function was improved by basing it on the cumulative probability, which solved the violation of stochastic dominance – if worse outcomes become less likely and good outcomes become more likely, the utility must increase. Furthermore, this also made the weighting function more close to real-life behaviour by also incorporating diminishing sensitivity with regards to probability changes (a change in probability of 99% to 100%, or 0% to 1%, has a much larger effect than 50% to 51%). Graphically, this shows itself in the following weighting function (graph 5, based on the parameters of Kahneman & Tversky (1992)).

Figure 6: gain-domain weighting function



Appendix 4: Influence of Alpha and Gamma on the CE of Prospect Theory

This appendix describes how both the alpha parameter (value function) and gamma parameter (weighting function) influence the Certainty Equivalent for a given probability. The goal hereof is to explain how an overweighting of low-probability high-value losses/gains within autistic individuals, without additional underweighting of high-probability gains/losses might show itself in an increase in the alpha/beta parameter (value function), instead of the gamma/delta parameter (weighting function).

$$U = \frac{P^{\gamma}}{(p^{\gamma} + (1-p)^{\gamma})\wedge(1/\gamma)} * 50^{\alpha} \rightarrow CE = \left(\frac{P^{\gamma}}{(p^{\gamma} + (1-p)^{\gamma})\wedge(1/\gamma)} * 50^{\alpha}\right)^{\frac{1}{\alpha}} \quad (17)$$

Figure 7:
The graph indicates the CE (y-axis) for a given level of probability (P) of outcome X1 (50 euros) (x-axis), and 1-P of outcome X2 (0 euros). This graph consists of line blue and line red, both with an alpha of 0.8, but with a differing <u>gamma</u> (blue = 0.5 and red = 0.7).

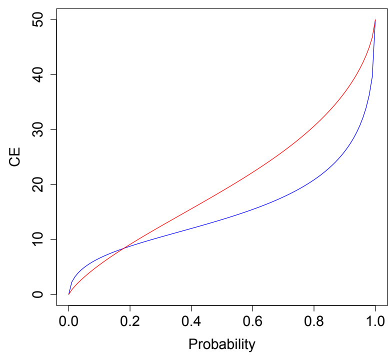


Figure 8:
The graph indicates the CE (y-axis) for a given level of probability (P) of outcome X1 (50 euros) (x-axis), and 1-P of outcome X2 (0 euros). This graph consists of line blue and line red, both with a gamma of 0.6, but with a differing <u>alpha</u> (blue = 0.75 and red = 0.85).

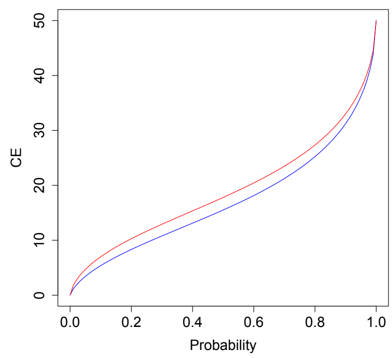
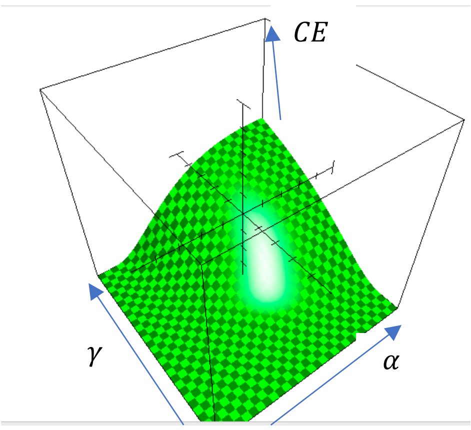


Figure 9:
This 3-dimensional graph indicates the CE (z-axis) for a 50% probability of outcome X1 (50 euros) and 50% probability of outcome x2 (0 euros). The x-axis and y-axis consist of the alpha and gamma parameter, respectively, in order to show the interconnectedness of both parameters. So, as displayed by this graph, a combination of parameters can lead to the same CE. However, given that the prospect theory questions consist of multiple levels of probabilities and outcomes, there only exists one optimal combination of parameters, which are as close to optimal as possible within the combination of decision sets.



So, as demonstrated by the three figures, an increase in gamma mostly affects mid to high p1 outcomes, with a higher gamma resulting in less underweighting of those outcomes. However, a change in alpha affects the whole curve, but relatively, it has the most effect on the low probability one outcome. Thus, a higher relatively overweighted CE for a low p1, without a larger CE for higher probabilities, might show itself in a raised alpha, and a slight decreased gamma. In practice, this results therein that the feeling of anxiety within autistic individuals, which might result in overweighting the probability of a small-probability large-monetary loss outcome, can show itself in the value function (alpha) instead of in the weighting function (gamma). This can thus explain why prospect theory might not be fully accurate to optimally predict the value and weighting function of autistic individuals, given that the higher degree of 'fear' without the higher degree of 'hope'[19] might lead to another optimal weighting function, as can be modelled using the weighting function of prospect theory.

[19] Within the loss domain, a feeling of 'fear' leads to overweighting small-probability outcomes, a feeling of 'hope' can result in underweighting high-probability outcomes.

Appendix 5: Overview of the Experimental Questions

This appendix provides an overview of the main questions of the experiment. It combines both the original questions, in Dutch, and a translation.

Start of Block: Introduction questions

Q4 Ben je gediagnostiseerd met een van de volgende psychiatrische stoornissen? (indien het er meerdere zijn, graag kiezen voor ADHD, depressie, etc.)

◯ Ja, autisme, hoog functionerend / asperger / PDD-NOS / level 1 (DSM-V) (1)

◯ Ja, een andere vorm van autisme (deelname is uitgesloten) (2)

◯ AD(H)D, depressie, paniekstoornissen, schizofrenie, of een andere psychiatrische stoornis (deelname is uitgesloten) (3)

◯ Nee (4)

Translation: “are you diagnosed with one of the following psychiatric disorders?”. Only those diagnosed with high-functioning ASD / no psychiatric disorder are included.

Skip To: Q5 If Ben je gediagnostiseerd met een van de volgende psychiatrische stoornissen? (indien het er meerde... = Ja, autisme, hoog functionerend / asperger / PDD-NOS / level 1 (DSM-V)

Skip To: Q9 If Ben je gediagnostiseerd met een van de volgende psychiatrische stoornissen? (indien het er meerde... = Nee

Q5 Welke vorm van autisme? (translation: which form of autism)

____

Q114 Heb je minder dan een jaar geleden nog medicatie ingenomen voor de behandeling van de symptomen van autisme? (translation: have you taken medication to treat autistic symptoms, within a year from this date?. Yes = excluded)

○ Ja (deelname is uitgesloten) (1)

○ Nee (2)

Q6 Heb je ooit een training gehad, zoals gedragstraining, theory of mind, sociale vaardigheden, e.d.? (translation: Have you ever received training for autism?)

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Q9 Wat is je leeftijd? (translation: what is your age?)

____

Skip To: End of Survey If Condition: Wat is je leeftijd? Is Less Than 18. Skip To: End of Survey.

Q10 Wat is jouw geslacht (translation: what is your gender?)

○ Man (1)

○ Vrouw (2)

○ Non-Binair (3)

Q11 Wat is je hoogst genoten opleiding (inclusief huidige opleiding)
(translation: what is your highest level of education, including your current education?)

- VMBO (1)
- HAVO (2)
- VWO/Atheneum/Gymnasium (3)
- MBO niveau 1 (4)
- MBO niveau 2 (5)
- MBO niveau 3 (6)
- MBO niveau 4 (7)
- HBO Bachelor (8)
- HBO Master (9)
- Universitair Bachelor (10)
- Universitair Master (11)
- Universitair doctoraat / PhD (12)

End of Block: Introduction questions

Start of Block: Short Raven based APM test

Q92 Dadelijk krijg je 11 sets met patronen te zien. Hierbij moet je kiezen welke van de 6 patronen aansluit op de reeks.

(translation, you will be shown 11 sets of patterns. Hereby, you have to choose the pattern that matches the series).

(These questions are matrix reasoning questions 1-11 from the ICAR project. Due to copyright limitations the pictures are not shown within this document. Furthermore, only questions one of the eleven questions is shown, as the options are all the same from question 1-11).

Q116 Welk patroon sluit aan op de reeks?

- A (1)
- B (2)
- C (3)
- D (4)
- E (5)
- F (6)
- Geen van deze (7)
- Ik weet het niet (8)

(translation: which pattern matches the series? A until F, or I do not know, or none of these)

End of Block: Short Raven based APM test

Start of Block: financial literacy test

Q13 Stel, je hebt 100 euro op je spaarrekening en de jaarlijkse rente is 2%. Hoe veel geld heb je na 5 jaar op je spaarrekening staan, als je dit geld laat groeien.

- ○ Minder dan 102 euro (1)
- ○ 102 euro (2)
- ○ meer dan 102 euro (3)
- ○ ik weet het niet (4)
- ○ ik wil geen antwoord geven (5)

(translation: if you have 100 euros on your savings account, and the annual interest equals 2%. How much money do you have on your savings account after five years, if you let the money grow? Below, equal to, or above 102 euros, or I do not know, or I do not want to answer).

Q14 Stel, de rente op jouw spaarrekening is 1% en de inflatie is 2%. Kun je na één jaar meer of minder kopen, met het geld op jouw rekening.

- ○ meer dan vandaag (1)
- ○ precies even veel (2)
- ○ minder dan vandaag (3)
- ○ ik weet het niet (4)
- ○ ik wil geen antwoord geven (5)

(translation: if the interest rate on your savings account is 1% and the inflation is 2%, can you buy less or more with the money on your account? More/The same/Less/I do not know/I do not want to answer)

Q15 Is de volgende stelling wel of niet waar: Een enkel aandeel kopen van een bedrijf geeft een veiligere investering dan een aandeel in een beleggingsfonds.

○ Waar (1)

○ Niet waar (2)

○ Ik weet het niet (3)

○ Ik wil geen antwoord geven (4)

(Translation: is the following statement true: buying one share of a single company gives a safer investment than investing in an investment fund? True / Not true / I do not know / I do not want to answer).

End of Block: financial literacy test

Start of Block: prospect theory introduction

Q29 Bedankt voor het invullen van de vragen tot dusver. Je bent nu aanbeland in het volgende blok met vragen.

Hierin krijg je 10 verschillende vragen te zien, met betrekking tot loterijen. Je krijgt op het scherm een loterij te zien, met een bepaalde win-kans en een bepaald bedrag wat je kunt winnen (bijvoorbeeld 5% kans op het winnen van 100 euro, en 95% kans op het winnen van niets). Je kunt kiezen voor meedoen aan de loterij, of het ontvangen van een vast bedrag (X). Wat moet dit vaste bedrag (X), minimaal zijn, om het voor jou aantrekkelijker te maken dan de loterij. (het gaat hierbij om JOUW voorkeur)

(Voor dit onderdeel van het experiment ontvang je een vast bedrag. Maar neem de besluiten alsof het echt jouw eigen geld is)

Translation:
Thank you for filling in the questions so far. You have now reached the next block of questions. Herein, you will be shown 10 questions about lotteries. You are shown a lottery with a certain chance of winning and an amount to win (for example 5% of winning 100 euros, and 95% of winning

nothing). You can choose to participate in the lottery, or to receive a fixed amount (X). What does this fixed amount have to be, at minimum, in order to make it more attractable to you than the lottery?

(for this part of the experiment you will receive a fixed amount. But take the decisions as if it is your own money).

End of Block: prospect theory introduction

Start of Block: prospect theory gain domain (these questions are not strictly indifferent, in order to increase the understandability. This leads to a slight overprediction of the CE. However, this does not cause any difference within this study, given the minor difference and given that it affects both the ASD and neurotypical group). Furthermore, these questions are presented in random order to the subjects.

*

Q17 De loterij geeft je 5% kans op het winnen van 50 euro (en 95% kans op het winnen van niets).

Stel je kunt kiezen tussen de loterij en het ontvangen van het vaste bedrag X. Wat moet dit vaste bedrag dan minimaal zijn, om het aantrekkelijker te maken voor jou dan de loterij?

(translation: the lottery gives you 5% chance of winning 50 euros, and 95% of winning nothing. If you can choose between the lottery, and receiving the fixed amount X. What does this fixed amount X have to be, at minimum, in order to make it more attractive to you than the lottery?)

This question is repeated 10 times, with the paid amounts and probabilities as provided in chapter 3.3.

____

Q128 De loterij geeft je 100% kans op het winnen van 50 euro en 0% kans op het winnen van 150 euro.

Stel je kunt kiezen tussen de loterij en het ontvangen van het vaste bedrag X. Wat moet dit vaste bedrag dan minimaal zijn, om het aantrekkelijker te maken voor jou dan de loterij?

Dit is om te testen of je op let. Je moet hier 50 invullen.

(translation: the lottery gives you 100% chance of winning 50 euros and 0% chance of winning 150 euros. If you can choose between the lottery and winning the fixed amount X. What does this fixed amount X have to be, at minimum, in order to make it more attractive to you than the lottery?

This is a build-in attention check. Please fill in 50.)

____

End of Block: prospect theory gain domain

Start of Block: prospect theory loss domain explanation

Q39 In dit onderdeel krijg je 10 verschillende vragen te zien, met betrekking tot een bepaalde kans op verlies. Bijvoorbeeld: je hebt 5% kans om 100 euro te verliezen, en 95% kans om niets te verliezen. Hoe veel zou je maximaal willen betalen, om je te beschermen tegen dit verlies? (en dus geen risico te hebben)

(Voor dit onderdeel van het experiment ontvang je een vast bedrag. Maar neem de besluiten alsof het echt jouw eigen geld is)

Translation:
In this block you will be shown 10 questions with a certain probability of losing. For example, you have 5% chance of losing 100 euros and 95% chance of losing nothing. How much do you want to pay, at max, in order to protect yourself against this loss (and thus face no risk).

(For this part of the experiment you will receive a fixed payment. But, take the decisions as if it is your own money).

End of Block: prospect theory loss domain explanation

Start of Block: prospect theory loss domain. These questions are presented in random order to the participatns.

*

Q40 Je hebt 5% kans om 50 euro te verliezen (en 95% kans om niets te verliezen).

Hoe veel zou je maximaal willen betalen, om je te beschermen tegen dit verlies?

(Translation: you have a 5% chance of losing 50 euros, and 95% chance of losing nothing. How much do you want to pay, at max, in order to protect yourself against this loss?)
This questions is repeated 10 times, with the probabilities and amounts as given in chapter 3.3.

____

End of Block: prospect theory loss domain

Start of Block: mixed domain explanation

Q54 Nu volgen een paar andere vragen, waarin je een loterij te zijn krijgt met 50% kans op het verliezen van een bepaald bedrag, en 50% kans op het winnen van een bepaald bedrag (x). (Bijvoorbeeld, een loterij geeft 50% kans op het verliezen van 100 euro, en 50% kans op het winnen van X euro). Welk bedrag moet X minimaal zijn, voordat je mee wilt doen aan deze gratis loterij?

(Voor dit onderdeel van het experiment ontvang je een vast bedrag. Maar neem de besluiten alsof het echt jouw eigen geld is)

Translation:
Now you will be shown a couple of different questions, with a lottery with a 50% chance of losing a certain amount, and a 50% chance of winning a certain amount (X). (for example, the lottery gives you a 50% chance of losing 100 euros, and a 50% chance of winning X euros). Which amount does X have to be, at minimum, in order to make you willing to participate in this free lottery?

(For this part of the experiment you will receive a fixed amount, but take the decisions as if it is your own money)

End of Block: mixed domain explanation

Start of Block: prospect theory mixed domain. These questions are presented in random order to the participants.

*

Q55 Deze loterij geeft 50% kans op het verlies van 25 euro, en 50% kans op het winnen van 'x' euro.

Welk bedrag moet X <u>minimaal</u> zijn, voordat je mee wilt doen aan deze loterij?

Translation:

This lottery gives 50% chance of losing 25 euros, and 50% chance of winning ‘x’ euros. Which amount does X have to be, at <u>minimum,</u> in order to make you willing to participate in this free lottery?

____

*

Q56 Deze loterij geeft 50% kans op het verlies van 150 euro, en 50% kans op het winnen van 'x' euro.

Welk bedrag moet X <u>minimaal</u> zijn, voordat je mee wilt doen aan deze loterij?

Translation:

This lottery gives 50% chance of losing 150 euros, and 50% chance of winning ‘x’ euros. Which amount does X have to be, at <u>minimum,</u> in order to make you willing to participate in this free lottery?

____

End of Block: prospect theory mixed domain

Start of Block: Dictator game

*

Q88 Je krijgt dadelijk 10 euro, om samen met een ander anoniem persoon te delen. De andere persoon kan jouw aanbod niet weigeren. Hoe veel wil jij geven aan de andere persoon?

(let op, een gedeelte van dit bedrag kun je ook echt ontvangen)

(het gedeelte wat je geeft, gaat naar een random gekozen andere persoon)

Translation:
You will be given 10 euros, to share with an anonymous other person. The other person cannot refuse your offer, how much do you want to give to the other party?

(be aware, you can receive a part of this in real money)

(the part that you give, will be given to a randomly chosen other participant)

____

End of Block: Dictator game

Start of Block: Ellsberg urn gain domain explanation

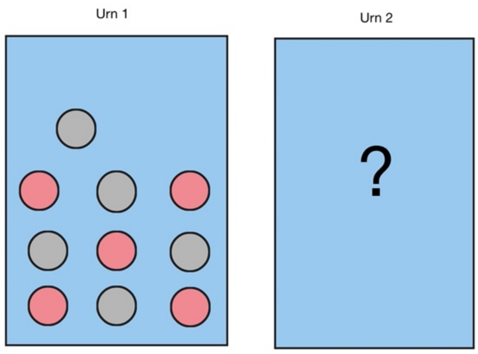
Q60 Je krijgt dadelijk 2 bakken met ballen te zien. Bak 1 bevat 5 rode en 5 blauwe ballen. Bak 2 bevat ook tien ballen, die allen rood of blauw zijn. De verhouding tussen rood en blauw is echter onbekend. De computer haalt random één bal, uit de door jouw gekozen bak. Als deze bal de kleur is die jij gekozen hebt, dan ontvang je x tokens. Als deze bal niet de kleur is die jij gekozen hebt, dan ontvang je niets.

(Voor dit onderdeel van het experiment ontvang je een vast bedrag. Maar neem de besluiten alsof het echt jouw eigen geld is)

Translation:

You will be shown two urns with balls. Urn 1 contains 5 red and 5 blue balls. Urn 2 also contains 10 balls, which are all red or blue. The distribution between red and blue is unknown. The computer will randomly draw one ball, from the urn you choose. If this is the colour you have chosen, you will receive x tokens. If this is not the colour you have chosen, you will not receive a thing.

(for this part of the experiment you will receive a fixed payment. But take the decisions as if it is your own money).



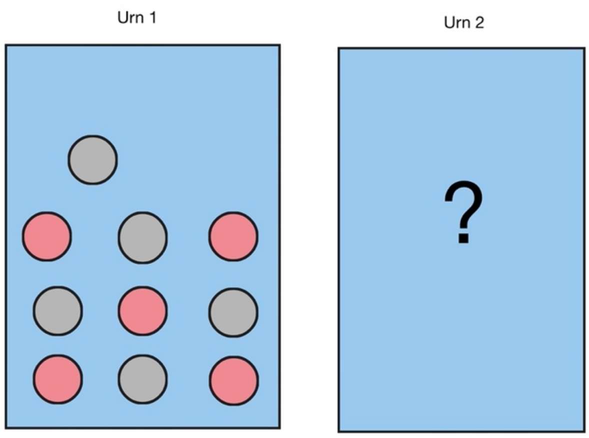
End of Block: Ellsberg urn gain domain explanation

Start of Block: Ellsberg urn gain domain. These questions are NOT in random order. Skip logic is applied to prevent that subjects have to answer unnecessary questions. But not for the first questions, in order to measure a lack of understanding (continuous switching between URN 1 and URN 2). Furthermore, this picture of urn 1 and urn 2 is also shown within the experiment, as an aid in understanding the questions.

Q59 Als jouw gekozen kleur uit bak 1 getrokken wordt, ontvang je 200 tokens. Als jouw gekozen kleur uit bak 2 getrokken wordt, ontvang je 180 tokens.

Welke bak en welke kleur kies je?

- ◯ Bak 1 Rood (1)
- ◯ Bak 1 Blauw (2)
- ◯ Bak 2 Rood (3)
- ◯ Bak 2 Blauw (4)



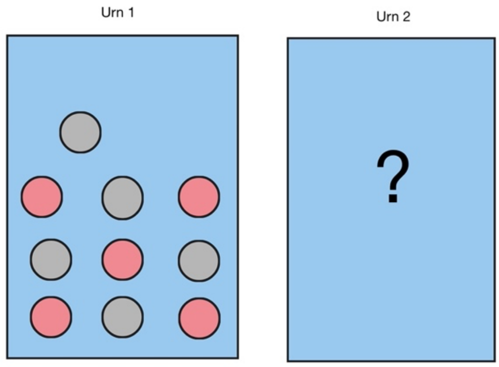
Translation:

If your chosen colour is drawn from urn 1, you will receive 200 tokens. If your chosen colour is drawn from urn 2, you will receive 180 tokens. Which colour and which urn do you choose? (urn 1 and 2, and colour red or blue).

This questions is repeated 11 times, with the amount of urn 2 increasing in each round (see chapter 3.3).

Start of Block: Ellsberg URN loss domain explanation

Q72 Nu krijg je soortgelijke vragen als zojuist. Echter, nu verlies je een bepaald bedrag, als de door jouw gekozen kleur uit de door jouw gekozen bak getrokken wordt.



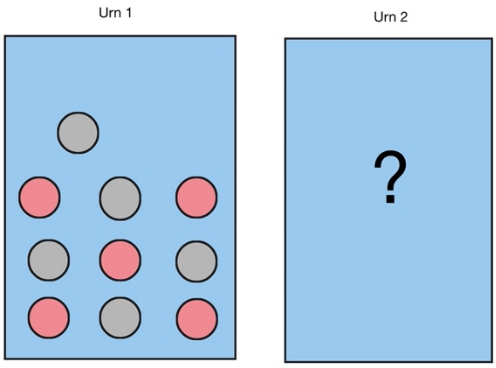
Translation; now you will be shown a similar set of questions. However, now you lose a certain amount of money, if your chosen colour is drawn from the urn you choose.

End of Block: Ellsberg URN loss domain explanation

Start of Block: Ellsberg URN Loss domain. Those questions are not in random order.

Q73 Als jouw gekozen kleur uit bak 1 getrokken wordt, verlies je 200 tokens. Als jouw gekozen kleur uit bak 2 getrokken wordt, verlies je 100 tokens. Welke bak en welke kleur kies je?

- Bak 1 Rood (1)
- Bak 1 Blauw (2)
- Bak 2 Rood (3)
- Bak 2 Blauw (4)



Translation: if your chosen colour is drawn from urn 1, you lose 200 tokens. If your chosen colour is drawn from urn 2, you lose 100 tokens. Which urn and which colour do you choose?

This questions is repeated 11 times, with the amount of urn 2 increasing in each round (see chapter 3.3).

Start of Block: Ultimatum game proposer

Q84 Dadelijk ontvang je 10 euro. Deze tien euro moet je delen samen met een anoniem persoon. Hierbij kun je niet onderhandelen. Jij mag kiezen hoe veel je van dit bedrag aan de andere persoon geeft (de computer koppelt je automatisch random aan deze andere persoon).
Op het moment dat de andere persoon dit aanbod accepteert, dan ontvang je beide het bedrag, in de door jouw gekozen verhouding. Op het moment dat de andere persoon dit aanbod niet accepteert, dan ontvang je beide niets.

(let op, een gedeelte van dit bedrag kun je ook echt ontvangen)

Translation:
You will receive 10 euros, which you have to share with another anonymous party. Hereby, you can not negotiate. You can choose how much you will give to the other party (the computer automatically links you to another random chosen participant). If the other party accepts your offer, you will both receive the amount, in the ratio you proposed. If the other party denies the offer, neither one of you will be paid.

(be aware, a certain amount hereof will be transferred to you in real money)

Q85 Hoe veel van deze 10 euro wil je aan de andere persoon geven? (translation: how much of those 10 euros are you willing to give to the other party?)

____

End of Block: Ultimatum game proposer

Start of Block: Ultimatum game responder

Q87 Een ander persoon heeft de opdracht gekregen om 10 euro samen met jou te delen. Hoe veel euro moet deze persoon minimaal aan jou geven, voordat jij het aanbod wilt accepteren.
Als het bedrag wat de ander aanbiedt lager is dan dit bedrag, dan ontvang je beide niets.
Als het bedrag wat de ander aanbiedt hoger is dan dit bedrag, dan ontvang je beide het bedrag, in de door de andere partij gekozen verhouding.

(let op, een gedeelte van dit aanbod kun je ook echt ontvangen; hiervoor word je random gekoppeld aan een andere deelnemer)

Translation:
An other party was given the order to share 10 euros with you. How much does this person have to give to you, at mimimum, in order to make you willing to accept the offer?
If the offer from the other party is lower than this amount, you neither will receive anything.
If the offer by the other party is above this amount, you will both receive the offer, in the ratio as preferred by the other party.

(be aware, you will actually receive a share of this amount; herefore, you will be randomly linked to another respondent).

Q86 Wat is het laagste aanbod dat je zou accepteren? (what is the lowest offer you are willing to accept?)

____

End of Block: Ultimatum game responder

Appendix 6 – Descriptive Statistics of the Sample

Education Distribution

	autism dummy 0		1		Total	
	N	%	N	%	N	%
HAVO	2	4,8%	0	0,0%	2	2,9%
HBO Bachelor	12	28,6%	13	46,4%	25	35,7%
HBO Master	3	7,1%	1	3,6%	4	5,7%
MBO niveau 1	0	0,0%	1	3,6%	1	1,4%
MBO niveau 3	0	0,0%	1	3,6%	1	1,4%
MBO niveau 4	4	9,5%	3	10,7%	7	10,0%
Universitair Bachelor	6	14,3%	3	10,7%	9	12,9%
Universitair doctoraat / PhD	0	0,0%	1	3,6%	1	1,4%
Universitair Master	11	26,2%	4	14,3%	15	21,4%
VMBO	1	2,4%	1	3,6%	2	2,9%
VWO/Atheneum/Gymnasium	3	7,1%	0	0,0%	3	4,3%
	42	100,0%	28	100,0%	70	100,0%

Gender Distribution

		autism dummy 0		1		Total	
		N	%	N	%	N	%
Q10	Man	19	45,2%	14	50,0%	33	47,1%
	Non-Binair	0	0,0%	1	3,6%	1	1,4%
	Vrouw	23	54,8%	13	46,4%	36	51,4%
Total		42	100,0%	28	100,0%	70	100,0%

Financial Literacy Distribution

(max score = 3)

		autism dummy 0		1		Total	
		N	%	N	%	N	%
total fl score	1	1	2,4%	0	0,0%	1	1,4%
	2	11	26,2%	10	35,7%	21	30,0%
	3	30	71,4%	18	64,3%	48	68,6%
Total		42	100,0%	28	100,0%	70	100,0%

IQ Distribution

(IQ score ranges from 0-11)

total IQ score

autism dummy	Mean	N	Std. Deviation	Kurtosis	Skewness
0	7,12	41	2,629	-1,011	-,252
1	6,81	27	2,113	-1,090	,051
Total	7,00	68	2,425	-,988	-,136

Appendix 7 – Assumption Tests and Additional Model Information

Prospect Theory

Table 10

Model information

	Gain Domain	*Loss Domain*	*Mixed Domain*
R^2	.886	.893	.379
Df of the regression	15	15	10
Df of the residual	596	413	105
No. of observations in autism group	252	203	51
No. of observations in neurotypical group	360	226	65

Prospect Theory Gain Domain

Given the unique nature of the non-linear regression, some assumption tests of OLS are not necessary, and thus are not conducted. Namely, the linearity between the dependent and independent variable. And, testing for autocorrelation is generally seen to be unimportant within cross-section data; using the Durbin-Watson test within SPSS's non-linear regression is thus also not possible (Field, 2018). But, based on the evidence of the linear regression in the other questions and the type of data, it is highly unlikely that the data is autocorrelated.

Significant Outliers

All data is manually checked for significant outliers. Based on this analysis, 8 respondents are fully removed from the gain-domain prospect theory, as they showed a clear lack of understanding and/or attention. This resulted therein that those respondents gave certainty equivalents below the minimum possible outcome of the lottery or well above the maximum possible outcome in the lottery; this is highly unlikely in reality. Furthermore, this also makes the results hard to compare to other studies, as many other studies, including the study of Kahneman and Tversky (1992) also did not allow answers outside the boundaries of the prospects. However, it should be noted that those answers were 'allowed' in the online experiment on purpose, as it hereby becomes easier to determine a lack of understanding and/or attention of some of the respondents.

Of the remaining 62 respondents, in total 8 (out of 620) individual answers were removed which were clearly below the minimum possible outcome of the lottery or well above the maximum possible outcome of the lottery. But, as the rest of the answers of those respondents are found to be fine, only those outliers are removed, as they are likely caused by a typographical error.

Test for Heteroscedasticity

Given the unique nature of a non-linear regression, the Breusch-Pagan test for heteroscedasticity cannot be used within SPSS. Therefore, the data is manually checked for heteroscedasticity, using a scatterplot of the prediction on the x-axis, and the residuals on the y-axis. As shown by the plot, the data is somewhat heteroscedastic, which is to be expected in this dataset, given that absolute deviations are expected to be higher for higher certainty equivalents. In order to solve this problem, this regression makes uses of robust standard errors, using bootstrapping with 500 iterations.

However, this also results in the need for another estimation algorithm. By default, the Levenberg-Marquardt (LM) algorithm, which only needs a starting point (the default alpha and gamma parameters of Kahneman and Tversky), is preferred. However, given that this algorithm does not support bootstrapping – nor any other method of robust standard errors – the Sequential Quadratic Programming (SQP) algorithm must be used, which is based on a Newton's approximation (Field, 2018; IBM, 2022; Prastyo, Suhartono, & Sofyan, n.d.). Furthermore, to make this model as accurate as possible, the maximum number of interations is increased to 200.

However, within the prospect theory model, this model does also need boundaries (minimum and maximum values) to accurately determine the parameters. This is needed due to the unique way in which the prospect theory formulas are designed, with a high degree of interaction between the alpha and gamma parameter. When not setting a strict boundary on one of the two parameters, the model can reach a cycle or a non-optimal point and finally stop at its max. number of iterations. By setting a strict boundary on alpha (or gamma) - based on the estimation of the LM algorithm – this circle can be prevented, and thus a higher R^2 can be reached. Furthermore, strange results with a very high alpha and very low gamma (or the other way around) can also be prevented hereby. (This problem is caused due to the way this model works, based on Newton's method.) Furthermore, boundaries are also needed to prevent stationaries, as they would lead to a division by zero, which causes the model to fail (as stationaries have a first order derivative of zero, which leads to a division by zero). Therefore, this model also uses a non-centered version of age, given that the centered version of age causes problems, due to it leading to a division by (almost) zero.

So, in order to accurately determine the prospect theory parameters, a two-step approach is used. The parameters are first approximated with the LM algorithm. These approximations are used as a starting point for the SQP model, combined with loose boundaries on the parameters to prevent a division by zero and unrealistic results, and a stricter boundary on the alpha parameter, in order to maintain the highest R^2 and to prevent the model from getting in a cycle.

Newton's method states $x_1 = x_0 - \frac{f(x_0)}{f'(x_0)} \gg x_2 = x_1 - \frac{f(1)}{f'(x_1)} \gg x_{n+1} = x_n - \frac{f(x_n)}{f'(X_n)}$.

Within this model, it starts with a first guess of the outcome (x0), which is filled in within the formula. Thereby, iteratively, the formula gets closer and closer to the optimal solution.

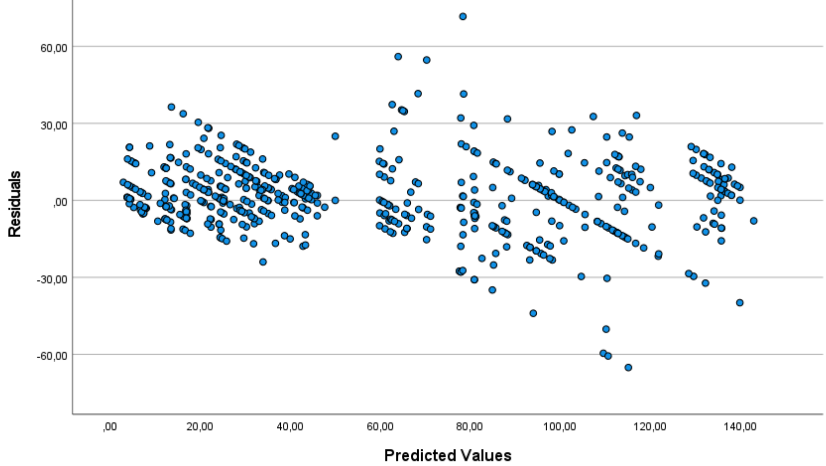
For example:

Solving: $f(x): 19 * x^2 - 40 = 0; first\ guess = 2 ; f'(x) = 38 * x$

Step 1: $2 - \frac{f(2)}{f'(2)} \approx 1.526 = x_1$

Step 2: $1.526 - \frac{f(1.526)}{f'(1.526)} \approx 1.453 = x_2$ etc. to get closer and closer to the optimal solution.

Figure 10: Heteroscedasticity



Multicollinearity

As this regression includes two variables that are to be predicted (alpha and gamma), and the control variables are added onto both of those predictions, correlation between the control variables on alpha and gamma is to be expected. However, this does not matter, as this does not affect the validity of the model. But, there is one exception. Very high correlation is found between the control variable 'Higher Education' on Alpha and Gamma. And this does matter, since this is a dummy which is 'true' for most respondents. Thus, this high correlation has detrimental effects on the statistical power of both the 'alpha' and 'gamma' parameter. As this leads to strange biases, it has been chosen to remove this control variable from both the alpha and gamma domain.

Within both the alpha and gamma domain, there is furthermore no significant collinearity found (all correlation coefficients are well below 0.8).

Table 11

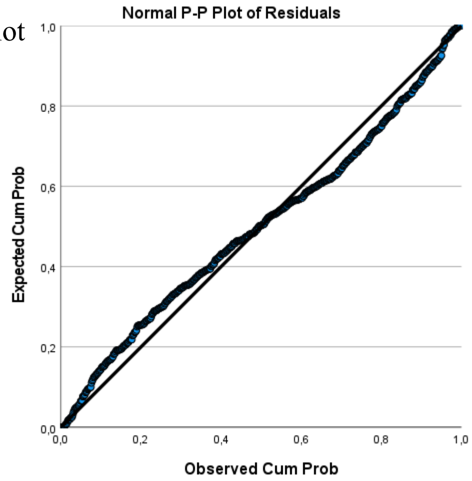
Collinearity Table

	alpha	gamma	AAutism	AAutismIQ	AAge	AHig-herEdu-cated	AMale	ANonBi-nary	AIQ	AFL	ADu-ra-tion
alpha	1	-0.655	-0.24	-0.106	-0.253	-0.815	-0.015	-0.26	0.143	-0.044	-0.046
gamma	-0.655	1	0.18	0.064	0.167	0.521	0.021	0.167	-0.104	-0.02	0.04
AAutism	-0.24	0.18	1	-0.107	0.138	-0.008	-0.038	-0.215	0.034	0.036	0.071
AAutismIQ	-0.106	0.064	-0.107	1	0.102	0.135	0.043	0.23	-0.491	-0.047	-0.066
AAge	-0.253	0.167	0.138	0.102	1	0.311	-0.115	-0.031	-0.318	-0.062	-0.125
AHig-herEduca-ted	-0.815	0.521	-0.008	0.135	0.311	1	-0.35	0.262	-0.235	-0.019	-0.117
AMale	-0.015	0.021	-0.038	0.043	-0.115	-0.35	1	0.069	0.051	-0.255	-0.003
ANonBi-nary	-0.26	0.167	-0.215	0.23	-0.031	0.262	0.069	1	-0.042	-0.104	-0.034
AIQ	0.143	-0.104	0.034	-0.491	-0.318	-0.235	0.051	-0.042	1	0.107	0.012
AFL	-0.044	-0.02	0.036	-0.047	-0.062	-0.019	-0.255	-0.104	0.107	1	0.132
ADuration	-0.046	0.04	0.071	-0.066	-0.125	-0.117	-0.003	-0.034	0.012	0.132	1
GAutism	0.164	-0.435	-0.48	0.045	-0.073	-0.021	0.016	0.087	0	-0.012	-0.049
GAutismIQ	0.048	-0.18	0.052	-0.538	-0.054	-0.056	-0.04	-0.112	0.329	0.026	0.032
GAge	0.124	-0.256	-0.074	-0.054	-0.545	-0.157	0.068	0.023	0.18	0.033	0.064
GHig-herEduca-ted	0.403	-0.561	0.018	-0.038	-0.171	-0.511	0.191	-0.128	0.114	0.025	0.061
GMale	0.031	-0.058	-0.005	-0.038	0.053	0.13	-0.425	-0.035	-0.015	0.097	0.007
GNonBi-nary	0.142	-0.173	0.106	-0.11	0.025	-0.141	-0.043	-0.648	0.018	0.064	0.019
GIQ	-0.056	0.234	-0.004	0.237	0.155	0.088	-0.023	0.011	-0.494	-0.048	-0.001
GFL	-0.068	0.26	-0.006	0.043	0.051	0.08	0.142	0.087	-0.069	-0.558	-0.065
GDuration	0.034	-0.085	-0.046	0.02	0.064	0.056	0.004	0.014	0.006	-0.047	-0.621

Normal Distribution of Residuals

Based on the P-P plot, the residuals are found to be normally distributed.

Figure 11: P-P plot



Prospect theory loss domain

Significant Outliers

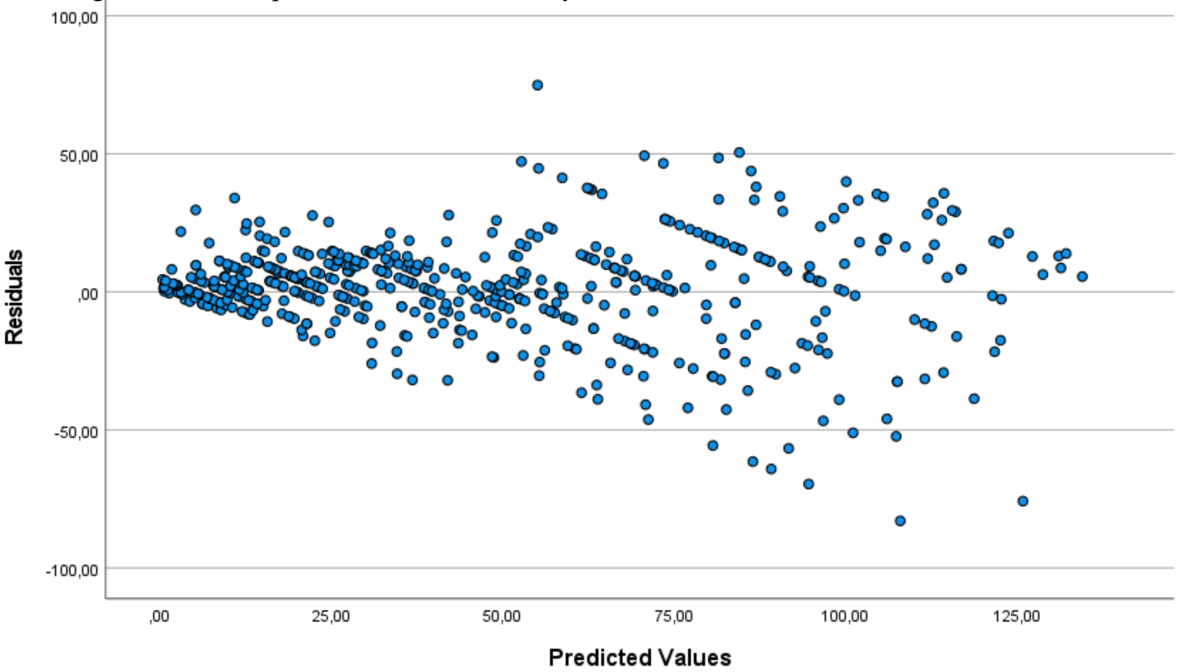
Within the domain with an x percent loss of 150 euros, and a 1-x percent loss of 50 euros, some outliers are to be expected, due to risk seeking behaviour of people and irrationality. However, this paper follows the approach of many other previous papers, including the paper of Kahneman and Tversky out of 1992, and thus only allows choices between the extremes of the prospect (so not below or above the highest possible loss). However, it should be noted that this study allowed such answers on purpose. Because, in a way, this serves as an additional attention and comprehension check, since if people answer (widely) outside these boundaries, it likely indicates a lack of understanding. If this study had not allowed such answers, the people without proper understanding would have probably chosen an answer somewhere in the middle, instead of an answer that does not make sense. So, hereby, this enables to check if the subjects properly understand the questions.

Furthermore, of some respondents the full responses were removed, when they showed a clear lack of misunderstanding throughout all of the questions (CE well below/above the max/min possible loss). In total, this combination of selection criteria resulted therein that 429 out of 590 answers were deemed correct.

Test for Heteroscedasticity

As indicated by the scatterplot (figure 12), there is a large degree of heteroscedasticity. This results in invalid results of a ‘normal’ non-linear regression. This is solved by using ‘standard’ bootstrapping with 500 bootstraps. Furthermore, in order to use bootstrapping within SPSS, the parameter estimation algorithm is changed from Levenberg-Marquardt (LM) to Sequential Quadratic Programming, as that algorithm does support bootstrapping. In order to make this algorithm as accurate as possible, the default max number of iterations is increased to 200 iterations (Field, 2018; IBM, 2022).

Figure 12: scatterplot for heteroscedasticity



Multicollinearity

As this regression includes two variables that are to be predicted (beta and delta), and the control variables are added onto both of those predictions, correlation between the control variables on beta and delta is to be expected. However, this does not matter, as this does not affect the validity of the model. Within both the beta and delta domain, there is no significant collinearity found (all correlation coefficients are well below 0.8)

Table 12

Collinearity table

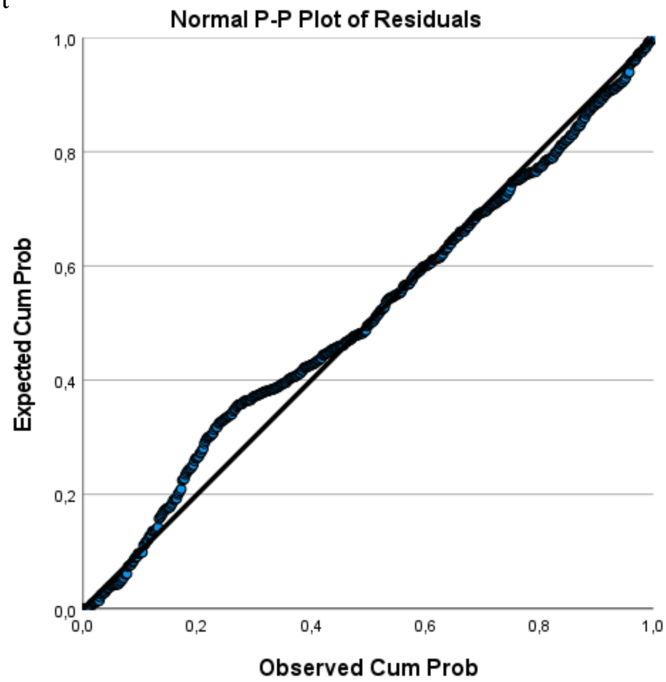
	Beta	Delta	BAutism	BAutismIQ	BAge	BHigherEducated	BMale	BNonBinary	BIQ	BFL	BDuration
Beta	1.000	-0.696	-0.528	0.063	0.005		-0.543		-0.147	-0.005	-0.168

Delta	-0.696	1.000	0.369	-0.009	0.007	0.366	0.060	-0.019	0.120
BAutism	-0.528	0.369	1.000	-0.182	0.056	0.027	0.108	0.076	0.059
BAutismIQ	0.063	-0.009	-0.182	1.000	-0.027	0.125	-0.545	-0.050	-0.220
BAge	0.005	0.007	0.056	-0.027	1.000	-0.041	-0.236	-0.039	0.128
BHigherEducated									
BMale	-0.543	0.366	0.027	0.125	-0.041	1.000	-0.087	-0.258	-0.164
BNonBinary									
BIQ	-0.147	0.060	0.108	-0.545	-0.236	-0.087	1.000	0.100	0.188
BFL	-0.005	-0.019	0.076	-0.050	-0.039	-0.258	0.100	1.000	-0.055
BDuration	-0.168	0.120	0.059	-0.220	0.128	-0.164	0.188	-0.055	1.000
DAutism	0.398	-0.603	-0.685	0.067	-0.038	-0.025	-0.056	-0.029	-0.060
DAutismIQ	-0.007	-0.148	0.043	-0.689	0.024	-0.156	0.489	0.039	0.187
DAge	0.021	-0.052	-0.053	0.030	-0.667	-0.009	0.144	0.057	-0.085
DHigherEducated									
DMale	0.365	-0.480	-0.006	-0.122	-0.004	-0.674	0.094	0.162	0.107
DNonBinary	0.017	-0.075	-0.007	0.027	0.007	-0.028	0.011	0.005	0.004
DIQ	0.051	0.127	-0.049	0.387	0.136	0.098	-0.697	-0.078	-0.148
DFL	-0.026	0.125	-0.039	0.046	0.052	0.181	-0.078	-0.704	0.045
DDuration	0.148	-0.200	-0.067	0.169	-0.092	0.117	-0.172	0.048	-0.721

Normal distribution of residuals

Based on the P-P plot (figure 13), the residuals are found to be relatively normal distributed. The small deviation from the normal distribution does not matter in this large dataset, especially not since this regression also uses bootstrapping.

Figure 13: P-P plot



Prospect Theory Mixed Domain

Significant Outliers

Cook's distance is used to test for significant outliers, with a critical value of 0.03 (4/117). All seven significant outliers, as indicated by Cook's distance, are manually analyzed. Most of those cases are due to very high loss aversion, and some are due to very low loss aversion. But, as all those cases display a loss aversion that seems likely in reality (all are even above 1, and below 10) and also constant across domains (so a high OR low loss aversion in both the low and high value question) it is deemed that those people seem to have paid attention and also have not made a typographical mistake. Thus, none of those cases are removed.

Normal Distribution of the Dependent Variable

This test is optional, as it is not necessary for an OLS regression. But a non-normal distribution of the DV can lead to a non-normally distributed residual (Field, 2018). As is to be expected, given that this dataset combines the low and high value mixed domain question, the dependent variable (gain domain Cumulative Prospect Theory value) is not normally distributed, with excessive kurtosis and some excessive skewness (36.7 and 5,1 respectively). However, it has been decided to not use a form of transformation to make the DV more normally distributed. As the goal of this regression is to estimate the prospect theory parameters, any form of transformation will lead to changing coefficients that are hard to interpret as the loss-aversion parameter for Prospect Theory.

Test for Heteroscedasticity

The Breusch-Pagan test for heteroscedasticity shows a Chi Square of 144.365 and a significance level below 0.001. Thus, the null hypothesis of homoscedasticity must be rejected (see 'normal distribution of residuals' for the applied solution).

Test for Multicollinearity

All VIFs are below 5 and the correlation coefficients are all below 0.8, indicating no multicollinearity. Some mild forms of multicollinearity are detected but those are between the control variables, and thus do not have a major effect on the confidence intervals of the important independent variables.

Independent Residuals

As indicated by a Durbin-Watson score of 1.865 (critical values are 1.765 and 2.235), the residuals are found to be independent.

Normal Distribution of Residuals

As indicated by the P-P plot and the histogram (figure 14 & 15), the residuals are found to be non-normal distributed. Given that there is both heteroscedasticity and non-normal distribution of the residuals, this regression makes uses of robost standard errors. The used method is bootstrapping, with 1000 iterations and Bias-Corrected Accelerated confidence interval, which is seen as the most reliable method available today in SPSS (Field, 2018; IBM, 2022).

Figure 14: Histogram of residuals

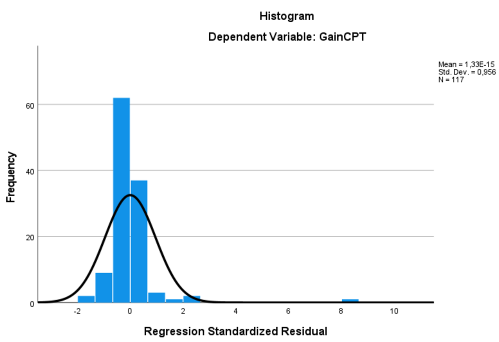
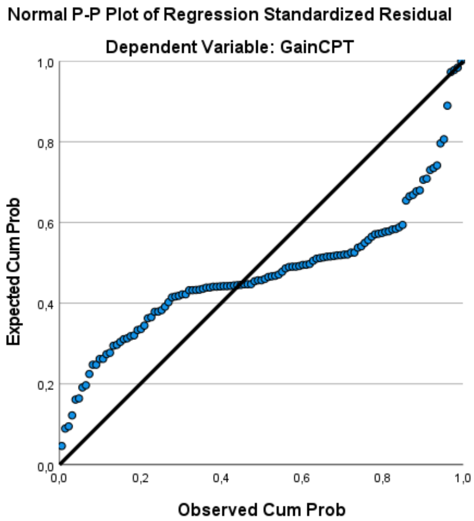


Figure 15: P-P plot of residuals



Linearity Between the Independent Variables and the Dependent Variable

Using both partial plots and the curve estimation function of SPSS, the linearity of all relationships is checked. Based on this evidence, the existing linear form gives an accurate explanation of the model. Within some parameters, having a non-linear effect would have a slight increase on the explanatory power, but those are likely so by chance, due to outliers.

Ellsberg's URN

Table 13

Descriptive statistics

	Gain Domain	*Loss Domain*
R^2	.196	.118
Ad. R^2	.071	-.020
Df of the regression	9	9
Df of the residual	60	60
No. of observations in autism group	28	28
No. of observations in neurotypical group	42	42

Ellsberg's Urn Gain Domain

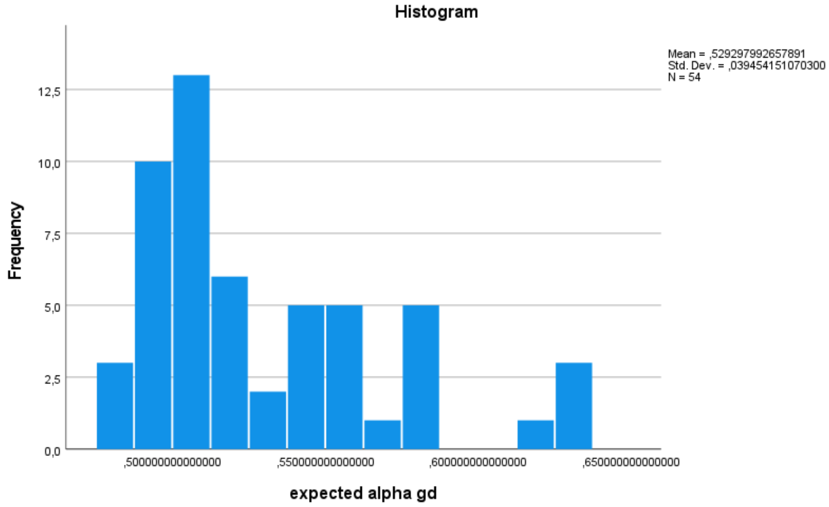
Significant Outliers

Given the nature of the experiment, only one type of significant outliers are possible, namely respondents that prefer the ambiguity/non-ambiguity urn within all questions. Of those respondents the ambiguity value is too high/low to be measured in the experiment, thus those 5 cases are excluded. Furthermore, there are also 10 cases that did not finish the experiment, and 2 cases that showed inconsistency within the Ellsberg's urn task. All those 17/69 cases are replaced with imputated values.

Normal Distribution of the Dependent Variable

The independent variable is found to be not fully normally distributed, but reasonably close to a normal distribution (skewness = 1.05; kurtosis = .29; Kolmogorov-Smirnov sig <.001). So, it will not cause any problem within the OLS regression. Especially not since this assumption is not required within an OLS regression (Field, 2018).

Figure 16: Histogram of the normal distribution of the DV



Test for Heteroscedasticity

The Breusch-Pagan test for heteroscedasticity shows a Chi Square of 1.087 and significance level of .297. Thus, the null hypothesis of homoscedasticity cannot be rejected.

Multicollinearity

All Variance Inflation Factors (VIF) are below 5 (max=2.016) and the correlation coefficients are well below 0.8, indicating no multicollinearity.

Independent Residuals

The Durbin-Watson score of 1.926 indicates that the residuals are independent (critical values are 1.754-2.246).

Normal Distribution of Residuals

The residuals are found to be not fully normally distributed. However, given this sufficiently large sample size, the expected effect on the statistical significance is expected to be very minor (Field, 2018; Lumley, Diehr, Emerson, & Chen, 2002).

Figure 17: Histogram of residuals

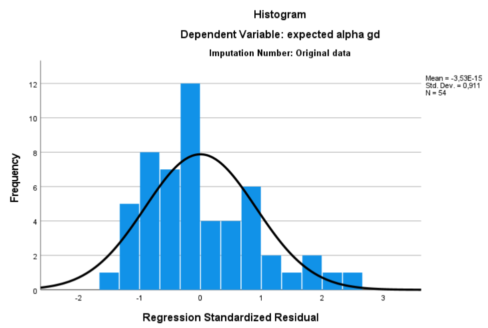
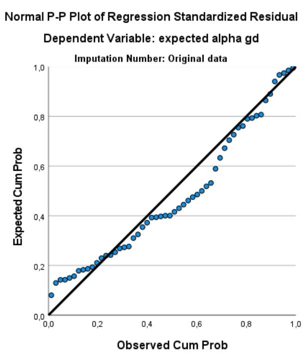


Figure 18: P-P plot of residuals



Linearity Between the Independent Variables and the Dependent Variable

The linearity of each independent variable, with the dependent variable is tested using the curve estimation function of SPSS and using the partial regression plots of each IV with the DV. Based on this analysis, no adjustment was deemed to be necessary.

Ellsberg's Urn Loss Domain

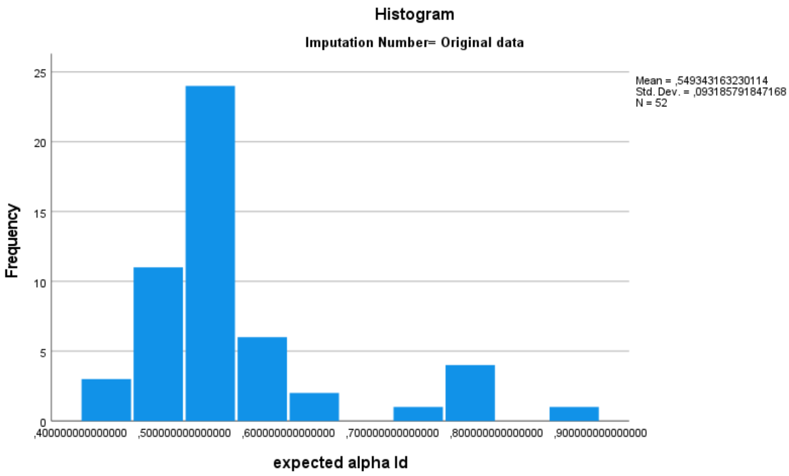
Significant Outliers

Given the nature of the experiment, only one type of significant outliers is possible; people that prefer the ambiguity/non-ambiguity urn within all questions. Of those respondents the ambiguity value is too high/low to be measured in the experiment, thus those 5 cases are excluded. Furthermore, there are also 10 cases that did not finish the experiment, and 3 cases that showed inconsistency within the Ellsberg's urn task. All those 18/70 cases are replaced with imputated values.

Normal Distribution of the Dependent Variable

The dependent variable is found to be not normally distributed, with a skewness of 1.86 and a kurtosis of 3.39. This can be reduced using a natural log transformation. But, given that this does not have a significant influence on the regression analysis, but it does make the results harder to interpret, it has been decided to not use any transformation.

Figure 19: Histogram of the normal distribution of the DV



Test for Heteroscedasticity

The Breusch-Pagan test for heteroscedasticity shows a Chi Square of 1.166 and a significance level of .280. Thus, the null hypothesis of homoscedasticity cannot be rejected.

Multicollinearity

All Variance Inflation Factors (VIF) are below 5 (max=1.884) and the correlation coefficients are well below 0.8, indicating no multicollinearity.

Independent Residuals

The Durbin-Watson score of 1.867 indicates that the residuals are independent (critical values are 1.754-2.246).

Normal Distribution of Residuals

The residuals are found to be not fully normally distributed. However, given this sufficiently large sample size, the expected effect on the statistical significance is anticipated to be very minor (Field, 2018; Lumley, Diehr, Emerson, & Chen, 2002).

Figure 20: Histogram of residuals

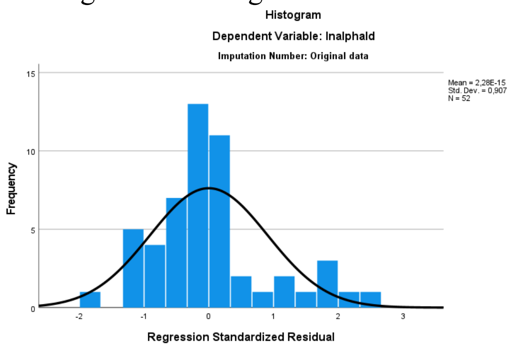
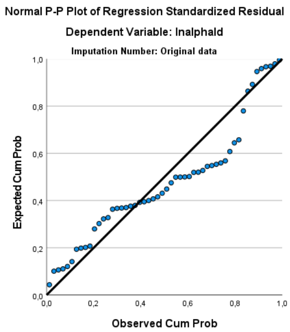


Figure 21: P-P plot of residuals



Linearity Between the Independent Variables and the Dependent Variable

The linearity of each independent variable, with the dependent variable is tested using the curve estimation function of SPSS and using the partial regression plots of each IV with the DV. Based on this analysis, no adjustment was deemed to be necessary.

Ultimatum & Dictator game

Table 14

Descriptive Statistics of the Ultimatum and Dictator Game

	Ultimatum Propose	*Ultimatum Minimum Acceptable Offer*	*Dictator Propose*
R^2	.328	.208	.224
Ad. R^2	.211	.062	.082
Df of the regression	10	10	10
Df of the residual	57	56	56
No. of observations in autism group	28	28	28
No. of observations in neurotypical group	40	39	39

Ultimatum Game Proposer Side

Significant Outliers

Cook's distance is used to indicate the outliers, with a critical value of 0.06 (4/69 cases).

Analysis using Cook's distance indicates that there are 3 outliers. Those are analyzed on a case-by-case basis, and 2 of them seem somewhat unlikely, but not completely unlikely from a rational point of view (giving a very low amount of money). One case has been removed, the largest outlier (0.233) as the answer indicates that the respondent would be giving the total amount of money to the other party, which is highly unlikely, and furthermore, the well-below average time spend (874 seconds) indicates a lack of attention, which might indicate that the respondent did not properly read the instructions.

Normal Distribution of Dependent Variable

This is an optional test, as it is not necessary for an OLS regression. However, a non-normal distribution of the dependent variable can lead to a non-normally distributed residual (Field, 2018). Based on the evidence, the dependent variable is not normally disturbed (Kolmogorov-Smirnov sig <0.001; skewness = 0.698; kurtosis = 13.136). Normally, this can be solved by a transformation. However, given that many respondents filled in the exact same answer (5), it can only be mildly reduced, using an advanced transformation, known as the SINH-ARCSINH distribution formula of Jones & Pewley (2009) (see formula 18). The best possible parameters for this variable are a delta of 30, and an epsilon of zero. However, given the only small improvement hereof on the normal distribution (skewness = 0.196; kurtosis = 9.84) and the detrimental effect on the explanatory power (R^2 0.322 > 0.179), the choice is made to not make the DV normally distributed.

$$SINH - ARCSINH = SINH(\delta * SINH^{-1}\left(\frac{UltimatumGameProposer}{10}\right) - \epsilon) \quad (18)$$

Test for Heteroscedasticity

The Breusch-Pagan test for heteroscedasticity shows a Chi Square of .131 and significance level of .718. Thus, the null hypothesis of homoscedasticity cannot be rejected.

Multicollinearity

All Variance Inflation Factors (VIF) are below 5 (max=1.717) and correlation coefficients are well below 0.8, indicating no multicollinearity.

Independent Residuals

The Durbin-Watson score of 2.207 indicates that the residuals are independent (critical values are 1.716-2.284).

Normal Distribution of Residuals

The plots indicate a non-normal distribution of the residuals. A likely cause lies in the non-normal distribution of the dependent variable. But, given the detrimental effect of a transformation, it is chosen to keep the variable as is. Furthermore, within this sufficiently large sample, the effect hereof on the statistical significance is only very minor (Field, 2018).

Figure 22: Histogram of residuals before transformation

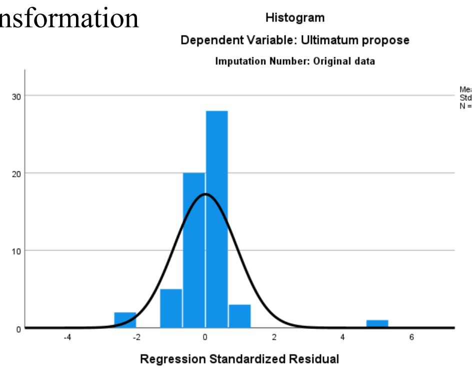


Figure 23: P-P plot of residuals before transformation

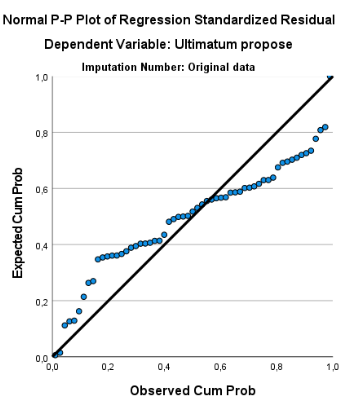


Figure 24: Histogram of residuals after transformation

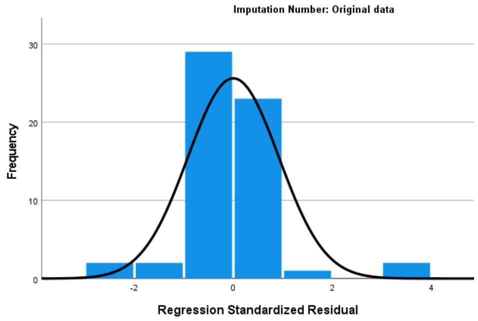
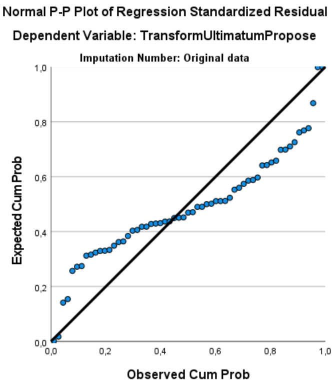


Figure 25: P-P plot of residuals after transformation



Linearity Between the Independent Variables and the Dependent Variable

The linearity of each independent variable, with the dependent variable is tested using the curve estimation function of SPSS and using the partial regression plots of each IV with the DV. Only the variable 'IQ' showed the need for an adjustment, namely the addition of the squared term. This squared term was added based on the centered version of IQ (as also used within the regression).

Ultimatum Game Minimum Acceptable Offer

Significant Outliers

Cook's distance is used to indicate the outliers, with a critical value of 0.06 (4/69 cases). Analysis using Cook's distance indicates that there are 2 large outliers. As both of these outliers are imputed cases, it has been chosen to remove them from the analysis, as it indicates an inaccurate imputation for those cases. A likely cause for the inaccurate imputation for both of these cases, are that those two cases had a larger amount of missing data, due to the respondents not fully finishing the survey. This likely caused the imputation algorithm to inaccurately imputate those variables.

Normal Distribution of the Dependent Variable

Based on the skewness and kurtosis (-0.56 and -0.95 respectively) the DV seems to be normally distributed. However, given the nature of this data, many respondents only fill in integers, which makes the data not completely normally distributed. This is also shown by the Kolmogorov-Smirnov test for normal distribution, which indicates a non-normally distributed DV (sig<0.001). However, this does not cause any problems in this dataset with over 50 observations (Field, 2018).

Test for Heteroscedasticity

The Breusch-Pagan test for heteroscedasticity shows a Chi Square of .023 and significance level of .879. Thus, the null hypothesis of homoscedasticity cannot be rejected.

Multicollinearity

All Variance Inflation Factors (VIF) are below 5 (max=1.717) and correlation coefficients are well below 0.8, indicating no multicollinearity.

Independent Residuals

The Durbin-Watson score of 1.827 indicates that the residuals are independent (critical values are 1.716-2.284).

Normal Distribution of Residuals

Based on the plots (P-P plot and histogram) the residuals seem to be reasonably normally distributed. The small deviation does not cause any problem, with this sufficiently large dataset (Field, 2018).

Figure 26: Histogram of residuals

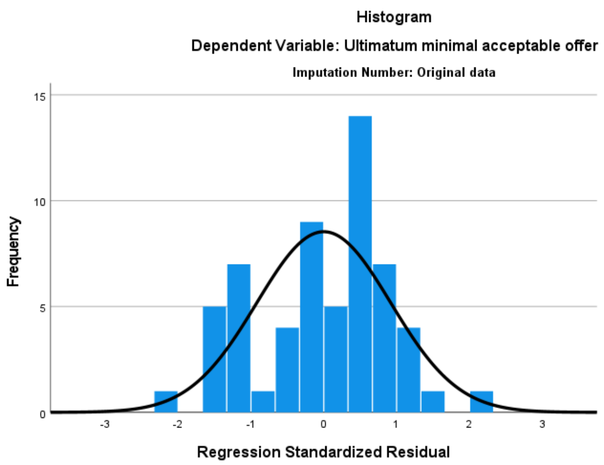
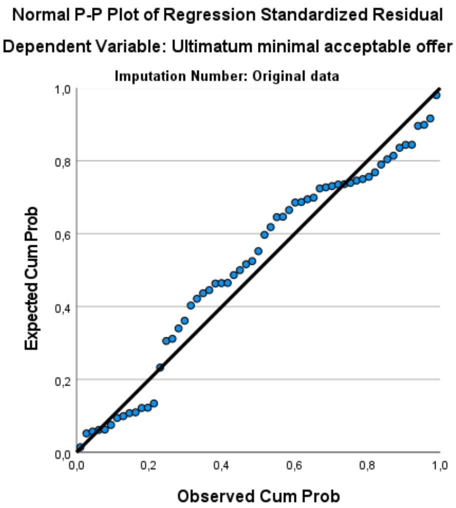


Figure 27: P-P plot of residuals



Linearity Between the Independent Variables and the Dependent Variable

The linearity of each independent variable, with the dependent variable is tested using the curve estimation function of SPSS and using the partial regression plots of each IV with the DV. The results are comparable to the proposer side of the ultimatum game. Thus all variables show linearity, except IQ, which also needs the squared term.

Dictator Game

Significant Outliers

Cook's distance is used to indicate the outliers, with a critical value of 0.06 (4/69 cases). Analysis using Cook's distance indicates that there are 6 outliers. Those outliers are analyzed on a case-by-case basis. Two of those cases show a proposed amount of 10 euros (the maximum amount). One of those two cases is of the same respondent as within the denied case of the ultimatum game proposer side, who showed a lack of attention/effort. The other case showed a proposal of 10 euros, but only a proposal of 5 euros in the ultimatum game. Given the explanation within chapter two of this study, it is highly unlikely that a subject would want to propose more within the dictator game; and, even though some inconsistency is to be expected, proposing the full amount to the other party seems highly unlikely in reality, combined with only proposing 5 euros in the ultimatum game. Thus, it is chosen to remove both of those cases.

When considering the other 4 outliers, all 4 of those respondents answered that they would offer no amount of money to the other party (thus would act fully in their own interest). Given that, based on the total duration and them not failing any other question, it seems likely that this describes their real-world behaviour. Thus, those cases are not removed.

Normal Distribution of the Dependent Variable

Within this experiment, a similar pattern as in the ultimatum game also is visible. Based on the skewness and kurtosis (-1.42 and 1.00 respectively) the DV seems to be normally distributed. However, given the type of data, many respondents only fill in integers, which makes the data not completely normally distributed. This is also shown by the Kolmogorov-Smirnov test for normal distribution, which shows a non-normally distributed DV (sig<0.001). But, within this dataset with over 50 observations, this does not cause any problems (Field, 2018). Especially not, since it is not a requirement for an OLS regression.

Test for Heteroscedasticity

The Breusch-Pagan test for heteroscedasticity shows a Chi Square of .033 and significance level of .855. Thus, the null hypothesis of homoscedasticity cannot be rejected.

Multicollinearity

All Variance Inflation Factors (VIF) are below 5 (max = 1.717) and correlation coefficients are well below 0.8, indicating no multicollinearity.

Independent Residuals

The Durbin-Watson score of 2.094 indicates that the residuals are independent (critical values are 1.716-2.284).

Normal Distribution of Residuals

Based on the plots (P-P plot and histogram) the residuals seem to be reasonably normally distributed. The small deviation does not cause a problem, with this sufficiently large dataset (Field, 2018).

Figure 28: Histogram of residuals

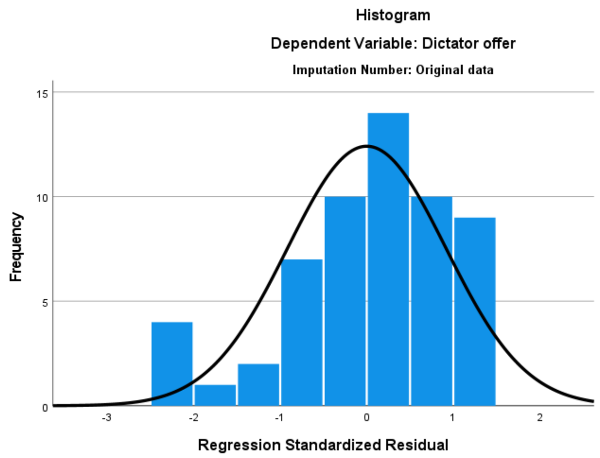
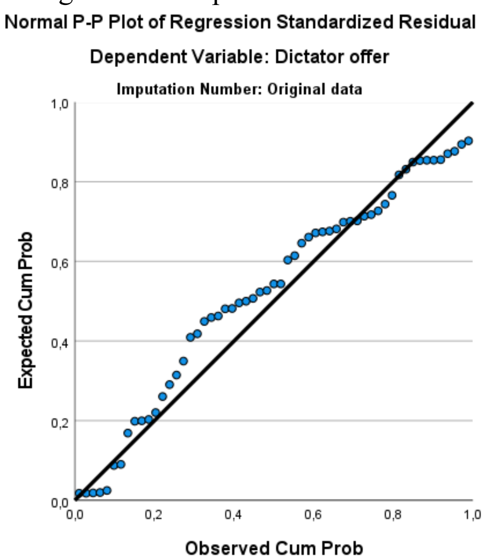


Figure 29: P-P plot of residuals



Linearity Between the Independent Variables and the Dependent Variable

The linearity of each independent variable, with the dependent variable is tested using the curve estimation function of SPSS and using the partial regression plots of each IV with the DV. The results are comparable to the ultimatum game. Thus, all variables show linearity, expect IQ, which also needs the squared term.

Appendix 8: Prospect Theory (50,0) Domain Compared to (150,50) Domain

This chapter compared the predicted parameters of the 50,0 domain with the 150,50 domain. The equation is exactly the same as within the main regression analysis, but since bootstrapping[20] is not used, the confidence intervals are inflated. Hereby, this appendix aims to find whether there are significant differences in the alpha/beta and gamma/delta parameter between the 50,0 and 150,50 domain. This helps to act as an additional robustness check, by checking if a change in the monetary values would lead to far different parameters. Furthermore, given that alpha/beta has a much higher effect on the CE within the 50,0 domain compared to the 150,50 domain, it also checks whether alpha is consistent across both domains.

50,0 Gain Domain

Table 15

50, 0 Gain Domain Parameter Estimates, 311 observations

			95% Confidence Interval	
Parameter	Estimate	Std. Error	Lower Bound	Upper Bound
alpha	.890	.230	.436	1.344
gamma	.652	.171	.315	.989
AAutism	.100	.118	-.132	.332
AAutismIQ	-.050	.048	-.145	.045
AAge	.001	.007	-.013	.015
AMale	.050	.115	-.177	.277
ANonBinary	.300	.567	-.816	1.416
AIQ	.000	.027	-.053	.053
AFL	.010	.000	.010	.010
ADuration	1.000E-5	.000	-1.001E-6	2.100E-5
GAutism	.020	.082	-.141	.181
GAutismIQ	.016	.028	-.039	.071
GAge	.004	.005	-.006	.015
GMale	-.085	.080	-.242	.072
GNonBinary	.057	.430	-.790	.903
GIQ	.004	.018	-.031	.039
GFL	.030	.000	.030	.030
GDuration	.000	.000	-6.336E-6	6.336E-6

[20] Bootstrapping is not used in those regressions, since these are only used as an extra robustness check. Given the nature of these complex non-linear regressions, bootstrapping is found to be very time consuming, with a calculations time of 3-4 hours per regression, due to the compute-intensive nature of this regression.

150,50 gain domain

Table 16

150,50 Gain Domain Parameter Estimates, 302 observations

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
alpha	.890	.634	-.358	2.138
gamma	.597	.135	.331	.863
AAutism	.100	.316	-.523	.723
AAutismIQ	.020	.131	-.239	.278
AAge	.001	.019	-.036	.038
AMale	.050	.307	-.554	.654
ANonBinary	-.010	1.481	-2.926	2.906
AIQ	.114	.079	-.041	.268
AFL	.010	.000	.010	.010
ADuration	.000	.000	-3.951E-5	3.951E-5
GAutism	.042	.071	-.097	.182
GAutismIQ	.015	.028	-.040	.071
GAge	.000	.004	-.008	.008
GMale	.091	.069	-.044	.227
GNonBinary	-.056	.240	-.529	.416
GIQ	.001	.017	-.033	.035
GFL	.030	.000	.030	.030
GDuration	1.000E-5	.000	-1.464E-5	3.464E-5

50,0 loss domain

Table 17

50,0 Loss Domain Parameter Estimates, 245 observations

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
alpha	.840	.207	.432	1.248
gamma	.516	.132	.257	.776
AAutism	.110	.096	-.079	.299
AAutismIQ	-.050	.040	-.129	.029
AAge	.001	.007	-.012	.014
AHigherEduca-ted	.000	.000	.000	.000
AMale	.050	.100	-.148	.248
ANonBinary	-.010	4.579	-9.031	9.011
AIQ	.000	.022	-.044	.044
AFL	-.002	.097	-.193	.188
ADuration	.000	.000	-9.889E-6	9.889E-6
GAutism	-.031	.056	-.141	.078
GAutismIQ	-.014	.023	-.060	.031
GAge	.004	.004	-.004	.013
GHigherEduca-ted	.000	.000	.000	.000
GMale	.054	.060	-.065	.173
GNonBinary	1.199	7.787	-14.140	16.539
GIQ	.005	.013	-.021	.031
GFL	-.013	.058	-.127	.101
GDuration	.000	.000	-5.796E-6	5.796E-6

5.1 150,50 loss domain

Table 18

150,50 Loss Domain Parameter Estimates, 355 observations

			95% Confidence Interval	
Parameter	Estimate	Std. Error	Lower Bound	Upper Bound
alpha	0.839	0.000	0.839	0.839
gamma	0.492	0.037	0.390	0.594
AAutism	0.110	0.010	0.082	0.138
AAutismIQ	3.496E-14	0.000	2.249E-14	4.742E-14
AAge	0.001	0.003	-0.007	0.009
AHigherEducated	0.000	0.000	-1.295E-12	1.295E-12
AMale	0.050	0.038	-0.056	0.156
ANonBinary	-0.010	0.000	-0.010	-0.010
AIQ	7.729E-14	0.039	-0.110	0.110
AFL	2.597E-15	0.000	2.597E-15	2.597E-15
ADuration	0.000	0.000	0.000	0.000
GAutism	-0.023	0.045	-0.147	0.101
GAutismIQ	3.132E-13	0.000	-1.805E-12	2.431E-12
GAge	-8.377E-18	0.000	-4.386E-13	4.386E-13
GHigherEducated	0.000	0.000	-6.829E-16	6.829E-16
GMale	0.084	0.037	-0.018	0.186
GNonBinary	2.270E-16	0.000	-1.301E-15	1.755E-15
GIQ	5.067E-13	0.004	-0.012	0.012
GFL	1.773E-14	0.000	1.760E-14	1.785E-14
GDuration	0.000	0.000	0.000	0.000

Based on these regressions, both within the loss domain as in the gain domain, there is found to be no large differences in the alpha and gamma parameters between the 50,0 and 150,50 prospect. So, the main regressions, as included in chapter 4 of the paper, are found to be robust in both the 50,0 and 150,50 prospects.

Appendix 9: Risk Aversion with Expected Utility Value Function

In order to make the results more comparable to the studies of Fujino, et al., 2017 and Gosling & Moutier, 2018, the risk aversion is also calculated using the Expected Utility function. Given that both of those studies did not use extreme probabilities (e.g. a P1 of 5% and 95%), it has been decided to remove those extreme values from this regression. Both of those regression are calculated using a non-linear regression with 500 bootstraps.

Formula: $$(Certainty\ Equivalent)^x = P_a * €_a^x + P_b * €_b^x \rightarrow (certainty\ equivalent) = (P_a * €_a^x + P_b * €_b^x)^{\frac{1}{x}} \quad (19)$$

Regression equation:

$$CE = (⟦P_a * €_a^{(\beta 0+\beta 1*autismdummy+\beta_n*Control\ Variables)} + P_b * €_b^{(\beta 0+\beta 1*autismdummy+\beta_n*Control\ Variables)}\big)^{\frac{1}{(\beta 0+\beta 1*autismdummy+\beta_n*Control\ Variables)}} \quad (20)$$

Table 19
Regression Output for Predicting the EU Parameter in the Gain Domain
R^2 = .779, 394 observations

			95% Trimmed Range	
Parameter	Estimate	Std. Error	Lower Bound	Upper Bound
X	.830	.000	.830	.830
Autism	.093	.000	.093	.093
AutismIQ	.037	.036	-.033	.116
Age	.002	.006	-.009	.012
HigherEducated	.000	.000	.000	.000
Male	.100	.007	.085	.100
NonBinary	-.055	7.919	-1.857	.818
IQ	.012	.020	-.032	.046
FL	-.040	.115	-.258	.169

Table 20

Regression Output for Predicting the EU parameter in the Loss Domain

R^2 = 0.762, 359 observations

			95% Trimmed Range	
Parameter	Estimate	Std. Error	Lower Bound	Upper Bound
X	.562	.196	-.051	.745
Autism	.026	.210	-.188	.568
AutismIQ	-.033	.102	-.304	.181
Age	-.007	.011	-.035	.009
HigherEducated	.000	.000	.000	.000
Male	.169	.141	-.085	.499
NonBinary	.174	.273	-.199	.802
IQ	.046	.078	.006	.348
FL	.032	.202	-.269	.577
Duration	.000	.000	.000	.000

So, also while using the EU formula, a higher degree of rationality can be found with the autistic individuals, within the gain domain. However, within the loss domain, no significant difference can be found.

Furthermore, as is to be expected, the x parameter is somewhat lower than the alpha/beta parameter within the prospect theory, given that there is no probability function which, on average, results in underweighting of the probabilities, with three probabilities included – 25%, 50% and 75%.

Appendix 10: Ultimatum vs Dictator Game

Within this additional regression, it is tested whether people propose significantly more money in the ultimatum game, compared to the dictator game. This is based on the fact that people would only give money in the dictator game due to a feeling of 'fairness', but in the ultimatum game people would also give money due to the 'fear of rejection'.

The dependent variable = $UltimatumDictator = UltimatumProposedAmount - DictatorProposedAmount$ (21)

All assumptions are tested, with outcomes similar to the other assumption tests of the dictator and ultimatum game. One statistically significant outlier is removed, which indicated highly unlikely behaviour (proposing 10 euros in the dictator game, and 5 euros in the ultimatum game).

Table 21

Regression coefficients for predicting the UltimatumDictator variable, 67 observations

	Unstandardized Coefficients			95,0% Confidence Interval for B	
Variable	B	Std. Error	Sig.	Lower Bound	Upper Bound
Constant	0.249	0.476	0.603	-0.708	1.206
Autism Dummy	-0.247	0.389	0.527	-1.029	0.534
Higher educated dummy	0.335	0.538	0.537	-0.747	1.416
Male gender dummy	0.717	0.443	0.112	-0.173	1.607
Non-binary gender dummy	0.205	1.513	0.893	-2.837	3.246
Age centered	0.030	0.026	0.248	-0.022	0.082
Financial Literacy Centered	0.544	0.386	0.165	-0.232	1.321
Autism <> IQ interaction centered	0.274	0.168	0.110	-0.064	0.613
IQ Centered	-0.028	0.100	0.783	-0.229	0.173
IQ Squared	-0.021	0.037	0.581	-0.095	0.054

The outcome thus indicates no significant difference in choices made between the ultimatum and dictator game. This thus shows that people likely make choices based on the feeling of 'fairness' and not based on the 'fear of rejection'. Furthermore, the outcome also does not support the hypothesis that autistic people are less strongly influenced by the feeling of 'fairness' and stronger influenced by the 'fear of rejection', as this would show itself with a significantly positive beta for the autism dummy.

Furthermore, although not statistically significant, the evidence indicates that autistic respondents with a higher IQ might be more driven by a feeling of fear. And this matters especially as IQ is found to be correlated with autism severity, with a higher IQ indicating a lower level of autism symptom severity (see chapter 3.6 and appx. 2 for more details).

Appendix 11: Ellsberg Urn When Not Considering Autism's Different Utility Function

In order to test the influence of the utility function on the outcomes of the Alpha maxmin parameter, the same regression as within the main research is also run, but with the utility function of the neurotypical individuals also applied to the monetary values of the ASD respondents. The outcomes hereof are shown below. As shown by those outcomes, the application of the same utility function to both groups does not significantly influence the outcomes of the hypothesis test (the significance of the autism dummy). Thus, applying the same utility function to both groups, as sometimes done within studies, does not likely have a large influence on the prediction of alpha maxmin, if the differences in the utility function are relatively minor (.10 in the gain domain, and .11 in the loss domain within this case). Furthermore, this does also show that the inability to find differences within this study is not caused by the different utility function for both groups.

Table 22

OLS Regression for Predicting Ellsberg's Urn Gain-Domain Parameters
R^2 = .262, 28 observations in ASD group, 42 observations in neurotypical group

	Unstandardized Coefficients			95,0% Confidence Interval for B	
Parameter	B	Std. Error	Sig.	Lower Bound	Upper Bound
(Constant)	.503	.012	<.001	.478	.528
autism dummy	.001	.010	.885	-.019	.022
higher educated dummy (HBO, University, or doctorate/PhD)	.028	.015	.064	-.002	.057
male gender dummy	-.004	.012	.749	-.028	.020
non-binary gender dummy	.008	.040	.833	-.072	.089
AgeCentered	.000	.001	.667	-.001	.002
Flcentered	-.011	.011	.295	-.032	.010
AutismIQCentered	.000	.005	.976	-.010	.010
IQCentered	.003	.003	.253	-.002	.009
Duration (in seconds)	1.398E-6	.000	.012	.000	.000

Table 23

OLS Regression for Predicting Ellsberg's Urn Loss-Domain Parameters
R^2 = .106, 28 observations in ASD group, 42 observations in neurotypical group

	Unstandardized Coefficients			95,0% Confidence Interval for B	
Parameter	B	Std. Error	Sig.	Lower Bound	Upper Bound
(Constant)	.534	.028	<.001	.477	.591
autism dummy	.020	.025	.435	-.031	.071
higher educated dummy (HBO. University. or doctorate/PhD)	-.004	.037	.924	-.078	.071
male gender dummy	-.001	.031	.978	-.063	.061
non-binary gender dummy	-.090	.095	.348	-.282	.102
AgeCentered	-.002	.002	.322	-.005	.002
Flcentered	.031	.026	.255	-.023	.084
AutismIQCentered	-.005	.012	.677	-.029	.019
IQCentered	-.002	.007	.821	-.015	.012
Duration (in seconds)	2.729E-7	.000	.833	.000	.000