Age differences in risk-taking behaviour: the role of risk preference and cognitive ability

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Impact of COVID-19

On March 13th, 2020, the University of Essex announced a series of measures to prevent the spread of coronavirus amongst students and staff. One of these measures was the effective closure of departments, and the suspension of any in-person testing involving participants. At this time, I had collected half of the data for my third study, intended to be included in this thesis. As my first two studies (chapters 2 and 3) focus on financial tasks that measure decisions based on description, the third study was designed to be a computerized driving task measuring decisions from experience, which would further investigate age differences in risk-taking behaviour across task type and domain. As per university guidelines, I paused data collection and worked from home. Unfortunately, the risks associated with resuming in-person testing with older adults remained too high throughout the remainder of my degree, and data collection has remained impossible since the start of the coronavirus pandemic. As I was not able to complete the study I intended for my thesis, I designed another study (discussed in the fourth chapter of this thesis), which was conducted online.

In summary, COVID-19 is a serious health risk and has impacted many lives. It has also impacted mine, and my ability to complete my planned third study to a degree that it could have made a significant contribution to my thesis, and or the field of research. I made changes to continue working with the age groups involved in this project in a safe manner, while keeping in line with my project's aims. This has changed my thesis in a substantial manner.

DECLARATION

I declare that the work presented in this thesis, “Age differences in risk-taking behaviour: the role of risk preference and cognitive ability” is my own. Contributions of others are clearly acknowledged at the beginning of the chapters. None of the work referred to in this thesis has been submitted for any other degree at this or any other University or institution. References and contributions by co-authors are provided when the chapter is based on a publication. Any quotations have been distinguished by quotation marks and sources of information are specifically acknowledged.

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Thesis Abstract

Previous research examining age differences in decision-making under risk has yielded mixed findings. In some studies, older adults took more risk than younger adults, in other studies these findings were the opposite, and in some studies, there were no age differences at all. These mixed findings may result from a) age differences due to age-related decline in cognitive abilities, and or (b) age differences in risk preference. The aim of this thesis is to provide insight in adult age differences in risk-taking behaviour, specifically concerning the role of cognitive ability and risk preference. The studies reported in this thesis examine risk-taking on a financial in-person behavioural measure (study 1), a financial computerized behavioural measure with multiple levels of complexity (study 2), and risk-taking in a real-life situation concerning the COVID-19 pandemic (study 3). The findings of these studies highlight the complexity of age differences in risk-taking, and their dependence on other factors, such as the type of measurements used for risk-taking, cognitive ability and risk preference (studies 1 and 2), and the risk domain (studies 1,2 and 3). It has also contributed other factors beyond cognitive ability and risk preference, such as the importance of risk comprehension (study 1, 2) and risk perception (study 3), and how these factors affect younger and older adults' risk-taking behaviour.

CHAPTER 1

INTRODUCTION

1.1 Overview

We are currently facing an unprecedented situation in which we will soon have more older adults than children. By 2050, it is projected that one in four people in the United Kingdom will be aged 65 years and over (Office for National Statistics, 2021). The rise in life expectancy and increase in the proportion of older adults also means that many important decisions will be made later in life. These decisions often involve a level of risk, such as choosing critical medical treatment (e.g. radiation or chemotherapy), each treatment with their own rates of success and severity of side effects. In addition, the process of ageing is characterized by changes in personality and cognition, and these changes may impact older adult decision-making (Strough & Bruine de Bruin, 2020).

A common societal belief is that older adults are risk averse and prefer to avoid risk at all costs. However, older adults do display some risk-seeking behaviours. For example, older adults are a common sight at gambling halls and casinos, as well as often purchasing lottery tickets. This common assumption that older adults are naturally risk averse may be inaccurate and may prevent the availability of support for older adults to make optimal decisions under risk and uncertainty.

In research on risk-taking behaviour, age differences in risk-taking have varied. These mixed findings may be a result of the materials used to measure risk-taking, the extent to which they reflect people's underlying preference towards risk, and how much they rely on cognitive abilities that naturally decline with age. As such, age differences in risk-taking could be caused by either age differences in risk preference, or age differences in cognitive abilities.

It is important to understand these age-related differences in risk-taking behaviour as the rise in living conditions in developed nations have allowed citizens to live longer than ever before, causing many important life decisions, often accompanied by risk and uncertainty, to be made in older adulthood. As such, this thesis aimed to investigate the role of risk preference and cognitive ability in age differences in risk-taking.

1.2 Age differences in risk-taking

1.2.1 Significance

In the United Kingdom alone, one in four people in the United Kingdom will be aged 65 years and over in 2050 (Office for National Statistics, 2021). Because of this shift in population age, it is important to examine the mechanisms of older adult decision-making, especially decisions that encompass risk.

The common assumption that older adults prefer avoiding risk at all cost can be harmful. By not acknowledging that older adults may also seek out risk, or are exposed to situations involving risk and uncertainty, suitable support for older adults may not be available. For example, findings show that lotteries are the kind of gambling most frequently played by older adults, followed by casino games (Ariyabuddhiphongs, 2012). British past-year gambling stood at 63% in 2010 in the over-75 age category (Wardle et al., 2011). The lack of attention given to gambling problems among older adults has been highlighted in the literature for over a decade, with a review by Matheson et al. (2018) finding only six studies that included adults aged 55 years and older when looking at the prevention and treatment of gambling problems. Despite this age group being often overlooked in gambling research, gambling habits can have severely impacted the quality of life through financial, and social harm, and in some cases, may lead to suicide (Landreat et al., 2019). Gambling problems among older adults may go undetected because healthcare professionals do not expect these issues from an older age group, as most prevention and treatment plans are aimed at young and middle-aged adults (Matheson et al., 2018). In addition, Han et al. (2017) reported a 250 percent increase of marijuana use among American older adults of 65 years and above in seven years, from 2006 to 2013. Older adults are currently not automatically screened for substance use, as they are not presumed to be consumers of recreational drugs (Han et al., 2017). As such, potential drug use problems among older adults may go undiscovered.

An ageing society does not only affect the individual, but also affects the nation's approach to spending and policies. On a governmental level, ageing impacts areas such as pensions, social care, housing, and healthcare (Office of National Statistics, 2018). People of working age contribute more in taxes than is returned to them in the form of public spending. However, this is the opposite as citizens age, as they contribute less in taxes but require more public spending in areas such as healthcare and pension (Office of National Statistics, 2018). As such, individuals making informed and optimal decisions is not only beneficial to the person themselves, but also to the state, as this may limit any additional spending on policies or programs. Understanding which changes accompany ageing, and how this affects decision-making in areas such as healthcare decisions, investments and pension schemes is essential to both the individual and their environment.

1.2.2 Background

Research on ageing and risk-taking has experienced a resurgence, likely due to the rising life expectancy in Western societies. So far, findings on age differences in risk-taking have varied, as older adults will take more risk in some studies (Chen et al., 2014; Denburg et al., 2005; Henninger et al., 2010; Samanez-Larkin et al., 2010; Samanez-Larkin et al., 2011; Schiebener & Brand, 2017; Zamarian et al., 2008) than in others (Henninger et al., 2010; Koscielniak et al., 2016; Mamerow et al., 2016; Rolison et al., 2012). Mata et al. (2011) conducted a meta-analysis on studies using behavioural measures of risk-taking and found that older adults' risk-taking differed across behavioural tasks. These findings were supported by a review by Liebherr et al. (2017). The authors of both works concluded that the conflicting findings on age differences in risk-taking were likely due to variations in design features of behavioural tasks, such as complexity and domain, and how much these tasks relied on cognitive abilities for comprehension of the task and optimal performance.

Some behavioural tasks that measure risk-taking are more complex than others, with some tasks requiring participants to learn on the task to avoid risk, remember prior information or choices, or by applying time pressure on participants' responses. Tasks that encompass these complex features are more likely to rely on cognitive abilities such as working memory and processing speed for optimal performance, whether that is characterized as taking risk or avoiding it on the task. However, many of these cognitive abilities required to make decisions on these tasks also decrease with age. The natural decline in abilities such as working memory and processing speed may lead to older adults taking more risk due to the cognitive demand of the task, instead of their underlying preference towards risk. For example, if a task applies time pressure, an older adult participant with naturally declining processing speed will have more difficulty understanding the task and choosing the optimal approach within the time given to them compared to younger adults. Thus, time constraints may not affect a younger person, but it will affect the likelihood that older adults comprehend the task and pick the optimal approach. As such, older adults' adoption of a sub-optimal approach would be considered risk-taking on the task, even though it was due to an age-related decline in cognitive abilities, instead of their underlying preference towards risk.

Though prior studies have examined the relationship between cognitive ability and risk-taking behaviour (e.g. Chen et al., 2014; Finucane et al., 2005; Frey et al., 2015; Henninger et al., 2010; Pachur et al., 2017), the research on how cognitive ability affects age differences in risk-taking is limited. As such, it is currently unclear whether age differences in risk-taking are due to age differences in risk preference, or age differences in cognitive abilities. This thesis aimed to investigate the role of cognitive ability and risk preference in age differences in risk-taking behaviour.

1. 3 Measurements of age differences in risk-taking

1.3.1 Self-reported risk preference

Risk preference, otherwise referred to as risk attitude, can be defined as the propensity to engage in behaviours or activities that are rewarding yet involve some potential for loss, such as including substance use or criminal activities associated with physical and mental harm to individuals (Mata et al., 2018). Risk preference is commonly assumed to explain risk-taking behaviour, as risk-taking is an expression of one's preference or attitude towards risk. Accordingly, one's risk preferences reflect tendencies towards or against risk-taking when making decisions, such that a risk-averse individual would be willing to sacrifice overall value to avoid selecting the riskier option (Henninger et al., 2010). Though risk preference is relatively stable over time (i.e. someone highly risk averse will likely not become highly risk-seeking) (Mata et al., 2018; Schildberg-Hörisch, 2018), risk preference may still change as people age. Age differences in risk preference across the life span have been studied extensively, and older adults have often been found to be more risk averse than their younger counterparts concerning risky decision-making (Bonsang & Dohmen, 2015; Dohmen et al., 2011; Josef et al., 2016; Mamerow et al., 2016; Rolison et al., 2014).

Risk preference is commonly captured through people's responses to hypothetical or real-life behaviours. Participants may be asked whether they agree with a given statement ("I enjoy taking risks") or provide the likelihood of them engaging in risky activities or behaviours ("Drinking heavily at a social function"). Additionally, some measures will provide a hypothetical scenario to respond to, such as a medical emergency in which decisions must be made about treatments or ask people to report on the frequency they engage in risky behaviour. Most self-report measures of risk preference include several items, though some only provide a single item (Bonsang & Dohmen, 2015; Dohmen et al., 2011).

Though there is evidence of a general risk preference, people's willingness to take risks may also be domain specific. As such, self-report measures can be split into measures of general and domain-specific risk preference. An example of a measure of general risk preference is the single item used by Dohmen et al. (2011). Participants are asked "Are you in general a risk-taking person or do you usually try to avoid taking risks?", and asked to provide an answer on a scale from 0 (0 = absolutely not risk taking) to 10 (10 = very risk taking). Dohmen et al. (2011) found that older adults reported being less risk-taking compared to younger adults.

Mamerow et al. (2016) and Josef et al. (2016) used the same item and report similar findings, with other adults reporting lower willingness to take risks, thus being more risk averse compared to younger adults. Another measure of general risk with multiple items is the General Risk Propensity Scale (GRiPS; Zhang et al., 2019), with 8 items measuring people's general propensity to take risks. Participants are given statements about themselves (“My friends would say I'm a risk taker") and rate on a 5-point Likert scale to what extent they agree with the statement.

An example of a popular domain-specific risk preference measure is the Domain Specific Risk Taking (Dospert; Weber et al., 2002). This measure consists of 5 domains (social, ethical, recreational, health and safety, and financial), each with three scales to measure a person’s likelihood to engage in risky behaviour, the perceived benefit and perceived risk of the risky behaviour. Participants respond to six items for each domain (i.e. “cheating on an exam” for the ethical domain), with identical items for each of the three scales (i.e. Likelihood, Expected Benefits, and Risk Perception). In the Likelihood scale, participants rated the likelihood that they would engage in the given behaviours on a seven-point Likert scale from 1 to 5 (1 = very unlikely, 5 = very likely). In the Expected Benefit scale, participants rated the benefits that they perceived in the outlined behaviours on a seven-point Likert scale from 1 to 5 (1 = no benefits at all, 5 = great benefits). On the third scale, Risk Perception, participants rated the risk they perceived in undertaking the outlined behaviours on a seven-point Likert scale from 1 to 5 (1 = not at all risky, 5 = extremely risky). The scale was later adopted into a shortened version (Blais & Weber, 2006), which has been used more regularly in ageing research compared to its original scale since its development. The Dospert has also been used for assessing age differences in risk preference. Findings by Rolison et al. (2014)

demonstrated that older adults were more risk averse on the Dospert's (Blais & Weber, 2006) financial, health, recreational, and ethical domains, but there was no age-related decline concerning social risk-taking. In Dohmen et al. (2011), the authors used 6 single items to measure risk-taking across 6 different domains (i.e. driving, financial, recreational, occupational, health, and social). People are asked to rate their willingness to take risk for each domain (i.e. "How is your willingness to take risks while driving?" for measuring driving risk). They then provide an answer on a scale from 0 ("not at all willing to take risks") to 10 ("very willing to take risks"). Age was negatively associated with willingness to take risks in all domains, indicating that people become more risk averse as they age. Josef et al. (2016) used these items in their longitudinal study and reported similar outcomes. In their study, older age was associated with a decline in willingness to take risks across all 6 domains, but at different rates. Willingness to take financial and health-related risk showed only a small decline until the age of 55, after which the decline increased, whereas willingness to take social risks only showed a consistently small decline as people aged.

Recent findings indicate that risk preference is not solely general or domain-specific but encompasses both components (Frey et al., 2017). People can have a general preference towards risk that encompasses risk overall but may be more or less comfortable with risk in different domains, such as health or recreational risk. As risk preference is often assumed to underlie risk-taking behaviour, self-report measures have occasionally been used together with measures of risk-taking, such as behavioural tasks, to connect risk preference to behaviour on a risk-taking task.

1.3.2 Risk-taking tasks

A common method of measuring risk-taking behaviour is through behavioural tasks. It is thought that people's underlying belief about risk, and their tendency to be risk averse or risk-seeking, is reflected in their behaviour on these tasks. In other words, people's risk-taking on behavioural tasks is thought to be related to their underlying preference towards risk. Despite the large number of existing behavioural tasks, most tasks apply monetary scenarios to gauge people's risk-taking behaviour. Monetary scenarios, such as using a lottery or the choice between a sure and risky option, are most popular. Behavioural tasks measuring risk-taking differ in one important dimension - whether the risk-taking decisions are description-based decisions or experience-based decisions.

1.3.2.1 Description-based tasks

Behavioural tasks that measure decisions based on description include full information about probabilities and outcomes, or those are made easy to obtain by the participants themselves (Mata et al., 2011). An example of such a situation is asking participants whether they believe it is more likely that a coin will be in a black or red box when these are displayed on the screen. Participants are not given the likelihood of the coin's presence in a black or red box, but they can easily calculate this by assessing the number of red and black boxes on the screen and dividing by the total number of boxes. Descriptive tasks differ in how these choice options are presented, either by displaying the options' probabilities or probabilities represented by objects instead.

In the Cups task (Weller et al., 2007) the sure and risky options and their probabilities are conveyed through cups. The task consists of gain and loss domains, three types of probability and three monetary amounts that can be earned or lost.

Based on the combinations, risky options could either have the same expected value as the safe options, or more advantageous or disadvantageous. Participants gamble with coins that are presented on the screen, with the task randomly deciding whether their choice for the risky option led to a loss or win. If the participant has won money, it is added to their earnings. If money has been lost, it is subtracted from their earnings.

The Cambridge Gambling Task (Rogers et al., 1999) presents participants with a row of 10 boxes, either red or blue. The ratio of red and blue boxes differs per trial, but a yellow token will be hidden in one of the 10 boxes. Firstly, participants are asked what colour box they expect the token to be hidden in. Secondly, participants are asked what proportion of their current earnings they would like to bet on their answer. Participants are not given the probability of the token being in a red or blue box, but they can calculate the likelihood of the token being in a specific box colour based on the ratio of the red and blue boxes on the screen.

Lastly, the Columbia Card Task (Figner et al., 2009) also measures description-based decisions in order to gauge risk-taking behaviour. The task consists of two versions, described as “hot” and “cold”. In both versions, participants are given 32 cards, displayed in 4 rows of 8 cards. Among these cards are loss cards, of which the frequency depends on the trial. Participants turn these cards and increase their earnings with each card they turn over. In the “hot” version, participants turn cards and receive feedback after each card. They can decide after each card whether they want to stop turning cards over and proceed to the next trial. In the “cold” version, participants decide how many cards they want to turn simultaneously, without receiving feedback as they have in the “hot” version. That also means that they cannot decide to stop turning cards after each card (like in the “hot” version), but simply decide the total number of cards they will turn over simultaneously. However, in either version, encountering a loss card ends the trial, and the loss amount is subtracted from their earnings. The task has three parameters, namely the probability of encountering a loss card (1, 2 or 3 cards), the gain amount per card (10, 20 or 30 points), and the loss amount (250, 500 or 750 points).

Description-based tasks have been used to examine age differences and the findings have varied. Weller et al. (2011) reported mixed findings on the Cups task and attributed these findings to the domains in the Cups Task. They found that older adults took less risk in the gain domain of the task, but not in the loss domain, suggesting that risk-taking decreased in age in terms of gains, but not for losses. They also found that sensitivity to the expected value of the choice options was stable through adulthood until about 65 years of age, after which decline in performance was observed, with older adults seemingly experiencing difficulty in adjusting for changes in expected value of choice options. This is further supported in research using the Columbia Card Task (Figner et al., 2009). Despite the “hot” (turning over one card at a time and receiving feedback on the outcome, relying more on affective processes) and “cold” (1 decision on how many cards to turn, relies on predominantly deliberative processes) domains, adjusting decisions in relation to expected value decreased in older age (Weller et al., 2019). Henninger et al. (2010) found age differences on the Cambridge Gambling Task, with older adults more frequently choosing options with low likelihood of winning, indicating that older adults' decision-quality was lower and that they were seeking out risk more than younger adults. When assessing the relationship between cognitive ability and the Cambridge Gambling Task, they found that processing speed and memory were positively correlated with task behaviour, with better memory and processing speed leading to higher quality decisions. When cognitive abilities were considered, the effect of age disappeared, suggesting that the age differences on the task were mediated by age-related decline in cognitive abilities. These findings were similar to those of Deakin et al. (2004), who reported that older adults took longer to make their decisions, were less likely to pick the optimal choice, gambled with similar amounts while the odds of winning differed, took smaller risks and made less adjustments. Zamarian et al. (2008) included the Probability Associated Gambling task (Sinz et al., 2008) in their study (which has a sure versus risky design), and found no age differences in risk-taking on the task, with older adults' choices as well as their estimations of probabilities similar to those of younger adults.

Overall, age differences in tasks measuring description-based decisions are somewhat varied, with age differences seemingly depending on domain, in terms of their direction and size. Across tasks, older adult performance seems to indicate underlying processes that impact their risk-taking, such as their sensitivity to expected values (Henninger et al., 2010; Weller et al., 2011, 2019) and the potential influence of cognitive abilities on age differences in risk-taking behaviour on these tasks (Henninger et al., 2010).

1.3.2.2 Experience-based tasks

Tasks that measure decisions based on experience do not supply information on probabilities and outcomes, instead relying on participants to learn these throughout taking part in the task. For example, participants learn over time how often they can click on a button to increase their earnings before confronted with a loss that can wipe out most, or all, of their earnings. The probability or the magnitude of the loss is not communicated to participants and can only be learned through experience on the task. Similar to tasks that measure decisions based on description, tasks measuring experience-based decisions differ in design features, including the direction or extent in which participants must learn on the task to understand the risk involved.

The Iowa Gambling Task (Bechara et al., 1994) is a well-known example of a task measuring experience-based decisions. Participants are given 4 decks of cards face down (A, B, C, D) and must choose one card at a time, over 100 trials. Participants start with a “loan” of $2000 and are told to make a profit. Each card deck has cards with rewards as well as penalty cards. Across decks, the win and penalty amounts differ, with some decks as more advantageous than others. Decks A and B pay double the amount of decks C and D, but the associated penalty amount is 5 times larger than the penalty of decks C and D. As such, participants learn over time that decks C and D are most advantageous as they result in an overall gain in the long run, thus learning to avoid risk.

Another example is the Balloon Analogue Risk Task (Lejuez et al., 2002), in which participants are given a balloon and pump on the screen, alongside a reset button, a button to collect earnings and an overview of their earnings in the past trial. Each balloon pump earns the participant 5 cents, which is put in a reserve that is not visible to them during the trial. With each pump, the total earnings are increased but so is the chance of the balloon exploding. The participant can decide at any time to stop and collect their earnings. However, if the balloon pops, they lose the monetary amount they have accumulated during the current trial. The Balloon Analogue Risk Task consists of 30 trials, with balloons diffing in their explosion points. The weakest balloon explodes on the first pump, whereas the strongest balloon explodes on the 128th pump. As such, participants learn over time how far they can pump the balloon, in which learning leads to an increase in risk-taking on the task.

Lastly, the Behavioral Investment Allocation Strategy task (Kuhnen & Knutson, 2005) has been used to measure age differences in risk-taking. The Behavioral Investment Allocation Strategy task consists of 20 blocks of 10 trials, a total of 200 trials overall. In these trials, participants are shown a screen with three investment options: two stocks and one bond. In the next screen, participants must choose which option to take (the screen shows "choose" above options). After a short wait, participants are shown their chosen options and how much it earned them, as well as their total earning. After this, the following screen shows them the outcomes of all options that were originally shown in the choice screen. After a fixation cross, they are given another trial. The bond option always has the same value across all trials, which is $1. The two stocks differ, and a "good" and "bad" stock are randomly distributed across the two options for each trial. The "good" stock has better outcomes on average (i.e. +$10 with 50% probability, $0 with 25% probability, and -$10 with 25% probability) than the "bad" stock (i.e. +$10 with 25% probability, $0 with 25% probability, and -$10 with 50% probability). In addition, each of the screens have a time limit of how long they are shown. The screen showing participants their options (2 seconds), the screens in which participants choose and the screen with the highlighted choice (combined duration of 4 seconds), the wait screen (2 seconds), the outcome screen (4 seconds), the overview of outcomes of original options (4 seconds), and screen with fixation cross (2 seconds) differ between each other in how long they are shown to participants.

Among tasks measuring experience-based decisions, age differences in risk-taking are mixed. Zamarian et al. (2008) found significant age differences when using the Iowa Gambling Task; older adults did show improvement in their choices over time, but made less advantageous decisions than younger adults, as well as shifting between advantageous and disadvantageous decks often, suggesting that this stems from older adults experiencing difficulty in developing a consistent and advantageous strategy.

Using the Balloon Analogue Risk Task to investigate age differences in risk-taking, Rolison et al. (2012) reported that younger adults initially took more risk on the task, but experience with the task allowed older adults to later make similar evaluations about gains and losses, and took as much risk as younger adults in later trials. Other studies reported older adults demonstrating lower performance on the Balloon Analogue Risk Task because of higher levels of risk aversiveness compared to younger adults (Henninger et al., 2010; Koscielniak et al., 2016).

Using the Behavioral Investment Allocation Strategy task to examine age differences in risk-taking, Samanez-Larkin et al. (2010) found that older adults chose a risky asset with a negative expected value over a less risky asset with a positive expected value more often than younger adults, suggesting age-related difficulties in understanding and using expected values in decision-making under risk. Overall, across the two studies discussed in the paper, older adults performed worse compared to younger adults. In a second study, older adults again made fewer rational choices than younger adults on the Behavioral Investment Allocation Strategy task. Despite these differences in rational choice, older adults did not differ from younger adults in their knowledge of which options were best, since older adults did not make more mistakes when identifying the correct stock at the end of a block (Samanez-Larkin et al., 2011).

Why age differences in risk-taking vary between studies as well as tasks may be due to differences in design across tasks measuring decisions from experience.

In addition, these differences in design may also cause varying levels of dependency on other abilities to be able to perform optimally.

1.4 Explaining mixed findings on age differences in risk-taking

There are many behavioural tasks currently used to assess age differences in risk-taking behaviour. Across these tasks, age differences have varied in magnitude and direction. Why some find effects of age and others do not (or in opposite directions) may be explained by the difference in task demands, and how the difference in task demands affect the involvement of both risk preference and cognitive ability in age differences.

1.4.1 Difference in task demands

Current behavioural tasks use mostly financial and monetary scenarios to measure risk-taking behaviour. However, there are differences in how these scenarios are designed, and how complex the designs are. Those that are more complicated are also more likely to depend on processes or abilities to be able to understand and perform optimally in the task, whether that is to avoid risk or take risk.

Firstly, whether decisions are made based on experience or description may affect age differences in risk-taking. In decisions based on description, participants are given full information about possible outcomes or that information is easily obtained through calculations. In decisions based on experience, the participants are not given information about probabilities, and must rely on experience acquired through the task. The latter has been found to yield the largest age differences (Mata et al., 2011), which is likely due to the added complexity of having to acquire knowledge on outcomes through the task, instead of this being provided prior to, or during the task.

However, even within these two distinct types of behavioural tasks, there are differences in the complexity of tasks. In tasks offering options to choose from, the types of options differ. Some studies offer a sure versus risky option, in which one is a guaranteed but smaller gain (e.g. Probability Associated Gambling task, Behavioral Investment Allocation Strategy task), and others offer only multiple risky options (e.g. Iowa Gambling Task). In the sure versus risky design, there is the option not to take risk and instead take the low-risk option, whereas the multiple risky options require participants to gamble. As such, more effort needs to be invested in estimating the optimal choice between all risky options. In addition, some tasks do not provide a choice between options, but require participants to decide on the proportion of something they wish to gamble. In the Balloon Analogue Risk Task, participants must decide how far they are willing to pump the balloon, and in the Cups Task participants must decide how much of their earnings they are willing to gamble. As such, the way people are asked to decide, which in turn measures their risk-taking, differs between tasks. In tasks where safe options are offered, participants can choose to opt out from risk-taking and accept the option that requires less strain to evaluate. In tasks that offer multiple risky options, participants need to evaluate the options and determine the option most likely to lead to an optimal outcome, which in turn is more demanding.

A design feature that is likely the most demanding of cognition is learning. Learning requirements are more common in tasks measuring experience-based decisions, such as the Iowa Gambling Task and Balloon Analogue Risk Task. The Iowa Gambling Task (Bechara et al., 1994) is an example of a task that relies heavily on the participant’s ability to learn how to maximize their gain on the task, while other tasks do not incorporate learning as part of the task (Liebherr et al., 2017; Mata et al., 2011). The Iowa Gambling Task requires participants to learn the reward and penalty structure of the four decks throughout the task to be able to maximize profit. If the participant does not learn that the two seemingly less advantageous decks are actually advantageous in the long run, they will take more risk and finish the task with a deficit. As such, those who experience difficulties in learning will likely take longer to understand tasks like the Iowa Gambling Task or complete the task without understanding the task's workings.

In addition, though the Balloon Analogue Risk Task (Lejuez et al., 2002) and the Iowa Gambling Task (Bechara et al., 1994) are both tasks measuring experienced-based decisions, and require participants to learn throughout the task, the outcome associated with learning is the opposite. On the Iowa Gambling Task, learning shows by choosing the advantageous decks, those with low pay-out amount and penalty, more often. However, learning on the Balloon Analogue Risk Task is characterized by a larger number of pumps to inflate the balloon (i.e. seeking out more risk).

Lastly, another feature that adds to the complexity of a task is the use of time constraints. In some tasks, participants are required to respond within a certain time frame. The Behavioral Investment Allocation Strategy task (decisions based on experience) and Probability Associated Gambling task (decisions based on description) are both tasks that use time constraints in their design. In the Behavioral Investment Allocation Strategy task, each screen shown to the participant during the trial has a set duration. The two screens likely most important are the choice screen and the screen showing the values associated with all options shown in the choice screen. The choice screen (including the screen with the highlighted choice) is shown for 4 seconds, and the screen with all options and their outcomes is shown for 4 seconds. Within those times, participants need to decide which option they will choose, and remember the outcomes associated with the options for a future trial. In the Probability Associated Gambling task (Sinz et al., 2008), participants are given 10 seconds to decide whether to go for the gamble with the higher pay-out (and loss) or the safe option with guaranteed, but lower, pay-out. The likelihood of obtaining the higher pay-out through choosing the gamble is displayed with a ratio of red and blue boxes. If no option is selected within that time, the safe option is automatically selected.

Though the varying demands of tasks may explain differences in risk-taking behaviour between younger adults, this may be more so for older adults. Tasks with complex designs may inadvertently tap into cognitive abilities to be able to decide optimally. However, some cognitive abilities decline with age, such as working memory and processing speed, and the involvement of these abilities may affect older adults' performance on behavioural tasks.

1.4.2 Role of cognitive abilities

Many behavioural tasks use features such as time constraints or learning in their designs. Aside from these features adding to the complexity of the task, they also rely more heavily on cognitive abilities such as memory and processing speed. These abilities are known to be sensitive to ageing, and often decline in older age. As such, a decline in these abilities may affect older adults' understanding of and performance on these behavioural tasks, and thus their risk-taking behaviour.

It is often thought that age-related cognitive decline is of late onset and is mostly limited to memory (Salthouse, 2004). However, studies have shown that this is not necessarily true. Age-related effects on fluid cognitive abilities such as processing speed, working memory and reasoning have been found to be rather large (Park et al., 2002; Salthouse, 2004), and most of these effects can be found before the age of 50 (Salthouse, 2004; Salthouse et al., 2003). The decline of these abilities often goes unnoticed in daily life as people have the tendency to adapt their lives to a level of cognitive strain that they find comfortable. Additionally, many situations in daily life do not require functioning at maximum cognitive capacity, whereas cognitive tests or tasks do (Salthouse, 2004). Cognitive changes related to normal aging can lead to a reduction in decision-quality, our ability to make reasonable and effective decisions, or the ability to manipulate and retain information, in which processing speed and memory are involved (Henniger, 2010). These abilities are often required in behavioural tasks and declines in these abilities may cause older adults to behave differently on a task than intended, due to a lack of understanding of the task or its process.

The distinction between the two types of tasks, those measuring decisions from experience or description, also finds its differences in the relationship between task performance, age, and cognitive abilities. Mata et al. (2011) report that age differences are more common and of larger size in studies using tasks that measure decisions from experience. As these tasks do not incorporate explicit information about the outcomes and their likelihood, this likely further complicates tasks measuring decisions from experience, separate from any other design features. Zamarian et al. (2008) used both types of tasks (Iowa Gambling Task and Probability Associated Gambling task) in their study and found age differences on the Iowa Gambling Task, but not on the Probability Associated Gambling task. The Probability Associated Gambling task allows participants to estimate the probabilities of outcomes by using the coloured boxes displayed on the screen, whereas the Iowa

Gambling Task does not provide information on probabilities and participants learn about the likelihood of wins and losses occurring throughout the task instead. As such, the Iowa Gambling Task is by comparison a more complex task due to the lack of information on its options and outcomes. In addition, measures of cognitive abilities (i.e. working memory, psychomotor speed and divided attention) were related to older adults' performance on the both tasks, indicating that age-related changes in cognitive abilities such as working memory are likely to affect older adults' risk-taking, especially on the Iowa Gambling Task (Zamarian et al., 2008). These findings are not limited to the Iowa Gambling Task and Probability Associated Gambling task, age differences in opposite directions have also been found when comparing the Cambridge Gambling Task and Balloon Analogue Risk Task (Henninger et al., 2010), with older adults taking more risk on the Cambridge Gambling Task, but less risk on the Balloon Analogue Risk Task. Performance on both tasks was related to cognitive abilities (i.e. memory and processing speed), which were found to decline with age. Mixed findings in age differences in risk-taking can be partially explained by the difference between tasks measuring decisions by experience or by description, as age differences on tasks based on experience are generally larger, likely due to the lack of a priori information about probabilities, and their reliance on learning. However, how cognitive abilities affect older adults' risk-taking behaviour on these tasks goes beyond task domain.

Using a learning paradigm is a common feature in behavioural tasks, especially those measuring decisions based on experience. As mentioned above, the Iowa Gambling Task is an example of a task that has been found to rely on cognitive abilities, including those associated with learning. Many studies have found that older adults took more risk on the Iowa Gambling Task by selecting disadvantageous decks more often, resulting in a decrease in their earnings or an overall loss at completion of the task.(Denburg et al., 2005; Mata et al., 2011; Schiebener & Brand, 2017; Zamarian et al., 2008). Risk-taking on the task is characterized by choosing cards from the two decks that initially look appealing but are disadvantageous in the long run. Older adults are more likely to shift between decks, and often for a longer period than younger adults, indicating that they have difficulties in learning what the advantageous decks are. As learning is a large component of performance on the Iowa Gambling Task, older adults' risk-taking on the Iowa Gambling Task is likely due to a decline in their ability to learn on the task. Performance on the Iowa Gambling Task has been found to be related to attention, psychomotor speed, and mental complex calculations (i.e. arithmetical calculations without any help from devices or other equipment) (Zamarian et al., 2008). Other studies have also found a relationship between older adult task risk-taking on the Iowa Gambling Task and cognitive abilities (Denburg et al., 2005; Henninger et al., 2010; Liebherr et al., 2017; Mata et al., 2011; Zamarian et al., 2008). As such, older adults appear to take more risk on the Iowa Gambling Task as a result of difficulties in learning, suggested by their inconsistent choices on the task, likely caused by a decline in cognitive abilities required to understand the workings of the task and avoid risk.

The Balloon Analogue Risk Task is another task measuring experience-based decisions, that also relies on learning. However, learning on the Balloon Analogue Risk Task leads to a different outcome than on the Iowa Gambling Task. Learning on the Balloon Analogue Risk Task leads to more risk-taking, as participants become more aware of how far a balloon can be pumped before it's likely to explode. Like on the Iowa Gambling Task, older adults generally perform the opposite of what is expected according to the direction of the task's learning component, with older adults taking less risk than younger adults. Older adults were found to display less optimal choices by pumping the balloon less and cashing in their earnings earlier, which the authors attributed to the effect of learning in the Balloon Analogue Risk Task (Mamerow et al., 2016). Both processing speed and memory have been found to predict performance on the Balloon Analogue Risk Task, and both abilities are known to decline in older age (Henninger et al., 2010).

Processing speed is a cognitive ability associated with learning, as it is the speed in which someone can perceive and process information to successfully complete a task or activity (Salthouse, 1996). However, processing speed is not solely a component of learning, and instead can directly affect decision-making and other cognitive processes. If the speed of processing is low, the quality of cognitive performance is generally decreased, as the relevant processes to complete a task are not successfully executed. Behavioural tasks, specifically those that apply time constraints, may involuntarily involve processing speed in task performance. As processing speed is found to decline in older age, this may impact older adults' risk-taking on these tasks, resulting in them displaying behaviour (the direction of which depends on the design of the task) not aligned with their preferences towards risk. A study by Henninger et al. (2010) included three decision-making tasks (Iowa Gambling Task, Cambridge Gambling Task, Balloon Analogue Risk Task) and eight psychometric tests measuring cognitive abilities such as processing speed and memory. Age differences were found on the Cambridge Gambling Task and Balloon Analogue Risk Task, with older adults taking more risk on the Cambridge Gambling Task but less on the Balloon Analogue Risk Task. Processing speed was related to age and task performance and mediated the relationship between age and risk-taking on both tasks. The decrease in processing speed appeared to result in a decrease in decision quality (i.e. adaptively obtaining and processing relevant information to decision-making), which then led to risk-taking (Cambridge Gambling Task) and risk averse behaviour (Balloon Analogue Risk Task) on both tasks (Henninger et al., 2010). In a study by Finucane et al. (2005), participants were given simple and complex versions of tasks (i.e. the complex task versions has considerably more options compared to the simple task), as well as cognitive tests. Older adults were found to score lower in terms of comprehension of the task and choice consistency, as well as having lower processing speed. The authors explain that the age difference in comprehension and consistency can partly be explained by age-related changes in processing speed, which is put under more strain as choice options increase. In Frey et al. (2015), age-related declines in processing speed were found to affect their search effort (i.e. sampling from the choice options before choosing, without consequence) when the number of options were increased (i.e. in tasks with more than 2 options). This suggests that older adults aim to decrease the cognitive load by searching less when task demand increases (Frey et al., 2015).

As most behavioural tasks employ monetary designs and incentives to capture risk-taking behaviour, it is likely that numerical ability may also affect participants' comprehension of the task and their choices. Numeracy encompasses the ability to do simple arithmetic operations and compare numerical quantities. However, higher numerical abilities also include logical and quantitative reasoning, and understanding concepts such as fractions, percentages, probabilities and proportions (Reyna et al., 2009). Those with lower numerical ability have been found to experience difficulties in judging risks, reading graphs, and are more sensitive to framing effects (Peters, 2012; Reyna et al., 2009; Weller et al., 2013). This may be the case even more so for older adults, as past research has found that higher age is associated with lower numerical ability (Bruine de Bruin et al., 2015; Delazer et al., 2013; Frey et al., 2015; Huang et al., 2013; Weller et al., 2013). Hibbard et al. (2001) found that more than half of older adults over the age of 65 had difficulties using numerical information to compare Medicare plans. As lower numeracy can cause difficulties in every-day decisions, it may also affect older adults' risk-taking on behavioural tasks, especially if those tasks are more complex. Pachur et al. (2017) aimed to disentangle cognitive and motivational factors from age differences in risk-taking, using monetary lotteries with two risky options. Age differences in decision quality disappeared when cognitive abilities were accounted for. The findings indicated that older adults' poorer decision quality could be explained by their lower fluid intelligence and numerical ability. In Chen et al. (2014), older adults made more risky choices on the Cups Task than younger adults and had lower numerical ability. Numeracy partially mediated the relationship between age and risk-taking, indicating that older adults' lower numerical ability was associated with risk-taking on the Cups Task.

Lastly, there is evidence that different choice types, as well as number of choices, result in varying directions of risk-taking in older age. Older adults appear to be more risk averse in tasks that use a sure versus risky design (Best & Charness, 2015) compared to those using two risky options (Pachur et al., 2017). In addition, Frey et al. (2015) specifically looked at age differences in risk-taking as a function choice size and cognitive abilities. Older adults performed worse on measures of cognitive abilities such as processing speed and working memory, as well as numeracy. These abilities were associated with search effort in older adults across three studies, with the correlation coefficients increasing in line with the number of options (i.e. number of options were 2, 4 and 8). These findings suggest that as the number of options increases, evaluating these options becomes more cognitive demanding, resulting in a decrease in search effort in older adults.

Though risk-taking is assumed to reflect one's underlying preference towards risk, this relationship may be affected by the extent cognitive abilities are relied upon in behavioural tasks. This may be the case even more so for older adults, as many of these abilities are sensitive to ageing. As such, risk-taking on these tasks may not reflect risk preference, and reflect age differences in cognitive ability instead.

1.4.3 The role of risk preference

Risk preference is presumed to underlie risk-taking, as risk-taking is an expression of how comfortable one feels with risk. Often, studies use only behavioural tasks to capture risk-taking, or solely self-reported risk preference measures. However, when they have been used simultaneously, the findings on their relationship have varied. In some cases, risk-taking on the behavioural task and self-reported preferences are weakly related, or not at all (Crosetto & Filippin, 2016; Frey et al., 2017; Josef et al., 2016; Mamerow et al., 2016).

In Mamerow et al. (2016) two behavioural tasks were used together with a self-report measure of risk preference. The self-reported risk preference scores were only weakly correlated with both measures, which was considered to potentially be due to self-reports and behavioural tasks measuring distinct facets instead of measuring the same construct. Similar findings were present in other studies such as Josef et al. (2016), who found significant but small correlations between self-report and task behaviour, and Crosetto & Filippin (2016), who reported small or no correlations between tasks and self-report measures. These studies are some of the few who have examined the relationship between self-reported risk preference and behavioural tasks in a sample that includes older adult subjects. The majority of the work on the gap between self-reported risk preference and risk-taking on a behavioural task was conducted with samples that often did not include participants of higher age.

A study by Frey et al. (2017) incorporated an extensive battery of self-report measures and behavioural tasks in a laboratory-based experiment with more than a thousand participants. Using common behavioural tasks, self-report risk preference measures, and participants' provided frequency of risky behaviours, the authors demonstrated that behavioural tasks are not as reliable as self-report measures. Results showed that self-report measures were weakly, or not at all, related to behavioural tasks, nor were the 8 behavioural tasks related to one another. This has been found in other studies in which tasks were not related to self-reported risk preference (Anderson & Mellor, 2009; Crosetto & Filippin, 2016; Deck et al., 2013; Menkhoff & Sakha, 2017; Szrek et al., 2012). These findings indicate either a problem with behavioural tasks, or the measurement of the construct of risk-taking as a whole (Frey et al., 2017; Palminteri & Chevallier, 2018).

In general, self-reported risk preference measures are considered stable and to have good test-retest reliability (Frey et al., 2017; Mata et al., 2018; Palminteri & Chevallier, 2018). This is not the same for behavioural tasks. Behavioural tasks have been found to have low test-retest reliability, are not capable of predicting behaviour over time, and are only weakly, or not at all, related to one another (Attanasi et al., 2018; Deck et al., 2013; Frey et al., 2017; Mamerow et al., 2016; Mata et al., 2018; Palminteri & Chevallier, 2018; Pedroni et al., 2017; Szrek et al., 2012). As such, for behavioural tasks to reflect an individual's underlying risk preference, adjustments will need to be made in the current approach concerning behavioural tasks measuring age differences in risk-taking. One of these adjustments is the role of cognitive ability in the measurement of age differences in risk-taking behaviour. The reliance of some of these tasks on cognitive abilities that decline with age may lead to these behavioural tasks measuring the effect of age-related cognitive decline on these measures, instead of older adults' underlying risk preference.

1.5 Present research

Findings on age differences in risk-taking have varied, and one possible explanation is that they are due to the inconsistencies between behavioural tasks. Some of the more concerning inconsistencies among tasks are the variability in complexity and the tasks' reliance on cognitive ability. Description-based tasks differ in their complexity, some highly demanding of cognitive resources (e.g. having multiple options or gambling outcomes). This also applies to experience-based tasks, of which complex varieties impose on cognitive resources (e.g. the number of choice options and the reliability of the given feedback) (Frey et al., 2015). The tasks with higher cognitive demand may put more strain on older adults, as many abilities associated with decision-making, such as working memory and processing speed, naturally decline with age (Liebherr et al., 2017).

These existing tasks, though differing in type and complexity, have in common that they do not have the means of assessing cognitive ability and risk preference in a way to determine which of these factors predominantly leads to risk-taking behaviour. Until now, it has been unclear whether the age differences in risk-taking behaviour are caused by 1) age differences in risk preference, or 2) age differences in cognitive ability.

The current project aims to further understanding of adult age differences in risk-taking behaviour, and how this may be explained by age differences in cognitive ability and risk preference. To do so, the project encompasses three studies, all approaching this issue from a different perspective. The first study uses a physical behavioural task that participants are able to interact with, the second study includes a computer-based behavioural task, and the third study investigates the role of risk preference and cognitive ability in a universal experience of health risk, the current COVID-19 pandemic.

CHAPTER TWO

Age differences in risk-taking behaviour: a matter of risk preference or cognitive ability?

2.1 Abstract

Objective. Previous research examining age differences in risk-taking has yielded mixed findings on risk-taking in older age, as older adults took less risk in some studies, more in others, and some studies found no age differences at all. These mixed findings may result from a) age differences in cognitive abilities as a result of cognitive decline, and or b) age differences in risk preference. This study aims to investigate the role of cognitive ability and risk preference in age differences in risk-taking. **Method.** 50 younger adults and 51 older adults took part in the study. Risk-taking and risk comprehension were measured by a novel gamble task. Cognitive abilities were measured through an objective numeracy scale, Digit Span Backward and Digit Symbol Coding. Risk preference was measured through the Domain-Specific Risk-Taking Scale. The Belief in Luck and Luckiness Scale and a shortened Positive and Negative Affect Schedule (PANAS-X) were also included. **Results.** Correct judgments of the probability to win and lose were associated with higher numerical ability, while older age was associated with a larger difference between estimated probability and actual probability. Gamble acceptance was associated with overestimating win probability and underestimating loss probability. Higher numerical ability was associated with a lower likelihood of accepting gambles. Age was not associated to gamble acceptance, nor did age differences in self-reported risk preference and processing speed predict task behaviour. There were no age differences in working memory, numeracy, affect, and belief in luck. **Conclusion.** Risk preference does not appear to explain risk-taking on the task, while higher numerical ability is positively associated with risk comprehension, and negatively associated with risk-taking, irrespective of age. The study adds to growing evidence

on the gap between risk preference and risk-taking behaviour and highlights the importance of numeracy skills in evaluating risk in a monetary setting.

2.2 Introduction

People of all ages are faced with decisions that impact areas of their lives, such as their health, finances, or emotional wellbeing. Studies focusing on decision-making across adulthood have recently become more prevalent, due to population ageing and the knowledge that these decisions, often involving risk and uncertainty, will impact us for more years to come than ever before. For example, serious medical procedures often have different options, with varying rates of success and severity of side effects. More medical procedures are performed on older adults, and they are predicted to make up 20 percent of surgical procedures in 2030 (Fowler et al., 2019). These high-risk decisions will become more common as we live longer. In addition to the increase of important decisions in later life, ageing is associated with emotional and cognitive changes that are likely to affect decision-making. As such, it is vital to understand how younger and older adults differ in their approach to risk.

Risk preference can be defined as the propensity to engage in activities or behaviours that are rewarding but also involve potential losses, such as substantial physical or mental damage (Mata et al., 2018). How risk preference is best measured is somewhat debated, as there is a lack of consensus of what (type of) measure captures people's risk preference best (Hertwig et al., 2019). Using self-report measures to gauge risk preference is popular, in part due to the convenience of its implementation. In these measures, a person's risk preference is often calculated from their responses to hypothetical situations ("Riding a motorcycle without a helmet") (Blais & Weber, 2006) or through their agreement to given statements ("Taking risks makes life more fun") (Zhang et al., 2019). Although one can have a general risk preference, indicating that an individual is generally more inclined to seek out or avoid risk, there is evidence that risk preferences may vary across domains such as health, social, and recreational risk (Josef et al., 2016; Rolison et al., 2014). Past studies have investigated the differences between younger and older adults in terms of risk preference, with findings suggesting that people become more risk averse as they get older (Dohmen et al., 2017; Josef et al., 2016). When examining risk preference across different domains, Rolison et al. (2014) found that younger adults reported a higher likelihood of taking risk in the domains social, and health and safety compared to older adults. Older adults were generally risk avoidant concerning health risks; they reported being less likely to undertake a health or safety risk, saw less benefit in the proposed risk, and reported higher risk perception than younger adults. These differences across domains are supported by other studies, such as Josef et al. (2016), who also reported declines in financial, driving, health, social and recreational risk-taking in older age, with differing rates of decline.

Risk-taking behaviour is often measured through behavioural tasks. Though these behavioural tasks aim to gauge someone's risk-taking behaviour, there are differences in methodology across tasks. For instance, behavioural tasks differ in the amount of information they provide to participants. Tasks that do not give explicit information concerning the consequences of available outcomes, nor about the likelihood of these outcomes occurring, are often described as tasks measuring decisions based on experience. The Iowa Gambling Task (Bechara et al., 1994) is a well-known example of such a task, in which participants are given 4 decks of cards face down. Each deck has cards with rewards as well as penalty cards. Across decks, the win and penalty amounts differ, with some decks as more advantageous than others. Over time, participants learn that the two decks with lower rewards, but also lower penalty amounts, are most advantageous over time. Another example of a task measuring decisions based on experience is the Balloon Analogue Risk Task (Lejuez et al., 2002) in which participants pump a balloon as often as they want without knowing when the balloon will explode. With each pump, the total earnings are increased but so is the chance of the balloon exploding. The participant can decide at any time to stop and collect their earnings but if the balloon explodes, they lose the monetary amount they have accumulated during the trial. Risk-taking on the Balloon Analogue Risk Task is characterized by the number of pumps in unexploded balloons.

Behavioural tasks measuring decisions based on description include information about the extent of the outcomes and their likelihoods, or they are easily calculated (e.g. the proportion of coloured objects indicate the likelihood of a win or loss) (Mata et al., 2011). A common design in tasks measuring decisions based on description is using a sure thing versus risky option, in which participants are offered a sure but less profitable option, and an option or multiple options with a higher pay-out but lower win probability. Tasks differ in how these options are presented, whether represented by objects or directly communicated to the participants. In the Cups task (Weller et al., 2007), these options and their probabilities are conveyed through cups. The task consists of gain and loss domains, three levels of probability and three different amounts to win or lose. Based on the combinations, risky options could either be of the same expected value as the riskless options, or more advantageous or disadvantageous. Participants would gamble with coins visible to them on the screen, with a random process determining whether their choice for the risky option led to a gain or loss (and subsequent addition or subtraction of coins from their earnings). The Cambridge Gambling Task (Rogers et al., 1999) is another example of a task measuring decisions based on description, and presents participants with a row of 10 boxes, coloured red and blue. The ratio of red and blue boxes differs per trial, but one of the 10 boxes will contain a yellow token. Participants are first asked what colour box they expect to contain the token. Following this, they are asked what proportion of their current score they wish to bet on their answer. In the Cambridge Gambling Task, participants are given the total number of boxes and can calculate the likelihood of the token being in a specific box colour, based on the ratio of the red and blue boxes on the screen (i.e. if there are proportionally more red boxes on the screen, it is more likely that a red box will contain the yellow token).

Behavioural tasks may also differ in their complexity. The complexity of the task can depend on a multitude of factors, such as time constraints, the number of options to choose from, or learning requirements. In both the Iowa Gambling Task and Balloon Analogue Risk Task, learning leads to either risk-taking (Balloon Analogue Risk Task) or risk averseness (Iowa Gambling Task). In the Iowa Gambling Task, participants learn over time to avoid the initially attractive, yet long-term disadvantageous decks in favour of the lesser attractive, but long-term advantageous decks. However, learning on the Balloon Analogue Risk Task leads to more risk-taking, as participants learn over time how often they can pump the balloon and increase their earnings, which is also known as inverse learning. These varying designs and levels of complexity may affect decision-making, especially in older age.

Research on age differences in risk-taking behaviour has seen an increase in studies in the past decade. Many studies have used behavioural tasks to examine age differences and have found varying results. Concerning decisions based on experience, Zamarian et al. (2008) found significant age differences when using the Iowa Gambling Task; older adults did show improvement in their choices over time, but made less advantageous decisions than younger adults, as well as shifting between advantageous and disadvantageous decks often, suggesting that this stems from older adults experiencing difficulty in developing a consistent and advantageous strategy. Measures of working memory, psychomotor speed and attention significantly correlated with different aspects of the Iowa Gambling Task, suggesting that older adults' performance on the task was affected by the cognitive strain related to the task. Using the Balloon Analogue Risk Task to investigate age differences in risk-taking, Rolison et al. (2012) reported that younger adults initially took more risk on the task, but experience with the task allowed older adults to later make similar evaluations about gains and losses, and took as much risk as younger adults. Other studies reported older adults demonstrating lower performance on the Balloon Analogue Risk Task as a result of higher levels of risk aversiveness compared to younger adults (Henninger et al., 2010; Koscielniak et al., 2016). In tasks measuring decisions based on description, Henninger et al. (2010) found age differences on the Cambridge Gambling Task, with older adults more frequently choosing options with low likelihood of winning, indicating that older adults' decision-quality was lower and that they were seeking out risk more than younger adults. When assessing the relationship between cognitive ability and the Cambridge Gambling Task, they found that processing speed and memory were positively correlated with task behaviour, with better memory and processing speed leading to higher quality decisions. When cognitive abilities were considered, the effect of age disappeared, suggesting that the age differences on the task were mediated by age-related decline in cognitive abilities. Zamarian et al. (2008) included the Probability Associated Gambling task in their study and found no age differences in performance on the task, with older adults estimating probabilities risk like younger adults. Also, Weller et al. (2011) reported mixed findings on the Cups task, as a product of domain. They found that older adults took less risk in the gain domain of the task, but not in the loss domain, suggesting that risk-taking decreased with age in terms of gains, but not for losses. They also found that sensitivity to the expected value of the choice options was stable through adulthood until about 65 years of age, after which decline in performance was observed, with older adults seemingly experiencing difficulty in adjusting for changes in expected value of choice options. This is further supported in other research with the Cambridge Gambling Task (Figner et al., 2009), another task measuring decisions based on description, which also involves expected value of outcomes. Despite the “hot” (turning over one card at a time and receiving feedback on the outcome, relying more on affective processes) and “cold” (1 decision on how many cards to turn, relies on predominantly deliberative processes) domains, adjusting decisions under risk in relation to expected value decreased in older age (Weller et al., 2019).

The conflicting findings may be explained by the complexity of task design, both in tasks measuring decisions based on experience and description. Across task types, older adults may experience difficulties on tasks with a more complex design, likely due to the natural decline in cognitive abilities such as working memory, and processing speed. The findings on age differences on behavioural tasks discussed in the prior paragraph highlight the influence of cognitive ability on older adults’ task performance, and subsequent risk-taking behaviour. In their meta-analysis, Mata et al. (2011) discuss how age differences on behavioural tasks are often a product of task characteristics, attributing age-related effects to older adults' difficulty in learning on the task. However, even tasks without a learning component, such as the Cambridge Gambling Task, showed that older adults chose less advantageous options than younger adults (i.e., showing a preference for the large reward and high risk options) (Liebherr et al., 2017).

Existing behavioural tasks measuring risk-taking differ in their complexity, and thus how much cognitive strain is put on participants. This suggests that older adults' decisions on these tasks may not (solely) originate from their risk preference but may be due to age-related decline in cognitive abilities essential to decision-making under risk. Overall, this may lead to older adults taking risks on these tasks without intending to do so. As such, age differences in risk-taking behaviour could be due to either 1) age differences in risk preference, or 2) age differences in cognitive ability due to age-related decline.

To our knowledge, there has not been a prior study aiming to disentangle contributing factors to age differences on a risky decision-making task, with the exception of Pachur et al. (2017), who looked at cognitive and motivational roots behind age differences in risky decision-making. Though they found that older adults had lower cognitive abilities and reported lower negative affect (which was related to accepting more risky choices on the task), they did not include self-report measures of risk preference in their study.

2.2.1 The present research

The current study aims to investigate to what extent cognitive ability and risk preference play a role in age differences in decision-making under risk. This will be done by means of a decision-making task that has been designed to assess the role of both cognitive ability and risk preference in risk-taking behaviour for the first time.

On the task, participants are given a card with the gamble information, including a priori probabilities of each outcome, and are asked to mimic the gamble being played 20 times. To do so, they are given a physical box with 20 compartments to fill with three types of coloured balls that represent the three possible outcomes (see Figure 2). After doing so, they are given the overall outcome of the gamble being played 20 times, based on their own estimations of the probabilities, and are given the option to gamble for real-life consequences.

We tested the following hypotheses:

Hypothesis 1a: cognitive measures would predict comprehension on the task, with those who have lower cognitive ability having less comprehension on the task (which is characterized by making correct estimations of probability less often and having a larger distance between estimation of probability and actual probability).

Hypothesis 1b: Older adults were expected to have lower comprehension on the behavioural task.

Hypothesis 1c: Older adults were expected to have lower scores on measures of working memory, processing speed and numeracy, which would explain age differences in task behaviour (described in hypothesis 1b).

Hypothesis 2a: participants' risk preference would predict behaviour in the risk-taking part of the task, with those who scored higher on risk-taking on the risk preference measure (and a higher score of belief in luck and luckiness) also be more likely to accept gambles in real life.

Hypothesis 2b: Older adults were expected to be more risk averse on the task, as older adults have been found to be more risk averse than younger adults in prior research.

Hypothesis 2c: older adults were also expected to be more risk averse in their self-reported risk preference, in line with prior findings.

In addition to the two hypotheses described above, we also conducted exploratory analyses. Similar to findings of Pachur et al. (2017), we expected that participants' affect would be related to their behaviour in the risk-taking part of the task. Those reporting higher positive affect were expected to be more likely to accept gambles on the study. We also expected older and younger adults to differ in positive affect; older participants were expected to report higher positive affect and lower negative affect compared to younger adults. This would be similar to the effect found by Pachur et al. (2017), in which older adults chose the riskier option more often than the younger adults in the gain and mixed domains due to lower negative affect among older adults.

2.3 Method

2.3.1 Participants

We recruited 105 participants, of which 4 were excluded due to incomplete data. The final analytical sample was 101 participants, of which 50 were younger adults and 51 were older adults. The overall age of participants ranged from 18 to 90 years of age (M_{age} = 47.18, SD = 25.48). Younger adults were recruited via the university's recruitment database for students and for research volunteers. They were aged between 18 and 35 years old, with a mean age of 21.98 (SD = 3.15). Exactly half of the younger adults were women (50%, followed by men, 50%). Over half of the younger adults had A levels as their highest completed education (54%), with the majority currently students (84%), and most common income range was £10.000 or less (44%). More than a third of younger adults were British (36%, followed by Chinese, 8%). Older adults were recruited via a specific university pool and through leafleting in Colchester Borough. The ages of the older adult group ranged between 65 and 90 years old, with a mean age of 71.88 (SD = 5.56), and a little more than half of participants were women (51%, followed by men, 49%). All participants in the older age group were of British nationality. Almost half of participants reported an undergraduate degree as the highest completed education level (45.1%). Almost all participants were retired (94.1%). Nearly half of participants reported a household income of £10.001 to £30.000 (47.1%). Participants in the older adult group also completed the Mini Mental State Examination (MMSE; Folstein et al., 1975) at the beginning of the experiment. All participants scored above the minimum score of 24, indicating an absence of cognitive impairment.

2.3.2 Materials and procedure

Participants were first given an information sheet and consent form to sign. They were told that the study aimed to understand how people make decisions. Older adults then completed the MMSE. The MMSE is designed to assess cognitive impairment and was used as an exclusion measurement, as our population consisted of healthy older adults. All older participants in the study scored above the minimum score of 24, indicating no cognitive impairment (the maximum score is 30). After completing the MMSE, all participants completed a demographic survey on their gender, education level and other information.

Participants were then given the Positive Affect Negative Schedule Extended (PANAS X; Grühn et al., 2010). The PANAS X is a questionnaire assessing mood and affect, specifically focusing on positive and negative affect. The PANAS X is an extended version of the original PANAS (Watson & Clark, 1994) and consists of 60 items. For this study, an abbreviated version of the PANAS X was used, which includes 8 items in total. This version was similar to the abbreviated PANAS X used in Pachur et al. (2017). Participants were given 8 words, associated with either positive ("happy") or negative affect ("upset"), and rated how much this word applied to them on a Likert scale from 1 to 5 (1 = very slightly or not at all, 2 = a little, 3 = moderately, 4 = quite a bit, 5 = extremely). The original positive and negative scales, of which these 8 items were taken, showed good internal consistency, with an overall Cronbach's alpha of α = 0.86. The score for each scale is the mean across the four items. The PANAS X was administered before and after completing the decision-making task, to measure any changes in affect caused by the decision-making task.

Participants then took part in the decision-making task. The decision-making task consisted of 10 gambles, given to participants in a random order. Each of these gambles had a chance to win, lose, or neither win nor lose. However, the amounts associated with the chances to win or lose differed. An example of such a gamble is "Win £2 with a chance of 40%, lose £1 with a chance of 40%, neither win nor lose with a chance of 20%". The gambles were modelled after those used in Rolison & Pachur (2017) and were selected out of 75 gambles trialled in a pilot study. The chosen gambles were selected due to their acceptance rate of around 50 percent (indicating that participants were not overly drawn to or put off by the gambles), as well as not being clearly advantageous or disadvantageous. The expected value of the gambles ranged between -0.8 and 0.95, with an even distribution between gambles with positive and negative expected value. Participants were given a card with the gamble information (see Figure 1) and were asked to mimic the gamble being played 20 times. Without implicitly being told to do so, participants would need to convert the chances of the gamble into frequencies.

“This gamble offers the following:
Win £1 with a chance of 25%
Lose £1 with a chance of 15%
Neither win nor lose with a chance of 60%”

Figure 1. *An example of the type of gamble included in the task, as given to participants during the instructions.*

Following this, participants were given a wooden box with 20 compartments to visualize the gamble outcomes for each round (see Figure 2). Each compartment in the box represented an outcome of playing the gamble and could be physically filled with the perceived outcome of that round. Each outcome (win, lose, neither win nor loss) was represented with a coloured ball: green balls represented wins, red balls represented losses, and yellow balls represented neither wins nor losses. These coloured balls were placed in the compartments to which participants thought the outcome to be applicable. The importance of the participant’s perception of what the chances of each outcome meant was emphasized in the instruction, and they were told that the box should resemble the gamble on the card (e.g. the probabilities for each outcome of the gamble), when played 20 times. They were also informed that it did not matter in what order they put the coloured balls for each gamble outcome as long as the frequency of each matched the gamble’s chances.

Figure 2. *Materials provided in the decision-making task.*

Note. The image on the far right displays an example of a completed box with outcomes for each 20 rounds that the gamble is (hypothetically) played.

After the participant filled the box with all 20 outcomes, the monetary earnings for each outcome were calculated, based on the outcomes that participant had entered in the box. Participants were shown the overall earnings of the gamble, as well as the amounts for wins and losses separately and were asked whether they wanted to play the gamble once, in real life, with actual consequences. In playing the gamble, participants could increase or decrease their participant payment (which was £5). Whether they won or lost was determined by the gamble's chances, and randomly selected using a number generator that was associated with the changes to win, lose, or neither. Participants were informed that any amount won or lost when choosing to play one or more gambles was theirs to take home; wins would be added to the participant payment, losses would be subtracted from their payment.

After completing the decision-making task, participants reported their affect for the second time, using the PANAS X, and then completed the Domain Specific Risk-Taking Scale (Blais & Weber, 2006), adapted by Rolison et al. (2019). Risk preference is measured across three subscales: the likelihood of undertaking risky activities, as well as the perceived benefits and perceived risk of these activities across domains. The adapted version (Rolison et al., 2019) includes items that are designed to be more suitable for older adults (e.g. instead of “engaging in unprotected sex”, the altered version included “taking an unfamiliar medication while on holiday abroad”). Only the Financial and Health and Safety subscales were used for this study. We were interested in seeing whether we will find age differences on the Health and Safety domain similar to prior studies (Josef et al., 2016; Rolison et al., 2014, 2019) but only included the Financial domain when relating self-reported risk preference to behaviour on the task due to the contextual overlap between the two measures. Participants’ responses are measured on a 7-point Likert scale, with -3 to 3 for Likelihood (-3 = extremely unlikely, 0 = not sure, 3 = extremely likely), and 0 to 6 for both Benefit (0 = no benefits at all, 6 = great benefits), and Risk Perception (0 = not at all risky, 6 = extremely risky). In their study, Rolison et al. (2019) reported a combined Cronbach’s alpha of α = 0.72, with an alpha of α = .65 for Likelihood, and α = .78 for Risk Perception . There is no information on the reliability of the Benefit subscale, as this was not included in their study. Scores on this measure were calculated by using the arithmetic mean for each scale. For the Likelihood scale, a higher score indicates a higher likelihood of taking risk, a higher mean on the Benefit scale indicates seeing more benefit in taking that specific risk, while a higher mean on the Risk Perception scale indicates perceiving more risk in the proposed risky activity.

Participants then completed the Belief in Luck and Luckiness scale (Thompson & Prendergast, 2013), a 16-item questionnaire on personal beliefs about luck. A distinction is made between belief in luck as a concept (“There is no such thing as good or bad luck”) and belief in luck as a personal trait (“I consider myself a lucky person”). Answers are provided on a Likert scale from 1 to 5 (1 = strongly disagree, 5 = strongly agree). Scores of this measure are the arithmetic mean across all items, as well as separate mean scores for the two scales (Belief in luck, belief in luckiness). Across the measure, the overall reliability was a Cronbach's alpha of α = 0.87, with α = 0.85 for Belief in Luck, and α = 0.88 for Personal Luckiness (Thompson & Prendergast, 2013). A higher mean on this measure indicates a stronger belief in luck in general or in one's personal luck.

The remaining three measures of the study were cognitive measures, assessing numeracy, working memory and processing speed. Participants were first given the Objective Numeracy Scale (Lipkus et al., 2001). The scale consists of 11 items, intended to measure the ability to understand and solve mathematical equations and probabilities. Three additional items from two types of cognitive reflection tests (Primi et al., 2016; Toplak et al., 2014) have been added to the scale for this study. These three items measure the ability to reflect on a question and to resist responding with the first answer that comes to mind. The added items all required participants to answer a mathematical question, similar to the Lipkus Objective Numeracy Scale. The reliability of the Objective Numeracy Scale, including the additional 3 items by Schwartz et al. (1997), was found by Lipkus et al. (2001) to be α = 0.78. Weller et al. (2013) reported a Cronbach's alpha of α = .76, and Thomson & Oppenheimer (2016) reported a Cronbach's alpha of α = .72. Participants' scores consist of a total score of correctly answered items, with a maximum of 14. A higher score indicates higher numerical ability.

Participants also took part in the Digit Span Backward, a subtest of the Wechsler Adult Intelligence Scale III (Wechsler, 1997), used to measure working memory. Participants are given number sequences and are asked to repeat those back to the researcher, but in reverse. Participants get two sequences of the same length before moving on to a more difficult level. Of the two sequences, one needs to be repeated correctly to proceed to the next level. If both are repeated wrong, the researcher will stop the test and will count the score of the participant, which is the sum of correctly repeated sequences. A higher score indicates better working memory.

Lastly, participants completed the Digit Symbol Coding, a measure of processing speed and a subtest of the WAIS-III (Wechsler, 1997). Participants are given a form with combinations of 9 numbers and symbols in the top of the form and are asked to copy the symbols underneath the associated numbers as swiftly and accurately as possible. To do so, they have 120 seconds. The score on the Digit Coding is the total number of correctly matched symbols and numbers, with a higher score indicating better processing speed.

At the end of the study, participants were debriefed on the aim of the study and participants were informed of their final balance (i.e. if they chose to play gambles, their payment could be different from the initial base payment). If participants lost more than the base payment, they left with a payment of £0 but without a further loss. Any money accrued would be added to their base payment.

All materials of this study can be found in the appendix.

2.3.3 Analysis

Age differences on self-report measures and cognitive tests were analysed in SPSS (version 25). The type of statistical analyses used includes Between-Subject MANOVAs for risk preference and Belief in Luck and Luckiness, and independent t-tests for working memory, processing speed and numerical ability. Performance on the task, both comprehension and risk-taking, was analysed in R. For generalized linear mixed-effects models, we used the *glmer* function from the *lme4* package (version 1-1.26). All generalized linear mixed-effects models were run with the

Bobyqa optimizer and 100.000 iterations, as these models were most sensitive to non-convergence. Linear mixed-effects models were conducted through the *lme* function of the *nlme* package (version 3.1-152).

2.4 Results

As age differences were expected in both risk preference and cognitive measures, we first analysed whether groups differed in their self-report measures and cognitive tests.

Age differences in risk preference, perception of luck, and affect

Risk preference. First, a Between-Subject MANOVA was used to examine age differences in the Financial, and Health and Safety Likelihood subscales of the risk preference measure. Results showed that younger adults reported being more likely to undertake financial risk and health and safety-related risk compared to older adults (see Table 1). A Between-Subject MANOVA was also used to assess the age differences in the Benefit subscales. Younger adults reported perceiving more benefits in taking both financial risk and health and safety risk compared to older adults. Lastly, a Between-Subject MANOVA between perceived risk of the two domains and age group revealed that younger and older adults did not differ in their risk perception of financial risk, but older adults rated the health and safety-related items as riskier than their younger counterparts (see Table 1). The results are in line with hypothesis 2c, as we expected older adults to be more risk averse than their younger counterparts. The results indicate that older adults' lower likelihood of taking risk is likely due to valuing the risks as less beneficial, and seeing more risk associated with these activities than younger adults.

Luck and Luckiness Scale. Differences between younger and older adults in how they felt about luck on the Luck and Luckiness Scale was assessed by means of a Between-Subject MANOVA. Younger and older adults differed in their general belief of luck, with older adults believing in luck more (see Table 1). However, groups did not differ in beliefs on personal luck.

PANAS X. A 4 x 2 Repeated Measures ANOVA was used to assess age differences on the PANAS X. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(5) = 138.27$, $p < .001$. As such, results were interpreted with the Greenhouse-Geisser adjustment. The results indicated that there was no significant interaction effect of age group and PANAS X (see Table 1). Hence, we conducted no follow-up tests. This finding suggests that older adults do not report higher positive affect and lower negative affect compared to younger adults, which is unlike what we expected as part of our exploratory analysis.

Age differences in cognition

Numeracy. An independent t-test was used to assess whether younger and older adults differed in their numerical ability. Results showed that there was no significant difference in numerical ability between younger and older adults (see Table 1). This is contradictory to our expectations (hypothesis 1c), as we expected that older adults would have lower cognitive ability due to age-related cognitive decline.

Working memory. To investigate age differences in working memory, an independent t-test was used to compare the total score on the Digit Span between the two age groups. The results showed no significant difference between the total scores of younger and older adults on the Digit Span (see Table 1). This is not in line with our expectations (hypothesis 1c), as we expected older adults to perform worse on this measure, in line with prior work on age differences in working memory.

Processing speed. The scores of younger and older adults on the Digit Symbol Coding were compared using an independent t-test. The results showed a significant difference between the two groups, with younger adults having a higher processing speed than older adults (see Table 1). This finding is in line with our expectations (hypothesis 1c), as we expected older adults to have a lower processing speed than younger adults due to age-related decline of cognitive abilities.

Table 1

Overview of results of self-report and cognitive measures.

Measures	Younger		Older		Age differences	Test value	Cohen's *d*
	M	SD	M	SD			
Dospert							
Likelihood HS	-0.13	0.90	-1.77	0.72	Yes	$F(1, 99) = 103.27$, $p < .001$	2.04
Likelihood F	-0.68	0.98	-1.18	1.02	Yes	$F(1, 99) = 6.14$, $p = .015$	0.50
Benefit HS	2.68	0.79	1.27	0.91	Yes	$F(1, 98) = 67.79$, $p < .001$	1.65
Benefit F	2.41	0.90	1.72	0.99	Yes	$F(1, 98) = 13.64$, $p < .001$	0.74
Risk Perception HS	2.71	0.85	4.31	0.94	Yes	$F(1, 99) = 81.39$, $p < .001$	1.81
Risk Perception F	4.27	0.56	4.06	0.92	No	$F(1, 99) = 1.98$, $p = .162$	0.28
Luck and Luckiness Scale							
General Luck	2.87	0.35	3.03	0.37	Yes	$F(1, 99) = 4.42$, $p = .038$	0.44
Personal Luck	2.44	0.63	2.54	0.54	No	$F(1, 99) = 0.78$, $p = .380$	0.16
PANAS							
Panas1 (pos)	14.08	2.91	14.42	2.56	No	$F(1.525, 297) = 2.81$, $p = .078$	0.12
Panas1 (neg)	5.20	1.59	4.66	1.32	No	$F(1.525, 297) = 2.81$, $p = .078$	0.37
Panas2 (pos)	14.00	2.76	14.68	3.20	No	$F(1.525, 297) = 2.81$, $p = .078$	0.23
Panas2 (neg)	5.82	2.27	4.86	1.34	No	$F(1.525, 297) = 2.81$, $p = .078$	0.51
Digit Symbol	85.40	17.47	53.60	22.66	Yes	$t(99) = 7.90$, $p < .001$	1.57
Digit Span Backward	8.68	2.22	8.44	2.23	No	$t(99) = 0.61$, $p = .545$	0.11
Objective Numeracy Scale	10.76	2.33	10.51	2.23	No	$t(99) = 0.55$, $p = .580$	0.11

Performance on the behavioural task

The behavioural task consisted of two elements; comprehension, measured through correct estimation of probability and the difference between estimated probability and actual probability, and risk-taking, measured through gamble acceptance. We will first discuss the results of the comprehension element of the task.

Comprehension. To measure comprehension on the task, we conducted two analyses; the first analysis tested whether people were correct in their probability estimation (which includes correctly estimating probability of win, loss, and neither win nor loss), the second analysis tested the distance from probability estimation to actual probability value.

Correct estimation. Overall, younger adults correctly judged the probability to win with an average of 6.70 out of ten gambles, compared to an average of 6.84 out of 10 among older adults. Younger adults correctly judged the probability to lose with an average of 6.72 of the 10 gambles, compared to an average of 6.63 among older adults. A visual overview of estimations for each gamble by younger and older adults is provided in Figure 3.

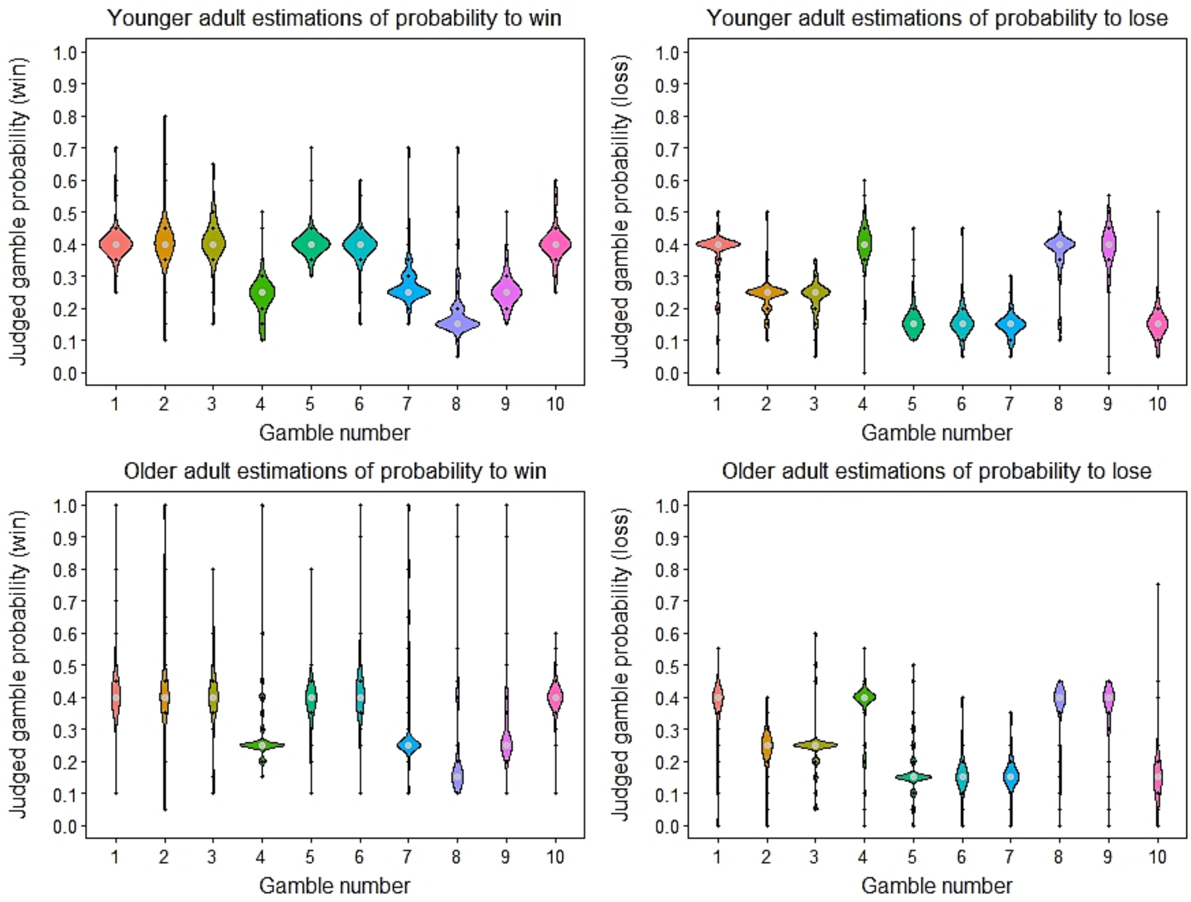

Figure 3. *Density plots showing participants' judgments of the chances to win and lose for each of the 10 gambles.*

To test for predictors of correct probability judgments, a random effects logistic regression was conducted. Random intercepts were included for participants only, as model fit did not significantly improve with the addition of random intercepts for outcome type. In a first model, gender was a significant predictor of correct probability judgments, but type of outcome and age group were not. In a second model, cognitive measures were included, which revealed that higher numerical ability was associated with a higher likelihood of correct judgment. The prior effect of gender disappeared. In the third model, personality measures were included, which revealed no significant predictors. In a fourth model, emotional measures were included, which also revealed no further significant predictors (see Table 2). The second, third and fourth model had convergence issues. For the second model, applying the *Bobyqa* optimizer and increasing the number of iterations to 100.000 solved the issue of non-convergence. The issue with non-convergence for the third and fourth model persisted. For those, several possible solutions were applied (i.e. using multiple optimizers, increasing number of iterations, rescaling variables) but none successfully addressed the models' convergence issue. Using the ANOVA function to compare models for best fit, model 2 was shown to be the best fitting model. Overall, the analysis on correct estimation of probability confirmed the hypothesis 1a, in which we expected that numeracy would predict task comprehension, but it did not support hypothesis 1b, as there were no age differences in comprehension.

Table 2

Multilevel logistic regression analysis on correct probability judgments.

	Model 1	Model 2	Model 3	Model 4
Intercept	0.70	-5.19**	5.18	-4.39
Type of outcome	-0.10	-0.10	-0.11	-0.11
Age group	0.41	-0.11	0.04	0.17
Male gender	2.15**	0.61	0.32	0.10
Cognitive measures				
Numeracy		0.73***	0.73***	0.73***
Digit span		0.11	0.10	0.09
Digit symbol coding		-0.02	-0.02	-0.02
Personality				
Financial risk-taking likelihood			0.20	0.22
Financial expected benefit			-0.15	-0.12
Financial risk perception			0.43	0.46
Luckiness belief			-0.59	-0.69
Luckiness personal			-0.11	0.17
Emotion				
Positive affect (Pan1)				-0.13
Negative affect (Pan1)				0.12
Goodness of fit				
-2 log likelihood	-774	-758.40	-756.10	-755.10
-2 log likelihood change †		15.60	2	1

Note. * p < .05, ** p < .01, *** p < .001; † Change in relation to previous model.

Distance between estimated chance and actual chance. A random effects linear regression analysis was conducted on trials on which participants provided an incorrect probability judgment. The model included random intercepts for participants and type of outcome (whether participants are estimating win or loss chance), as this was shown to be a better fit. In the first model, older age was associated with a larger distance between estimation of probability and actual probability, indicating that when older adults provided an incorrect estimate of probability, the distance between their estimation and the gamble’s probability was larger than those of younger adults. Further models did not show any additional significant predictors (see Table 3). Using the ANOVA function, model 3 was shown to be the best fitting model. The findings show support for hypothesis 1b, as we expected age differences in comprehension on the task, which included older adults having a larger difference between estimated and actual probability. We did not, however, find any support for hypothesis 1a, in which numeracy was expected to predict the difference between estimation and actual probability.

Table 3

Multilevel linear regression analysis on incorrect probability judgments.

	Model 1	Model 2	Model 3	Model 4
Intercept	0.09***	0.15**	0.18	0.28*
Type of outcome	0.02*	0.02**	0.02**	0.02**
Age group	0.05**	0.05*	0.05*	0.04
Male gender	0.01	0.01	0.02	0.02
Cognitive measures				
Numeracy		-0.01	-0.01	-0.01
Digit span		0.00	0.00	0.00
Digit symbol coding		0.00	0.00	0.00
Personality				
Financial risk-taking likelihood			-0.02	-0.02
Financial expected benefit			0.00	0.00
Financial risk perception			0.01	0.00
Luckiness belief			-0.04	-0.03
Luckiness personal			0.01	0.02
Emotion				
Positive affect (Pan1)				-0.01
Negative affect (Pan1)				-0.08
Goodness of fit				
-2 log likelihood	557.02	558.75	561.63	563.64
-2 log likelihood change †		-1.73	-2.88	-2.01

Note. * *p* < .05, ** *p* < .01, *** *p* < .001; † Change in relation to previous model.

Risk-taking. We tested participants' risk-taking on the task through gamble acceptance, which was coded dichotomously. The second hypotheses (2a and 2b) are tested in the section of the results described below.

Gamble acceptance. A mixed effects logistic regression analysis was conducted on decisions to accept or reject gambles. The analysis included random intercepts for participants. In the first model, judging the chance to win as higher than its actual win chance, or judging the chance to lose as lower than its actual loss chance, was associated with a higher likelihood to accept a gamble. In the second model, higher numerical ability was associated with a lower likelihood to accept a gamble. In the third model, which included a measure of risk preference and luck and luckiness, did not add any additional significant predictors to the model (see Table 4). This was equally the case for a fourth model, which included measures of affect. Similar to the analysis on correct probability estimations, models 3 and 4 had convergence issues. Again, several possible solutions were applied (i.e. using multiple optimizers, increasing the number of iterations, rescaling variables) but none successfully addressed the models' convergence issue. Using the ANOVA function to compare models for best fit, model 2 was shown to be the best fitting model.

The results did not show any evidence for hypothesis 2a (i.e. those who are risk averse, or belief less in luck will be less likely to accept gambles), and exhibited the opposite of was expected for hypothesis 2b (i.e. older adults taking less risk on the task). In addition, there was no evidence for the effect of affect on risk-taking (i.e. participants who score higher on positivity are more likely to accept gambles), which we investigated as part of our exploratory analyses.

Table 4

Multilevel logistic regression analysis on decisions.

	Model 1	Model 2	Model 3	Model 4
Intercept	-0.76**	-0.26	-0.64	0.65
Gain judgment (diff)	6.49***	6.30***	6.44**	6.34**
Loss judgment (diff)	-2.95*	-2.91*	-2.86*	-3.09**
Age group	0.47	0.66	0.75	0.74
Male gender	0.33	0.59	0.56	0.40
Cognitive measures				
Numeracy		-0.15*	-0.16*	-0.15*
Digit span		0.04	0.06	0.04
Digit symbol coding		0.01	0.00	0.00
Personality				
Financial risk-taking likelihood			0.21	0.22
Financial expected benefit			0.10	0.12
Financial risk perception			0.06	0.05
Luckiness belief			-0.06	-0.02
Luckiness personal			0.20	0.34
Emotion				
Positive affect (Pan1)				-0.10
Negative affect (Pan1)				-0.04
Goodness of fit				
-2 log likelihood	-605.50	-603	-593.50	-592
-2 log likelihood change†		2.50	9.50	1.50

Note. * p < .05, ** p < .01, *** p < .001; † Change in relation to previous model.

2.5 Discussion

This study aimed to assess the role of cognitive ability and risk preference in risk-taking to further understand the role of age in risk-taking behaviour. In this study, we used a physical behavioural task, in which participants used three types of coloured balls to mimic the gamble’s possible outcomes if it were played 20 times. Participants were then informed of the monetary outcome, based on their own estimations, and asked whether they would want to play a gamble with real-life consequences. Results showed that only numeracy positively predicted whether participants' correctly estimated gamble chances (i.e. participants were only correct if all outcomes were estimated correctly), older age was negatively associated with incorrect estimations of chance, while win outcome was positively associated with incorrect estimations of chance, and that risk-taking on the task was predicted by underestimating losses, overestimating wins and being less numerate. Risk preference was not significantly related to behaviour throughout the task. Numeracy, working memory and processing speed were hypothesized to be positively related to the difference between estimation and actual chance, with evidence of age-related decline on all three measures. We did not find evidence that cognitive ability was related to participants' incorrect estimations of probability, nor were there age differences on these measures, apart from processing speed (in which older adults performed worse compared to younger adults). In terms of numeracy, numeracy was related to both correct probability estimation and risk-taking, but age groups did not differ in numerical ability. The findings on the lack of age differences fit with those of others, as age differences on numerical measures have varied. In some studies, there were no age differences (Bruine de Bruin et al., 2017; Eberhardt et al., 2019; Weller et al., 2013) while older adults performed worse compared to younger adults in other studies (Bruine de Bruin et al., 2015; Delazer et al., 2013).

We also did not find any age differences in working memory. Though working memory is an ability commonly known to be sensitive to age-related decline, age differences may depend on the type of measure used for assessing working memory.

The manual for the Wechsler Adult Intelligence Scale III (Wechsler, 1997) reports that the Digit Span Backward is more affected by aging and by impairment (compared to its simplified version, Digit Span Forward), with older adults over 70 years old showing greater discrepancies, but other studies have found only small differences in working memory between age groups (Bopp & Verhaeghen, 2005). When comparing Digit Span Backward to its simplified version, Digit Span Forward, prior studies found that none of the variance between the two versions could be accounted for by age (Grégoire & Linden, 1997; Myerson et al., 2003). In addition, performance on other working memory measures show more decline as a function of age (Bopp & Verhaeghen, 2005; Elliott et al., 2011; Hale et al., 2011), such as spatial tasks (Myerson et al., 2003; D. C. Park et al., 2002). In this study, the older adult group encompassed participants aged 65 to 90 years old, which may have obscured any differences caused by age-related decline, due to the wide range of the group. For future research, a possible approach may be to compare subgroups of older adults, as there is evidence that oldest-older adults show differences in performance when compared to younger-older adults (Elliott et al., 2011). Working memory may not have been related to task performance due to participants being able to take as much time as needed (which may also explain why processing speed was not related to task performance), as well as the physical design feature of the task. It has been found that learning after performing actions, referred to as the *enactment effect,* leads to better memory (Engelkamp & Cohen, 1991; Steffens et al., 2015), more so when compared to learning based on observation (Charlesworth et al., 2014; Golly-Häring & Engelkamp, 2003). In this study, participants were able to make their calculations and decisions using a physical task, not having to observe or imagine what the outcomes would look like. Instead, they were able to visualize this using the coloured balls and box. As such, working memory may not have related to task performance as those with memory deficiencies benefitted from the task's physical design.

We expected age differences on the measures of self-reported risk preference and perception of luck and hypothesized that those measures would reflect risk-taking behaviour on the task. Though older adults appeared more risk averse than younger adults on the self-report measure of risk preference, there was no age difference in risk-taking on the behavioural task. In addition, self-reported risk preference did not correspond to behaviour on the risk-taking part of the task (or in the other models exploring task performance). This is not uncommon in risk research involving behavioural tasks (Anderson & Mellor, 2009) though this was something we specifically aimed to address in the current study. One explanation may be that self-reported risk preference and risk-taking (behavioural tasks) are inherently measuring different aspects of one's feelings towards risk; unlike the behavioural task, self-report measures involve either reflecting on prior experience with risk, or imagining a scenario in which one would be exposed to risk. This process is subjective and thus prone to bias, as the participants' assumption of how they will respond may not coincide with their actual behaviour when confronted with risk. There is also evidence that risk preference is domain specific (Blais & Weber, 2006, 2006; Josef et al., 2016; Rolison et al., 2014), indicating that context may be important when choosing a self-report risk preference measure in order to find a relationship between risk preference and risk-taking on a behavioural task. Unlike self-report measures, the behavioural task does measure direct behaviour, but this type of measure is also constrained in how much risk it can simulate. Asking participants to imagine a risky scenario is ethically sound, whereas recreating a truly risky scenario is not. The imaginary scenario used in self-report measures does not have the same ethical boundaries as a risk task does. As such, risk research generally has limitations in measuring natural risk-taking, having to rely on (experimental) methods that come as close as possible, without putting the participant in actual risk. To bridge the gap between self-reported risk preference and behavioural measures, future research could aim to develop two types of materials (both a self-report measure of risk preference and a behavioural task) of which the domain and circumstance overlap as much as possible.

We also expected that older adults would report higher levels of positive affect, and that positive affect would be related to higher gamble acceptance. We did not find age differences on the PANAS X, nor was affect related to task behaviour. Though age group was related to a larger distance from the actual chance, the differences between groups were small, suggesting that older adults' difference in chance estimations were not far from those of younger adults. These findings are unlike those of prior research. Pachur et al. (2017) found that older adults reported higher positive affect and lower negative affect compared to younger adults, as well as affect predicting participants' risky choices (low negative affect was associated with more frequently choosing the risky option). However, Pachur et al. (2017) offered participants the choice between two lotteries, one of which was the riskier option. In the current study, participants were given the choice not to gamble, instead of two options that both had a possibility of losing one's earnings (though one option with higher likelihood than the other). Their design also included different domains, such as gain, loss, and mixed domains, whereas ours did not. The distinction in design may (partly account) for differences in finding concerning the relationship between affect and task performance.

This study aimed to assess the role of cognitive ability and risk preference in age differences in risk-taking, using a novel measure to do so. Like other studies, this study also had its limitations. Firstly, the included measures were all physical measures, some of which required interaction with the researcher. Though this was intended to remove the potential difficulty of using computers for the older adult group, participants may have provided more socially desirable answers due to the presence of the researcher, in their task behaviour or self-reports (Krumpal, 2013). In addition, some of the multilevel models included in the analysis had convergence issues. Though steps were taken to address this, it was not successful for some. As different methods to address non-convergence had been applied, a reason for non-convergence is likely the number of predictors included for each analysis. Future research is advised to minimize the number of predictors in such a model or increase the number of observations to prevent convergence issues. Lastly, the older adults were recruited through an existing participant pool in the department. These older adults had signed up to take part in psychology studies, with most studies being memory-oriented, and most had done at least one study prior to the current study. Their experience with psychology studies, and especially the cognitive measures often used in studies with older adults, may have impacted their performance (i.e. learning effects), as well as being a generally highly educated sample. Future studies are advised to recruit older adult participants from the community with little to no experience in scientific studies, as to make sure that prior experience with cognitive measures cannot affect test performance.

CHAPTER 3

Taking chances: the role of cognitive ability and risk preferences in adult age differences in risk-taking behaviour

3.1 Abstract

Objective. To further investigate the role of cognitive ability and risk preference in age differences in risk-taking behaviour. **Method.** 53 younger and 48 older adult participants took part in a two-part risk-taking task designed to capture risk comprehension and risk-taking. They completed the complex task first, then proceeded with the simplified task. Participants also completed various self-report measures on risk preference as well as cognitive tests of numeracy, working memory and processing speed. **Results.** Older adults' numerical ability was lower than younger adults, as was their working memory and processing speed. Age differences on risk preferences measures were mixed, as older adults reported more risk-seeking on some, reported being risk-averse on others, and some measures had no age difference in risk preference. Older adults' risk comprehension was lower, as they estimated gamble probability correctly less often than younger adults across both tasks. Numeracy partially mediated the relationship between age and risk comprehension on the complex task. Older adults also accepted more gambles on both tasks. Despite age differences in risk-taking, both cognitive ability and risk preference did not mediate the relationship between age group and risk-taking on either task. **Conclusion.** Age differences in numerical ability explained older adults' lower comprehension of risk on the complex task, but numeracy nor any other abilities explained comprehension on the simplified task, or risk-taking overall. The gap between risk preference and risk-taking when considering age groups suggests that older adults' risk-taking may be driven by a lack of comprehension, instead of risk preferences.

3.2 Introduction

Findings from study 1 revealed that there were no significant age differences in correct estimation of chance, nor did older and younger adults differ detectably in their acceptance of gambles on the task despite age differences in self-reported risk preference and in some cognitive abilities. Those findings add to a growing body of research on the misalignment between people's risk preference and task behaviour (Anderson & Mellor, 2009; Crosetto & Filippin, 2016; Deck et al., 2013; Frey et al., 2017; Menkhoff & Sakha, 2017; Szrek et al., 2012), which seems especially prominent in older age (Josef et al., 2016; Mamerow et al., 2016). However, limitations of study 1 (i.e. usage of physical measures that required increased interaction with the researcher, convergence difficulties in some multilevel models in the analysis, and a potentially biased older adult sample) limit the inferences that can be drawn from the study's findings. A way to tackle these prior limitations is to conduct a study with a more thorough experimental design in which less interaction is required. In addition to improving the study's design, it is also highly beneficial to change the analytical approach to better fit a study of this design. As such, a computerized task with 2 task types (i.e. complex and simplified) will be used in the second study, to compare task performance when cognitive demand is high or low. Additionally, predictors of task performance will be selected from multiple risk preference and cognitive measures to only include the best fitting predictors instead of including all.

This approach would also address a gap in the current research. Currently, most research on risk-taking uses a single behavioural measure. If multiple tasks are used, differences in task design (e.g. risk domain, choice options, or whether decisions are based on experience or description) restrict comparisons of risk-taking across tasks. There are few studies who have used multiple risk-taking tasks (Henninger et al., 2010; Hess et al., 2018; Mamerow et al., 2016; Zamarian et al., 2008). Those who did include multiple tasks compared risk-taking across task types, but these tasks often had very different designs and pay-out structures. These differences in design or pay-out structure could equally result in differences in task performance and risk-taking. For example, the Iowa Gambling Task and the Balloon Analogue Risk-Taking Task are known risk-taking tasks that do not provide information and rely on participants to learn through experience. However, where learning on the Iowa Gambling Task leads to risk-averse choices, learning on the Balloon Analogue Risk Task leads to taking more risk. As such, the difference in the tasks' reliance on (reverse) learning may explain differences in risk-taking, and potentially mask other explanations.

Some studies did create different versions of the same task in which the design or pay-off structure has remained similar. Hess et al. (2018) included 4 versions with similar design: an experience-only task, a description-only task, a consistent experience task, and an inconsistent experience task. In the experience-only condition, participants were given only general information, such as the two bets having different chances of winning, and probability remaining constant over trials. At the end of the trial, participants were given feedback on how successful their bet had been and its earnings. In the description-only condition, two additional pieces of information were given concerning payoff structures to guide their choices. Participants were given the probabilities and were given a rule of thumb that they should select option B if its payoff was more than double of option A; otherwise they should choose option A. Participants were not given any feedback in the description-only condition, only at the end of the task were they told how much they had earned.

The two remaining conditions, consistent and inconsistent experience, were a combination of the first two conditions. Participants in both conditions received the same descriptive information as those in the description-only condition and received the trial-by-trial feedback received by those in the experience only condition. Ability, a composite score resulting from the working memory, processing speed and verbal ability measures, was also included. Hess et al. (2018) found that older adults made significantly less correct choices in the description-only task than younger adults (correct choice was characterized as choosing the option with the highest expected value), which seemed to be related to the lack of recall of the decision strategy they were given. Participants took more risk in the description-only version, but there were no age differences in risk-taking. Numeracy was positively associated with better decisions but did not differ between age groups, while ability was only related to correct choice on the inconsistent-experience condition. Though this task consisted of several versions, and assessed whether cognitive abilities were related to task performance, it did not ask participants to give a more clear account of their understanding of gamble probabilities and monetary outcomes (i.e. the assumption of misunderstanding was made due to participants' choices for less-optimal options), nor was risk-taking on the task compared to participants' risk preference.

Similar to the task used by Hess et al. (2018) The Columbia Card Task (Figner et al., 2009) also includes multiple conditions, using a "hot" and "cold" version of the task. In the "hot" version, participants are presented with 32 face-down cards and are given the chance to turn over one card during each trial. When the card is turned over, the participants receive feedback on whether the card's outcome was a win or loss. If a loss card has been turned, the loss is subtracted from the overall earnings and ends the task. In the "cold" version of the task, participants are presented with the set-up but are asked how many cards they wish to turn over at once. If their selection of cards does not include a loss card, the accrued amount is added to the overall earnings. If the selection does have a loss card, the amount is subtracted from the overall earnings and the task is ended. In order to maximize earnings, participants have to consider the chance of encountering a loss card, as well as win and loss amounts, when deciding how many cards to turn over. Though this task involves two separate, but similar, task parts, its focus does not lie in measuring the role of cognitive ability or risk preference in risk-taking; the task was designed to investigate affective versus deliberative processes, and assess how people's choice behaviour changes in response to feedback. Also, Figner et al. (2009) included several measures of cognitive ability, such as working memory, to assess whether differences in cognitive ability affected task performance but found no effect of cognitive ability on risk-taking on either task types. Huang et al. (2013) aimed to replicate findings by Figner et al. (2009) but did not find age differences between younger and older adults on the task, and as such did not conduct mediation analyses to assess whether numeracy, and two types of working memory measures mediated the relationship between age and risk-taking on the Columbia Card Task. Correlations between measures and task performance showed that only numeracy was significantly related to age, but it was not correlated with task performance, nor were the working memory measures. In addition, this task also does not allow a more precise measurement of probability comprehension, as the same assumption underlies the interpretation of misunderstanding of probability and expected value as the task used in Hess et al. (2018).

In summary, the majority of research on age differences in risk-taking includes a single risk-taking task, or multiple tasks that differ in design. If multiple tasks are used, they do not always allow precise measurement of participants' understanding of probability and expected value of the given options. As such, it is difficult to assess how age differences in task performance are mediated by cognitive abilities such as numeracy or working memory, as comparison is limited due to issues concerning similarity in design, or the absence of another task. In addition, many studies have not included a measure of self-reported risk preference, making it difficult to establish whether risk was taken intentionally, as a result of a person's preference towards risk, or whether risk was taken unintentionally, as a result of cognitive strain imposed on the participants by the task. To further investigate the role of cognitive ability and risk preference in age differences in risk-taking, we have adapted the risk-taking task from study 1 to include two task types: a complex and simplified task. The first type, the complex task, is similar to the task in study 1, but no longer allows participants to physically use the coloured balls and box. Instead, the task is computerized, with the box displayed on the screen and participants dragging the coloured balls into the box. This still requires participants to convert probabilities into frequencies but with less feedback (e.g. participants are no longer able to physically interact with the task parts, such as the coloured balls, nor is there a researcher present in the testing area). In the second type, the simplified task, participants are presented with a correctly filled box and are asked to count the coloured balls and enter the count for each outcome (win, loss, neither win nor loss). This process demands minimal cognitive exertion, which should make gamble acceptance more reflective of participants' risk preference, removing the potential mediating effect of cognitive ability. The change in task design will allow us to assess each task part separately and determine if cognitive ability is related to older adults' performance on the complex task part, while the simplified task (without cognitive demand) is reflective of risk preference, the latter being the general assumption among risk-taking tasks. Both task types have also been computerized to lower the time spent for each session (as some participants spent close to 3 hours completing the first study). To our awareness, there is no existing study that assesses whether both cognitive ability and risk preference mediate age differences in task performance across two similar tasks with a high and low cognitive demand, that directly ask participants to calculate gambles outcomes.

3.2.1 The present research

The current study aims to further investigate to what extent age differences in cognitive ability and risk preference can account for age differences in risk-taking behaviour. This will be done by using a computerized, two-type risk-taking task, with both types of similar design but with high and low cognitive demand. We hypothesized the following outcomes:

Hypothesis 1: older adults would estimate probability correctly less often in the complex task than younger adults, and this difference would be due to age-related cognitive decline. As the complex task was designed to be more cognitively straining, we predicted that older adults' correct estimations on this task would be affected by age-related changes in cognitive ability.

Hypothesis 2: age groups would not differ in their correct estimation of probability in the simplified task, nor would cognitive ability mediate the relationship between age group and correct estimation anymore. The simplified part was designed to remove any effect of age-related cognitive decline, and as such, we expected that task performance on the simplified task would not be related to cognitive ability.

Hypothesis 3: older adults would accept more gambles on the complex task, and this age difference in risk-taking was mediated by age-related decline in cognitive ability. As the complex task is more cognitively straining, cognitive ability was hypothesized to mediate the relationship between age group and gamble acceptance, with older adults accepting more gambles as well as having lower performance on the cognitive ability measures.

Hypothesis 4: older adults would accept less gambles on the simplified task compared to younger adults, and this was due to age differences in risk preference. As the simplified task has been designed to remove any cognitive strain, behaviour on the simplified task should reflect participants' underlying risk preference. As such, older adults were projected to accept less gambles on the task compared to younger adults, as we also expect them to report being more risk averse.

In addition to the hypotheses above, we also ran exploratory analyses. We were interested in seeing whether self-control and impulsivity would mediate the relationship between age and risk-taking, as both have been found to be related to risk-taking, especially concerning gambling behaviour (Bergen et al., 2012; Clarke, 2004; Ioannidis et al., 2019; Petry, 2001). As such, we ran identical analyses to examine whether impulsiveness and self-control affected risk-taking behaviour on the two task types.

3.3 Method

3.3.1 Participants

We recruited 105 participants, out of which 4 were excluded from the analysis (1 participant's score on our cognitive impairment check indicated (mild) cognitive decline, 3 participants had incomplete data). The final analytical sample was 101 and consisted of 53 younger adults (60.4% identified as female, $M_{younger} = 22.77$, SD = 3.21 years), and 48 older adults (49.8% identified as female, $M_{older} = 70.81$, SD =

4.68 years). A little over a third (34%) of participants in the younger adult group were British, followed by American (7.5%). The common education level was A levels or equivalent education (37.7%), followed by an undergraduate degree (34%). Most younger adult participants were students (86.8%), with an annual income of £10.000 or less (32.1%). All participants in the older adult group were British nationals. Almost a third (29.2%) of older participants had completed a university undergraduate degree, and (27.1%) had completed A levels or equivalent education. The most common form of employment status was retirement (83.3%), and the most common annual income between £10.001 and £30.000 (50%).

3.3.2 Materials and procedure

First, participants were given an information sheet and were asked to sign an informed consent form before commencing the study. In the information sheet, participants were told that they would be given gambles during the study. If they played one or more gambles, half of the amount accrued on the task would be given to them, whether this was an overall win or loss. In case of an overall win, they would receive half of the money won on the task as well as their flat participation fee of £5. If they lost money on the task overall, half of the loss amount would be subtracted from their participant payment. If the final loss (i.e. half of the loss amount accrued on the task) was larger than their flat participation fee of £5, they would leave with £0 (i.e. they could not acquire debt). They were told that the study was about decision-making across the life span, that the study duration averaged about 60 to 90 minutes, and that most of the activities allowed them to take as much time as they required.

After signing the consent form, the older adult participants took part in the MMSE (Folstein et al., 1975), a screener for cognitive impairment. Participants would be able to take part if they scored 24 or higher, as any score below 24 is considered indicative of decline. The most common score on the MMSE was 29 (the maximum score on the MMSE is 30). One participant scored below the cut-off score of 24 and was excluded from the study. After completing the MMSE, participants were asked to complete a demographic questionnaire on their gender, education level, employment status, nationality, and income.

Following the demographic questionnaire, participants took part in the behavioural risk-taking task. Its instructions were presented visually on the computer screen and spoken instructions were also available through headphones. The task was designed and run using experiment software Inquisit (version 5). The task consisted of two types: a complex task, which places higher demand on cognitive abilities, and a simplified task, which had been designed to require minimal cognitive demand. Twenty gambles were randomized across the complex and simplified task, with participants completing 10 gambles for each task type (i.e. one participant may complete gamble 1 in the complex task, while the next participant may complete gamble 1 in the simplified task). The complex task was given first to avoid any learning effects. The gambles' selection procedure was identical to the procedure described in study 1. The included gambles were originally selected from a pilot study in which participants were asked to evaluate 75 gambles. The 10 gambles used in study 1 were included once more, with 10 additional gambles from the pilot study. The additional gambles included in the task had varying expected values but were guessed correctly around 50 percent of the time in the pilot study. The gambles were modelled after those used in Rolison & Pachur (2017) and consisted of three outcomes; a chance to win, a chance to lose, and a chance to neither win nor lose. Each outcome had its own amount associated with its probability. In both task types, participants received on-screen instructions and were shown an example of the trial screen and gamble. They were then asked to imagine the gamble being played 20 times and asked to mimic the outcomes that would occur over those 20 times, effectively converting probabilities to frequencies.

In the complex task, participants were shown an empty box with 20 compartments on the screen, with a gamble and three types of coloured balls displayed next to the box (see Figure 4). The three types of coloured balls represented the different outcomes of the gamble: green balls represented wins, red balls represented losses, and yellow balls represented neither wins nor losses. Participants were instructed to drag and drop the coloured balls into the box compartments to mimic the outcomes of the gamble being played 20 times. Participants could enter any outcome in any order in the box, and any frequency up to 20 per outcome (i.e. each outcome had a maximum of 20 balls each). This allowed participants to enter their expected outcome with reasonable restriction. If any mistakes were made, the participant could click “reset” to empty the box and start over. Participants were not able to submit a partially filled box. If any compartments in the box had been left empty when the participants clicked “finished”, the task would prompt an error message. After clicking “finished”, participants would continue to the feedback screen.

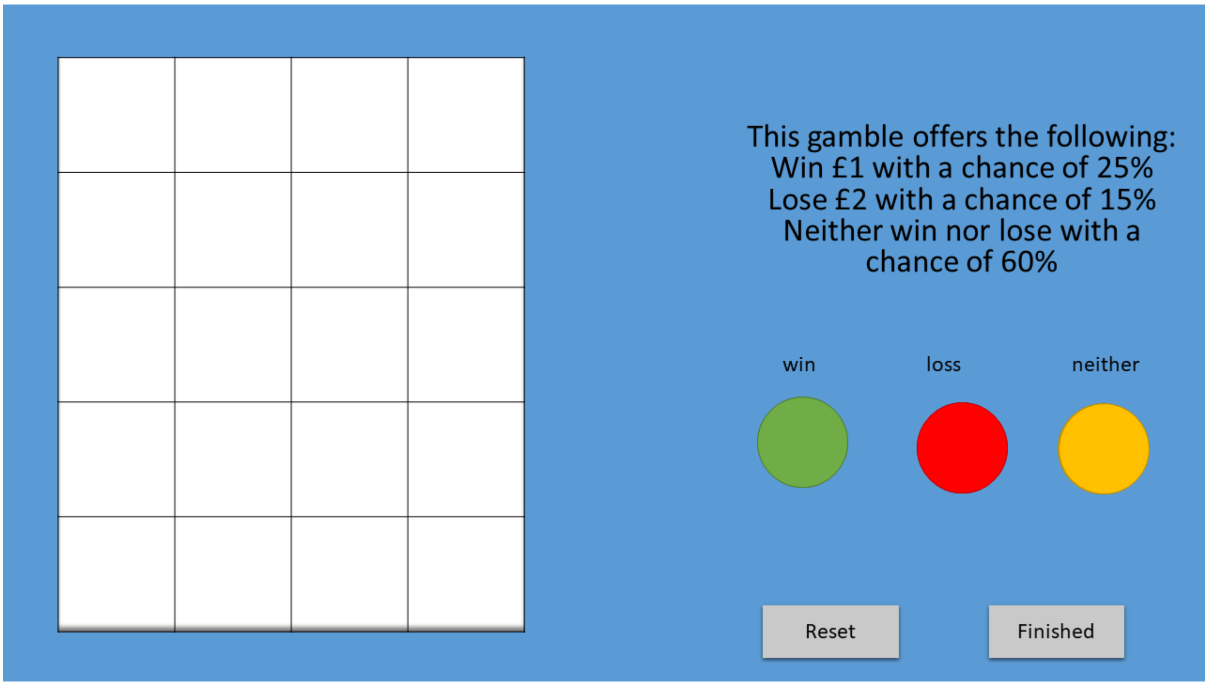

Figure 4. *Example of a trial in the complex task part.*

In the simplified task type, participants were given a pre-filled box with the correct number of balls for each outcome. They were asked to count the number of balls for each outcome and to enter the count into the answer cells on the screen. After doing so, participants continued to the feedback screen, similar to the trials in the complex task.

For both task parts, after filling the box with the expected outcomes, the participants were shown a feedback screen with the monetary value for each outcome (win, loss, neither) as well as the overall value of playing 20 times, on the left of the screen (see Figure 5). The values they were shown were based on the number of balls the participants put into the box for each outcome, and the amounts associated with the outcomes of the gamble.

Figure 5. *Example of feedback on the task after having filled in the box and having clicked "finished".*

Participants were also asked whether they wished to play the gamble in real-life by accepting the gamble on the screen. The gamble they were asked to mimic was shown on the right with buttons to click accept or reject. If participants decided to reject the gamble, they were given a new gamble and repeated the procedure for another gamble. If participants decided to accept the gamble, they were shown an additional screen that gave them the option to increase the amounts to win and lose (see Figure 6). Participants could use arrows to increase the win amount by 5 percent each time they click the arrow. However, the amounts to win and lose could not be decreased, only increased. If the win amount was changed, the loss amount changed accordingly to maintain the expected value of the gamble. The task determined the outcome of playing the gamble based on the objective probabilities to win, lose or neither win nor lose, associated with the gamble.

Figure 6. *Example of participants' options to increase the win and loss amounts of an accepted gamble.*

After completing the behavioural task, participants were given an online survey that included several measures, the first being the Objective Numeracy Scale (Lipkus et al., 2001). The Objective Numeracy Scale is a measure of the ability to understand and solve mathematical equations and probabilities. The scale consists of 11 items, with some items concerning probabilities in forms of percentages and fractions, others requiring participants to calculate the answer to a basic mathematical problem (e.g. "Imagine that we rolled a fair, six-sided die 1,000 times. Out of 1,000 rolls, how many times do you think the die would come up even (2, 4, or 6)?"). Three additional items from two types of cognitive reflection tests (Primi et al., 2016; Toplak et al., 2014) have been added to the scale for this study as participants generally score rather high on the Objective Numeracy scale alone. These three items measure the ability to reflect on a question and to resist responding with the first answer that comes to mind. The reliability of the Objective Numeracy Scale was found by Lipkus et al. (2001) to be α = 0.78. Weller et al. (2013) reported a Cronbach's alpha of α = .76, and Thomson & Oppenheimer (2016) found a Cronbach's alpha of α = .72. Participants' scores are the sum of correct items of all 14 questions.

After completing the numeracy scale, participants were given the Dospert (Blais & Weber, 2006), adjusted by Rolison et al. (2019), which aims to assess participants' self-reported likelihood to take risks and perception of risk-taking across domains such as financial ("Using your credit card to pay for an item on an unfamiliar website"), recreational ("Going camping in the wilderness"), social ("Moving to a city far away from your close friends and family") and health and safety ("Driving a car without wearing a seatbelt"). Items are similar or identical to items from the Domain Specific Risk-Taking Scale (Blais & Weber, 2006), but several items have been adjusted to ensure suitability for a diverse age range. For this study we used the Financial Likelihood scale only. Participants rated how likely they were to undertake the listed activities on a 7-point Likert Scale from -3 to 3 (-3 = extremely unlikely, 3 = extremely likely). Participants' scores are the mean response across all items, with a higher mean indicating a higher likelihood of taking financial risk. In their study, Rolison et al. (2019) reported a combined Cronbach's alpha of α = 0.72, with an alpha of α = .65 for Likelihood, and α = .78 for Risk Perception, suggesting sufficient reliability.

Participants were then given a questionnaire created specifically for this study. Research on risk is often characterized by limitations on the level of risk a participant will experience in an experiment, due to ethical boundaries and the clear communication of study outline and participants rights. As such, participants are often aware that actual risk is limited and may act accordingly. In addition, most self-report measures use hypothetical risk to measure risk preferences and this may (partly) explain prior gaps between self-report and behaviour. To reflect this, the designed questionnaire includes items in which the decision to hypothetically put oneself in a risky environment has already been made. An example of an item is the following: “You’re at the casino for a birthday party. Would you take some gambles at the slot machines or some other gamble at the casino?” The questionnaire consists of 11 items, with responses measured on a 7-point Likert scale from -3 to 3 (-3 = extremely unlikely, 3 = extremely likely) Participants’ scores are the arithmetic mean across all 11 items.

Participants then completed the 11th revision of the Barratt Impulsiveness Scale (BIS11; Patton et al., 1995) The BIS11 consists of 30 statements across 3 subscales: attentional impulsiveness (measuring focus on tasks, intrusive and racing thoughts), motor impulsiveness (measuring consistency of behaviour and lifestyle) and non-planning impulsiveness (assessing planning, careful thinking and enjoying challenging tasks). Participants rate to what extent the statement applies to them on a 4-point Likert scale ranging from 1 to 4 (1 = never/rarely, 4 = almost always/always). The reliability of the BIS11 was found to range between a Cronbach’s alpha of α = .79 and .83, depending on the population of the sample (Patton et al., 1995). Participants’ scores are the sum of responses across all 30 items. We chose to not use the three subscales and instead use the overall score, as it has been shown that the overall score is a more reliable measurement of impulsiveness (Patton et al., 1995).

The Tangney’s Self-control Scale followed the BIS11. Participants completed the Self Control Scale (Tangney et al., 2004), which was designed to assess people’s ability to control their impulses, emotions and thoughts, and their ability to refrain themselves from acting on undesirable tendencies. The scale consists of 36 statements related to self-control (such as “I don’t keep secrets very well”) within five dimensions: general capacity for self-discipline, deliberate/non-impulsive actions, healthy habits, work ethics and reliability. For each statement participants choose how it applies to them on a scale from 1 to 5 (1 = not at all, 5 = very much). The Self-Control Scale’s reliability is good, with a Cronbach’s alpha of α = 0.89 across two studies. Scores on the Self-Control Scale are the sum of responses across all items (Tangney et al., 2004).

Participants then completed the General Risk Propensity Scale (Zhang et al., 2019). The General Risk Propensity Scale is a domain-general disposition measure of risk-taking behaviour, measuring general propensity to take risks across situations. The scale consists of 8 items, an example of such an item is “I am attracted, rather than scared, by risk”. Participants are given statements about their personal feelings on taking risks, to which they rate on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) how much they agree with the statement. The General Risk Propensity Scale showed good reliability, with a Cronbach’s alpha of α = 0.92 (Zhang et al., 2019). Participants’ scores on this measure are the arithmetic mean across the 8 items.

The last two measures of the study were cognitive measures. Of the two measures, participants completed the Shortened Symmetry Span first. The Shortened Symmetry Span (Foster et al., 2015) is a complex span task, designed to capture working memory ability. In this study, the shortened version of the Symmetry Task was used. In the task, participants are given a distractor block in which they are asked to judge whether the figure on the screen is vertically symmetrical. This is followed by a series of 4 x 4 grids in which red blocks are located (see figure 7).

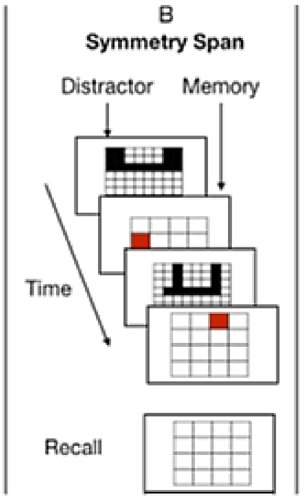

Figure 7. *Distractor and memory blocks of the Shortened Symmetry Span.*

At the end of the trial, participants are asked to number the locations in the grid that the red blocks were located, in the order of presentation. The number of symmetry-location pairs differs per trial, varying between 2 and 5 pairs. Scores on the Shortened Symmetry Task are calculated by summing the number of correctly recalled locations of squares in the correct order. The Shortened Symmetry Span Task was chosen due to its suitability to test higher educated samples compared to other complex span tasks (Draheim et al., 2018) as previous studies on these age groups showed that the majority of participants were highly educated. The Shortened Symmetry Span was run using the behavioural research software program E-Prime (version 2.0 Professional).

Before completing the study, participants completed the Digit Symbol Coding, a measure of processing speed and a subtest of the WAIS-III (Wechsler, 1997). Participants were given a form with combinations of 9 numbers and symbols in the top of the form and were asked to copy the symbols underneath the associated numbers as swiftly and accurately as possible. To do so, they had 120 seconds. The score on the Digit Symbol Coding is the total number of correctly matched symbols and numbers, with a higher score indicating better processing speed.

Finally, participants were debriefed and received payment for their participation (if their earnings on the decision-making task were more than £0). Participants could choose whether to take their payment home or donate it (in part) to three selected charities, which they told at the beginning of the study was an option. The materials used in this study can be found in the appendix.

3.3.3 Analysis

To assess the reliability of the self-report measures, Cronbach's alphas were computed using the *ltm* package (version 1.1-1). Due to the nature of the study (i.e. duration of sessions differing between 1 and 3 hours) and target group (i.e. older adult participants are more difficult to recruit), we had limited power. As such, we were unable to run complex analyses to establish the best predictors of comprehension and risk-taking (such as structural equation modelling). Instead, we used zero-order correlations to choose the best predictors of both risk preference and cognitive ability. Zero-order correlations were run using the *rstatix* package (version 0.7.0).

To test each hypothesis, we used mediation analyses. We first used simple linear regressions to establish relationships between variables (independent, dependent, and mediator), and used the *mediate f*unction from the *Psych* package (version 2.0.12) to run the multiple mediation models (used to assess the contribution of cognitive ability and risk preference to age differences in correct estimation and gamble acceptance). Each mediation model was run using a bootstrapping approach with 500 iterations and 95% confidence interval.

3.4 Results

3.4.1 Composite variables

Correct estimation of probability. Participants' correct estimation of probability was measured for each of the 20 gambles. Correct estimation was coded as 1 if all probabilities associated with a gamble (i.e. win, loss, neither win nor loss) were estimated correctly. If one or more of the probabilities were not estimated correctly, correct was coded as 0. For the analysis, correct was transformed into a proportional score of how often participants were correct across the gambles in the complex task part, and those in the simplified task part. This provided each participant with two (proportion) scores of correct estimation of probability between 0 and 1.

Gamble acceptance. Gamble acceptance on the task was measured for each of the 20 gambles and was coded as 1 if the participants chose to accept to play the gamble in real life, and 0 if they rejected the gamble. For the analysis, gamble acceptance was transformed into a proportional score of how many gambles participants accepted in the complex task part, and how many they chose to play in the simplified task part, giving each participant two gamble acceptance scores between 0 and 1.

General Risk Propensity Scale. Participants' risk preference on the General Risk Propensity Scale were measured as the arithmetic mean across its 8 items. The scale's reliability was good, with a Cronbach's alpha of $\alpha = 0.92$. As such, no changes were made to how participants' scores were calculated on this scale.

New Risk Scale. The New Risk Scale was created for this study, in which participants' risk preference was measured as the arithmetic mean across its 10 items. The scale's reliability was a Cronbach's alpha of 0.63. However, the item-total correlation test showed that the removal of item 6 ("You're travelling to a new city shortly and have already booked transportation. While looking for a place to stay you find accommodation for a low price that looks too good to be true. Would you book your stay there?") improved the scale's reliability from α = 0.63 to α = 0.68. As such, we removed item 6 and calculated participants' mean score on the New Risk Scale across its remaining 9 items.

Adjusted Dospert. Scores on the adjusted Dospert scale were measured using six items on the likelihood of taking financial risk. The measure's reliability was found to have a Cronbach's alpha of α = 0.46, which was insufficient. We then used an item-total correlation test to establish which item removal would lead to an improvement in reliability. Removing the second item ("Using your credit card to pay for an item on an unfamiliar website") was shown to increase the scale's reliability from a Cronbach's alpha of α = 0.46 to α = 0.58. As such, item 2 was removed and scores on the adjusted Dospert are measured as the arithmetic mean across the remaining 5 items.

Objective Numeracy Scale. Numeracy scores were measured as the sum of correct answers across 14 numerical problem scenarios. The scale's reliability was sufficient, with a Cronbach's alpha of α = 0.67. Thus, we maintained the original calculation of participant scores, the sum of correct items of its 14 items.

Tangney Self-Control Scale. Self-Control was measured across 5 subscales, with 36 items in total. For this study, we measured participants' self-reported self-control as the arithmetic mean across all items. The scale's reliability was good, with a Cronbach's alpha of α = 0.87. As such, we did not make any changes to the way participants' scores were calculated.

Barratt Impulsiveness Scale. Participants' self-reported impulsiveness was measured across 30 items. For this study, we calculated participants' scores as the arithmetic mean across all items. The scale's reliability was sufficient, with a Cronbach's alpha of $\alpha = 0.79$, allowing us to maintain the approach in calculating participants' scores without any adjustments.

3.4.2 Confirmatory tests of hypotheses

Hypothesis 1: age differences in correct estimations of probability

Complex Task. We hypothesized that older adults would less often estimate probability correctly on the complex task type, due to the cognitive strain of the task. As such, we expected that age differences in correct estimation on the complex task would be mediated by cognitive ability. Overall, we observed that older adult participants correctly estimated probability less often, as their proportion of correct estimations was lower than those of younger adults (see Figure 8). Older adults were correct about half as often as younger adults.

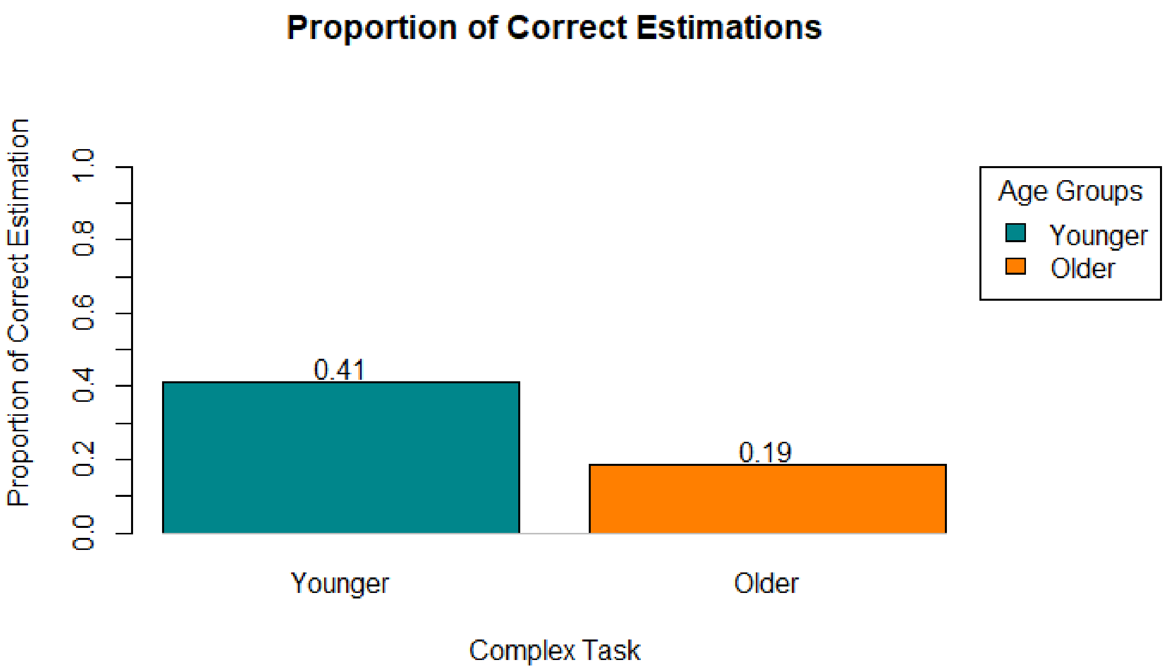

Figure 8. *Proportion of correct probability estimations in the complex task by younger and older adults.*

The differences between age groups in correct probability estimation are further illustrated when looking at the distance from actual probability (see Figure 9). Younger adults appeared to estimate the probability to win and lose closer to its actual value, with only some estimating above or below the probability value, whereas older adults appeared to have more difficulty estimating win and loss values in the complex task. The density plots displaying older adult's estimation show a thicker density in both the area around the actual value and further away. The estimation of win probability by older adults (bottom left) shows thicker lines near the top of the graph, indicating overestimation of win probability, whereas the opposite occurs in the estimations of loss probability (bottom right).

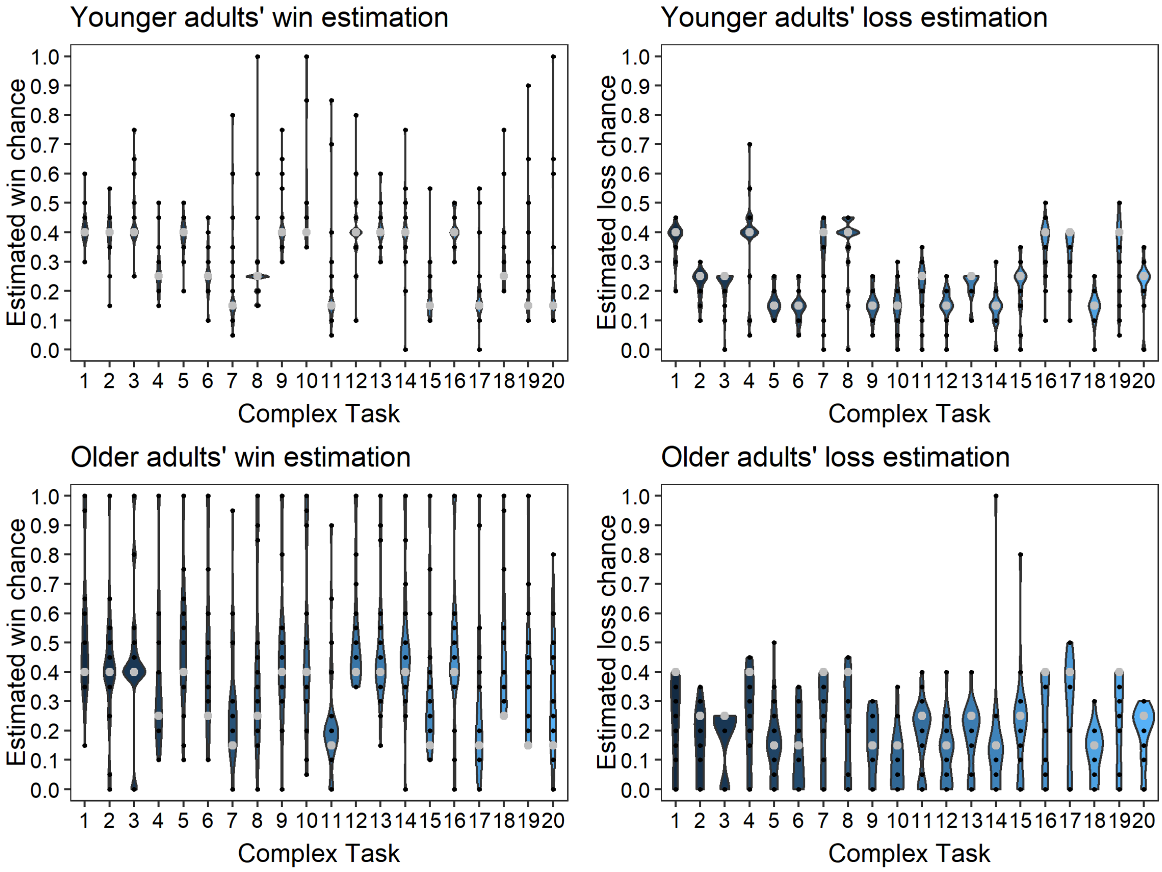

Figure 9. *Density plots of younger (top) and older adult (bottom) estimations of win and loss probability for each gamble on the complex task.*

Note. The actual gamble value is represented by a grey dot in the individual distributions. The actual probabilities differ between gambles (i.e. probabilities could be 0.15, 0.25, or 0.40). A thicker area around the grey dot indicates that many participants estimated the probability to be near its actual value. If the distributions are very thin, this indicates that most participants guessed the actual gamble value. The length of the distribution indicates the distance of the estimation from the actual probability.

To find the best predictors for risk preference and cognitive ability in the complex task, zero-order correlations were conducted. In the complex task, correct estimation of probability correlated most highly with the General Risk Propensity

Scale, $r = 0.17$, followed by the adjusted Dospert, $r = -0.11$. As such, the General Risk Propensity Scale was chosen as the predictor across risk preference measures. For measures of cognitive ability, numeracy was most highly correlated with correctly estimating probability, $r = 0.43$, followed by Shortened Symmetry Span, $r = 0.39$. Numeracy was chosen as the cognitive measure included in the analysis of correct probability estimation in the complex task.

To investigate the contribution of risk preference and cognitive ability to age differences in correct estimation of probability, we conducted a mediation analysis. Firstly, using a linear regression, correct estimation in the complex task part was regressed on age group. The results showed a significant difference between age groups in correct probability estimations, B = -0.23, $t(99) = -3.15$, $p = .002$, with older adults correctly estimating probability less often. Identical analyses were conducted to regress correct estimations on scores of the General Risk Propensity Scale, which showed no significant relationship between the two variables. When regressing the General Risk Propensity scores onto age group, the results showed that older adults reported taking significantly less risk, B = -0.48, $t(99) = 2.80$, $p = .006$. We then regressed correct estimation on numeracy, the second mediator, which showed a significantly positive relationship, B = 0.07, $t(99) = 4.69$, $p < .001$. Following this, numeracy was regressed on age group, which showed that older adults scored significantly lower on the numeracy measure, B = -0.97, $t(99) = -2.27$, $p = .025$.

We then proceeded with testing whether the relationship between age group and correct estimation of probability on the complex task was mediated by the General Risk Propensity Scale and numeracy, using a mediation model with multiple mediators. The indirect effect of age group on correct estimation, through the General Risk Propensity Scale was not significant (see Figure 10). However, the indirect effect through numeracy was significant, *ab* = -0.06, 95% *CI*[-0.13, -0.01], indicating that numeracy partially mediated the relationship between age group and correct estimation of probability.

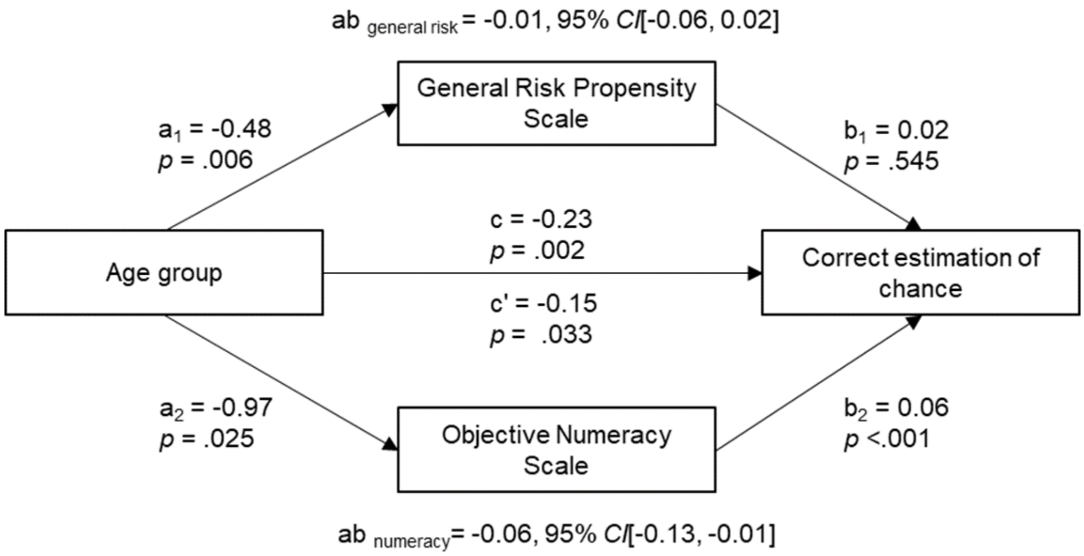

Figure 10. *Mediation analysis on estimation of correct probability in the complex task, with age group as independent variable, with General Risk Propensity Scale and Objective Numeracy Scale as mediators.*

Simplified task. For the simplified task, we hypothesized that any effects found on the complex task part would disappear, as correct estimation of probability on the simplified task should not be affected by cognitive strain. In line with our expectations, age differences in correct estimation were smaller on the simplified task (see Figure 11), as both groups improved in accuracy compared to their estimations of probability on the complex task.

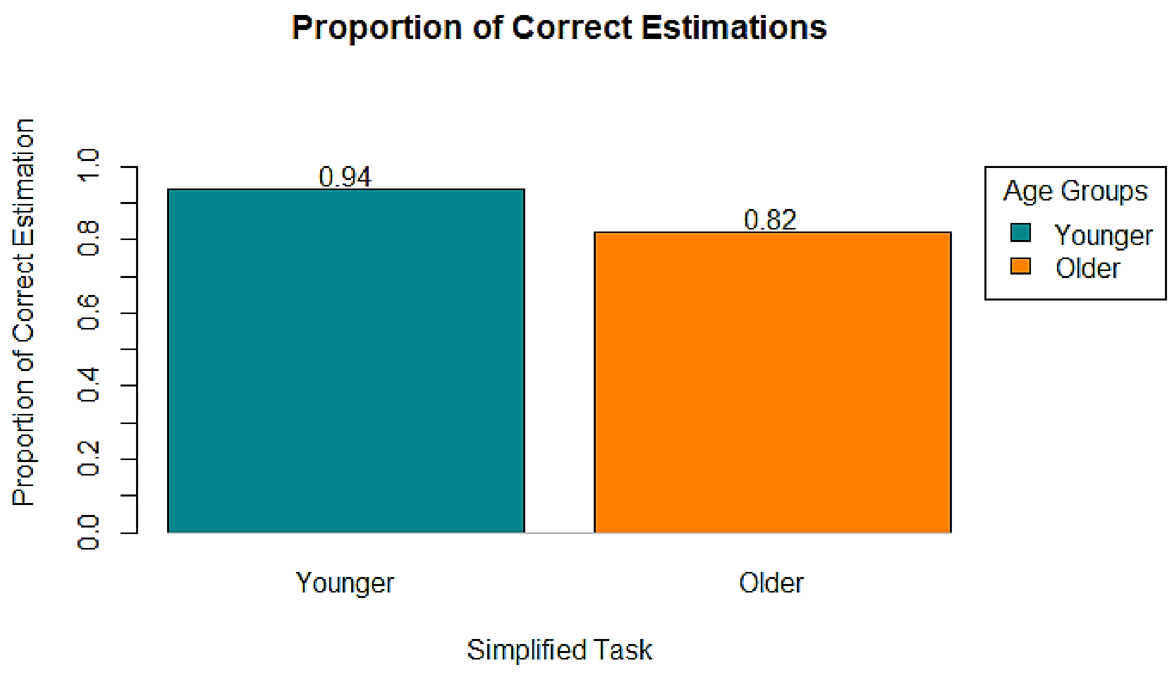

Figure 11. *Proportion of correct probability estimations in the simplified task by younger and older adults.*

However, a similar direction remained, with younger adults correctly estimating gamble probabilities correctly slightly more than older adults. When looking at the distribution of estimations, a similar pattern emerges (see Figure 12). Younger and older adults appear relatively similar in their estimations, both showing estimations of win and loss probability close to the actual values. However, the older adult group's estimations are more spread out, with estimations further from the actual value and estimations close to, but not exactly, the gamble's probability.

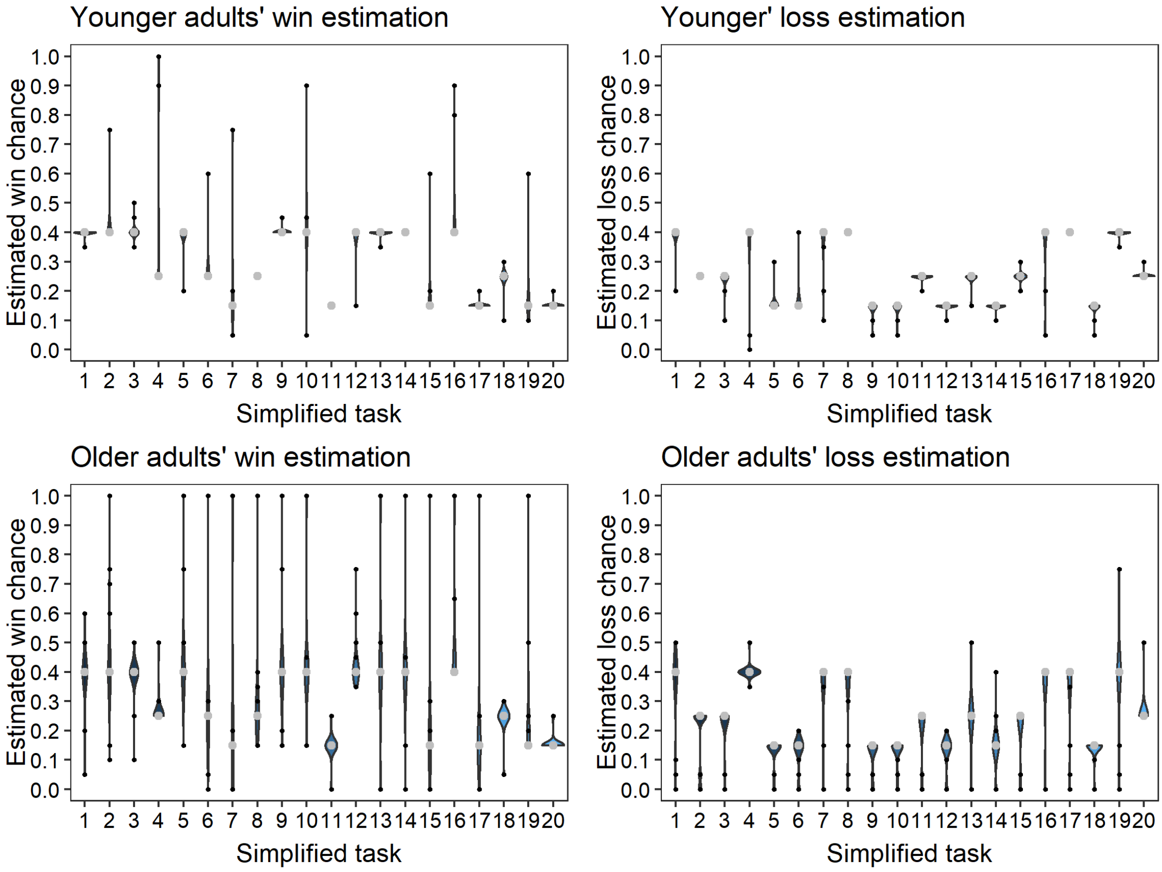

Figure 12. *Density plots of younger (top) and older adult (bottom) estimations of win and loss probability for each gamble on the simplified task.*

Note. The actual gamble value is represented by a grey dot in the individual distributions. The actual probabilities differ between gambles (i.e. probabilities could be 0.15, 0.25, or 0.40). A thicker area around the grey dot indicates that many participants estimated the probability to be near its actual value. If the distributions are very thin, this indicates that most participants guessed the actual gamble value. The length of the distribution indicates the distance of the estimation from the actual probability.

For the simplified task type, we again used zero-order correlations for both risk preference and cognitive ability measures to find the best predictor of correct estimations of probability. Among risk preference measures, the New Risk Scale correlated most highly with correct estimation, r = -0.14, other measures' coefficients were very small (r < 0.1). For cognitive measures, the Shortened Symmetry Span was most related to correct probability estimates, r = 0.15, followed by Digit Symbol Coding, r = 0.11. As such, the New Risk Scale was chosen to be the risk preference measure, and Shortened Symmetry Span to be the cognitive measure to be included in the mediation analysis on participants' correct probability estimation in the simplified task.

Similar to the mediation process for the complex task part, correct estimation in the simplified task was first regressed on age group, and showed a significant difference between age groups in correct probability estimations, B = -0.12, t(99) = -2.05, p = .043, with older adults correctly estimating probability less often. Identical analyses were conducted to regress correct on mean scores of the New Risk Scale, which showed no significant relationship between correct estimation and risk preference. When regressing New Risk scores onto age group, the results showed that older adults reported more risk-seeking, B = 0.86, t(99) = 4.69, p < .001. When exploring the model's second mediator, working memory, correct estimation was regressed on the Shortened Symmetry Span, which showed no significant relationship between working memory and correct probability estimation. Following this, Shortened Symmetry Span was regressed on age group, which showed that older adults scores significantly lower on the working memory measure, B = -5.41, t(99) = -9.45, p < .001. We then tested whether the relationship between age group and correct estimation of probability was mediated by the New Risk Scale and Shortened Symmetry Span, through a mediation analysis with multiple mediators. The indirect effect of age group on correct estimation, through the New Risk Scale and Shortened Symmetry Span, was not significant (see Figure 13). Findings indicate that differences between age groups in correctly estimating gamble probability on the simplified task were not related to risk preference or cognitive ability. These findings are in line with our expectations, as we hypothesized that the simplified task part would show no effects of cognitive ability or risk preference.

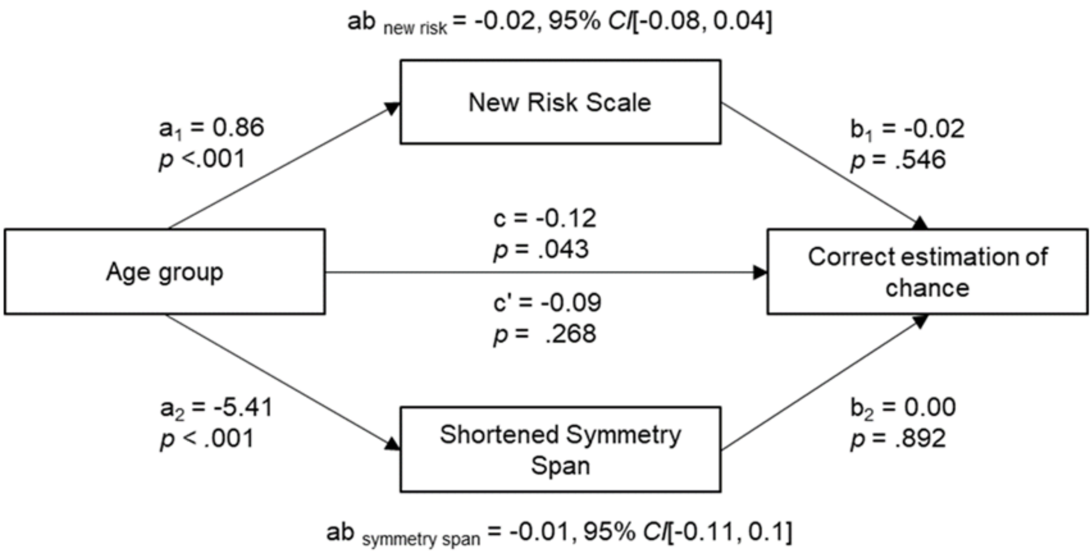

Figure 13. *Mediation analysis on estimation of correct probability in the simplified task, with age group as independent variable, with New Risk Scale and Shortened Symmetry Span as mediators.*

Hypothesis 2: age differences in gamble acceptance

Complex task. We hypothesized that older adults would accept more gambles on the complex task due to the increased strain this task type poses on cognitive abilities. As expected, the proportion of accepted gambles was higher for older adults than younger adults (see Figure 14)

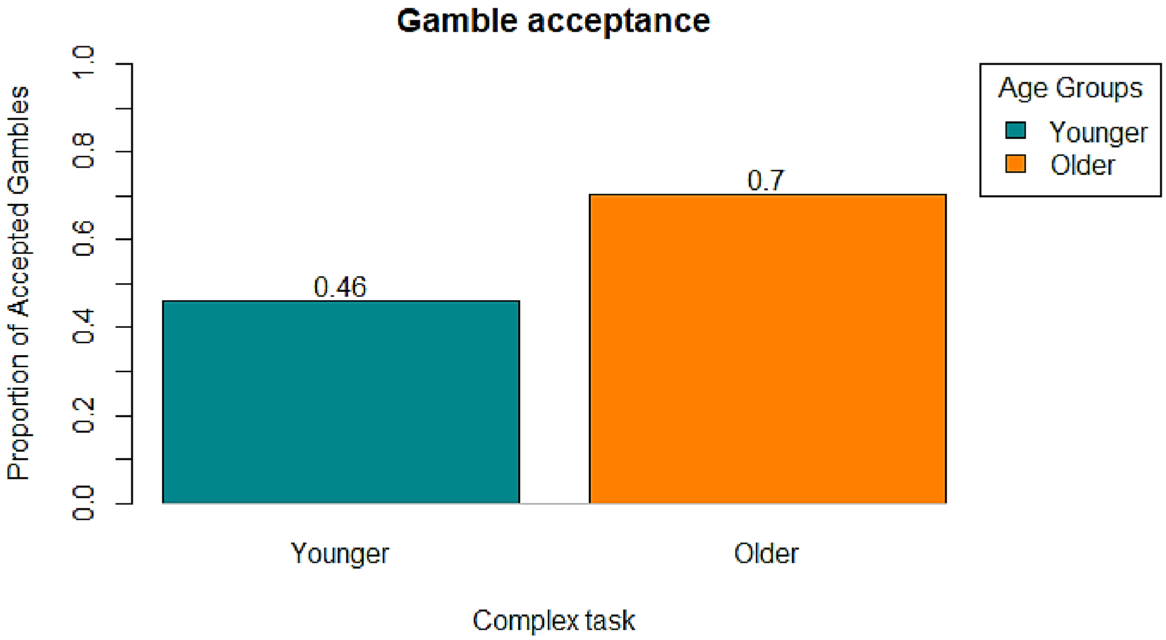

Figure 14. *Proportion of accepted gambles in the complex task by younger and older adults.*

We first conducted zero-order correlations to find the best predictors amongst risk preference and cognitive ability measures. Across the risk preference measures, the adjusted Dospert correlated most highly with gamble acceptance, *r* = 0.20, tied with the New Risk Scale, *r* = 0.20. As the adjusted Dospert would also be the largest correlating variable in the simplified task, we decided to include the adjusted Dospert as the risk preference measure for this analysis. Across cognitive measures, the Shortened Symmetry Span was most related to gamble acceptance, *r* = 0.28, with the other two measures having only negligible coefficients. Thus, the adjusted Dospert and Shortened Symmetry Span were chosen to be included in the mediation analysis on gamble acceptance in the complex task part.

We then proceeded with our planned mediation analysis on age differences in gamble acceptance. Firstly, gamble acceptance was regressed on age group to establish age differences in risk-taking, through linear regression. The results showed a significant difference between age groups in gamble acceptance, B = 0.24, $t(99) = 4.28$, $p < .001$, with older adults accepting more gambles than younger adults. Gamble acceptance was then regressed on the adjusted Dospert scale, which showed a significantly positive effect, B = 0.06, $t(99) = 1.99$, $p = .050$. When regressing the adjusted Dospert scale onto age group, the results showed no significant effect, indicating that older and younger adults did not differ in their self-reported risk preference towards financial risk. When exploring the model's cognitive mediator, the Shortened Symmetry Span, gamble acceptance was regressed on the Shortened Symmetry Span, which showed a significantly negative relationship between working memory and gamble acceptance, B = -0.02, $t(99) = -2.88$, $p = .005$. Then, regressing the Shortened Symmetry Span on age group, using a linear regression, findings showed that older adults scored significantly lower on the working memory measure compared to younger adults, B = -5.41, $t(99) = -9.45$, $p < .001$. We then tested whether the relationship between age group and gamble acceptance on the complex task was mediated by the adjusted Dospert and Shortened Symmetry Span through a multiple mediation model. The indirect effect of age group on gamble acceptance, through the adjusted Dospert scale and Shortened Symmetry Span, was not significant. Findings indicate that differences between age groups in gamble acceptance were not related to cognitive ability (or risk preference), thus disproving our hypothesis (see Figure 15).

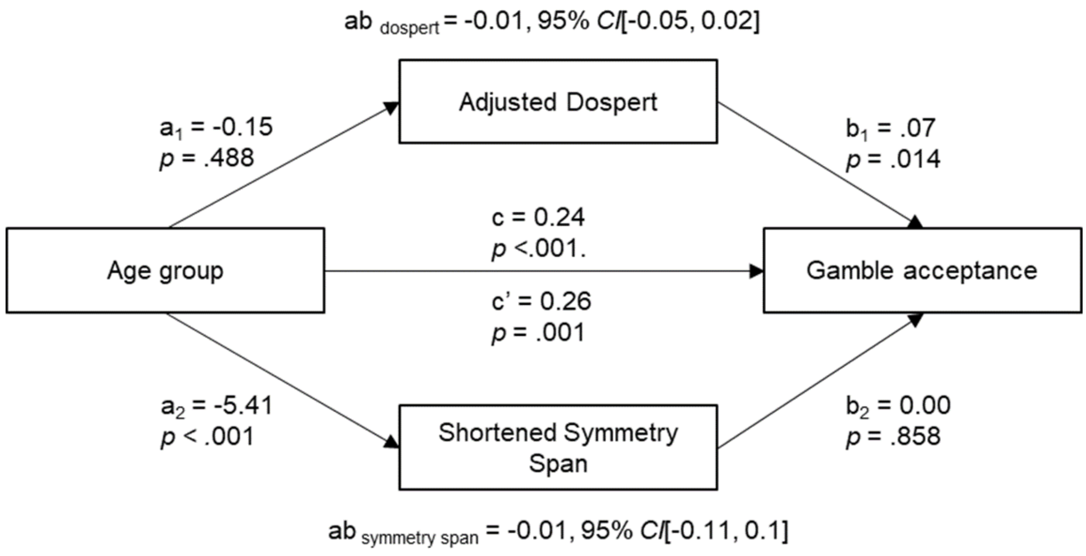

Figure 15. *Mediation analysis on gamble acceptance in the complex task, with age group as independent variable, with the adjusted Dospert and Shortened Symmetry Span as mediators.*

Simplified task. As the simplified task was designed to remove any cognitive strain, we expected that gamble acceptance on the simplified task part would solely reflect participants' risk preference. As such, we expected that older adults would accept fewer gambles, as they were hypothesized to be more risk averse compared to younger adults. Nevertheless, we observed that older adults accepted more gambles than younger adults (see Figure 16), though both groups accepted less gambles than in the complex task (in which younger adults accepted nearly half of gambles, and older adults seven out of 10 gambles).

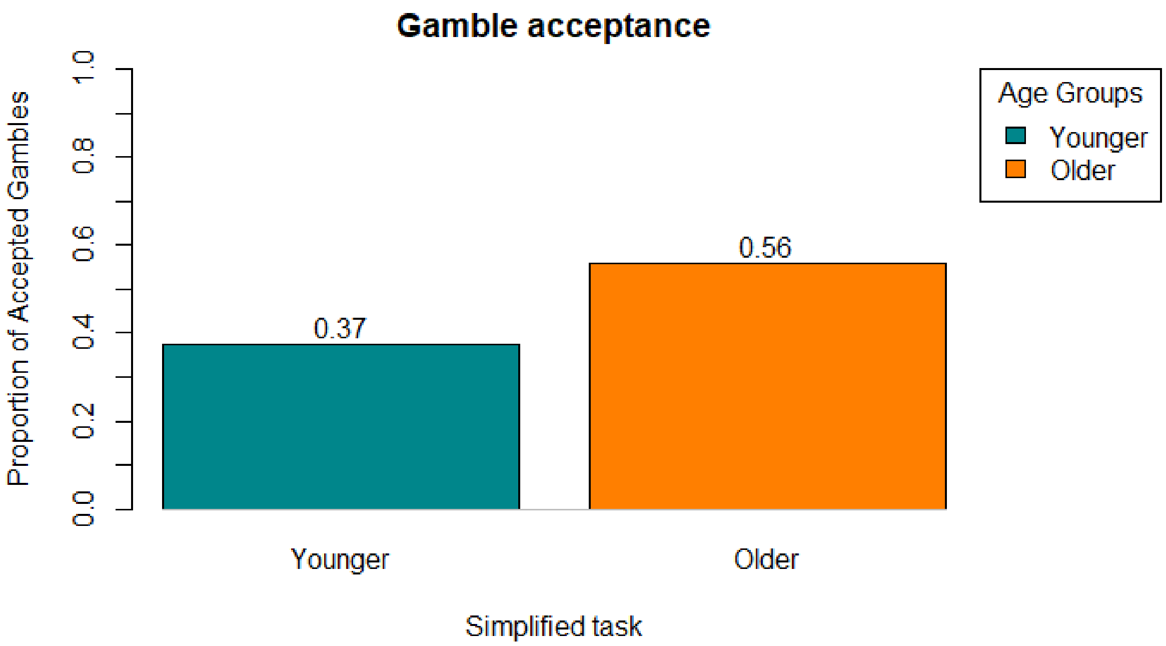

Figure 16. *Proportion of accepted gambles in the simplified task by younger and older adults.*

To find the best predictors of gamble acceptance amongst the risk preference and cognitive ability measures, we conducted zero-order correlations. Across risk preference measures, the adjusted Dospert was most highly correlated with gamble acceptance, *r* = 0.18, followed by new risk, *r* = 0.16. Among cognitive measures, the Shortened Symmetry Span was most related to gamble acceptance, *r* = -0.20, while numeracy and Digit Symbol Coding both had negligible coefficients. The adjusted Dospert and Shortened Symmetry Span, measuring working memory, were chosen to be included in the mediation analysis for the simplified task part.

We then proceeded with the mediation analysis. Firstly, gamble acceptance was regressed on age group to establish age differences in risk-taking, through linear regression. The results showed a significant difference between age groups in gamble acceptance, B = 0.18, *t*(99) = 3.30, *p* = .001, with older adults accepting more gambles than younger adults. Gamble acceptance was then regressed on the adjusted Dospert scale, which did not show a significant relationship between gamble acceptance and this measure of risk preference. When regressing the adjusted Dospert scale onto age group, the results also showed no significant relationship between age group and risk preference. When exploring the model's cognitive mediator, working memory, gamble acceptance was regressed on the Shortened Symmetry Span, which showed a significantly negative relationship between working memory and gamble acceptance, B = -0.01, $t(99) = -2.01$, $p = .047$. Regressing the Shortened Symmetry Span on age group, using a linear regression, showed that older adults scored significantly lower on the working memory measure compared to younger adults, B = -5.41, $t(99) = -9.45$, $p < .001$. We then tested whether the relationship between age group and gamble acceptance on the simplified task part was mediated by the adjusted Dospert and Shortened Symmetry Span, through a multiple mediation model. The indirect effect of age group on gamble acceptance, through the adjusted Dospert scale and Shortened Symmetry Span, was not significant (see Figure 17). The results suggest that differences between age groups in gamble acceptance were not related to age differences in risk preference (or cognitive ability), which is not in line with our expectations.

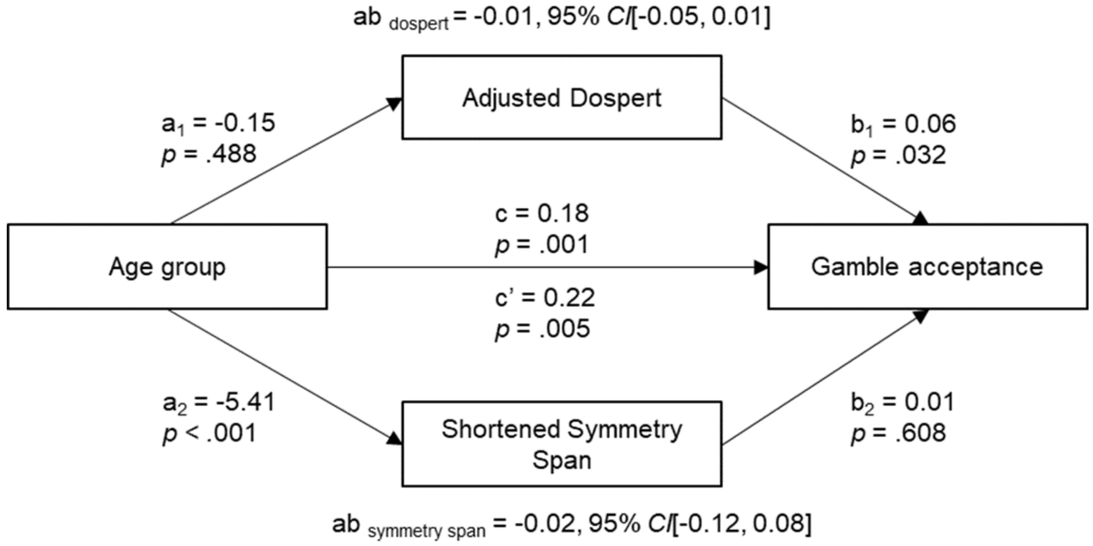

Figure 17. *Mediation analysis on gamble acceptance in the simplified task, with age group as independent variable, with the adjusted Dospert and Shortened Symmetry Span as mediators.*

3.4.3 Exploratory analysis

The Tangney Self-Control Scale and Barratt Impulsiveness Scale were included as additional variables of interest, as both self-control and impulsiveness have been found to be associated with risk-taking behaviour, especially concerning gambling behaviour. As such, we were interested in seeing whether these variables would mediate the relationship between age group and gamble acceptance.

Complex task

On the complex task, a similar approach to prior mediation analyses on gamble acceptance was taken. Firstly, a linear regression was run, with age group as independent variable and gamble acceptance as dependent variable. The results showed a significantly positive relationship between age group and gamble acceptance on the complex task, B = 0.24, $t(99) = 4.28$, $p < .001$. Following this, gamble acceptance was regressed on self-control, the first mediator, which showed no significant effect. When regressing self-control on age group, results showed that older adults reported significantly higher self-control than younger adults, B = 11.26, $t(99) = 3.23$, $p < .001$. When assessing the relationship between impulsiveness, the second mediator, and gamble acceptance in the complex task, the linear regression showed no significant relationship between the two variables. A similar pattern was present when regressing impulsiveness on age group, suggesting that older and younger adults did not differ in self-reported impulsiveness. Lastly, we ran a multiple mediation model on age group and gamble acceptance, with self-control and impulsiveness as mediators. Results showed that the indirect effect of age group on gamble acceptance was not significant (see Figure 18). This suggests that age differences in risk-taking on the complex task are not mediated by participants' self-control or impulsiveness.

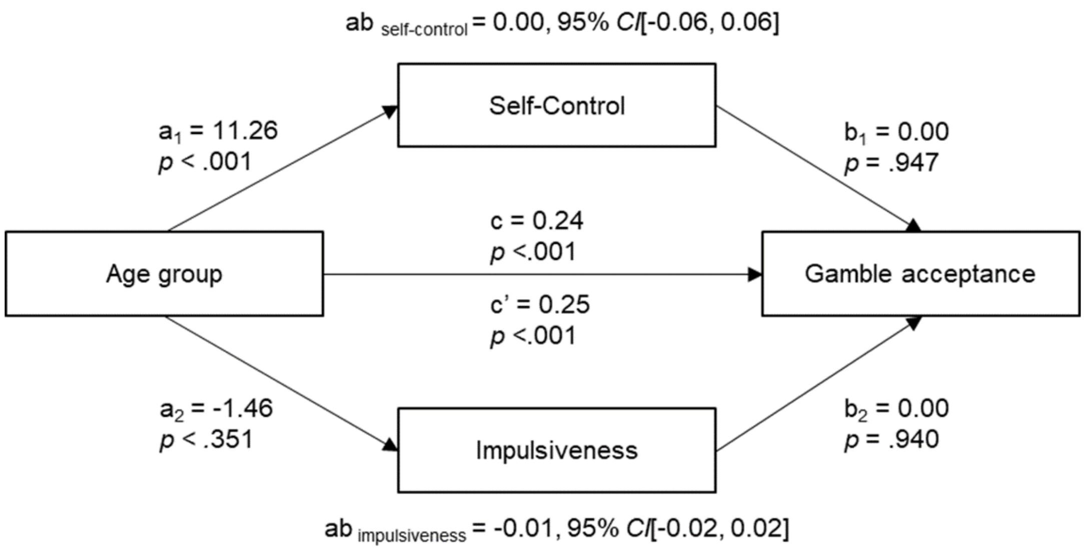

Figure 18. *Mediation analysis on estimation of correct chance in the complex task, with age group as independent variable, with self-control and impulsiveness as mediators.*

Simplified task

Similar to the prior mediation analyses on gamble acceptance, we first regressed gamble acceptance in the simplified task on age group, which showed that older adults accepted significantly more gambles, B = 0.18, $t(99) = 3.30$, $p = .001$. Following this, gamble acceptance on the simplified task was regressed on self-control, the first mediator, which was not significant. The following linear regression, in which self-control was regressed on age group, showed that older adults reported significantly higher self-control than younger adults, B = 11.26, $t(99) = 3.23$, $p < .001$. To assess the second mediator's relationship to the outcome variable, gamble acceptance in the simplified task was regressed on impulsiveness. This also showed to be non-significant. When assessing whether age groups differed in impulsiveness, the linear regression was also not significant, indicating no differences in self-reported impulsiveness between younger and older adults. A multiple mediation analysis was then used to assess whether the relationship between age group and gamble acceptance on the simplified task was mediated by self-control and impulsiveness. Using the *mediate* function from the Psych package, we used a bootstrapping approach (number of iterations = 500) to assess indirect mediation effects (see Figure 18) of self-control and impulsiveness. The indirect effect of age group on gamble acceptance was not significant (see Figure 19). Findings indicate that differences between age groups in gamble acceptance were not related to self-control or impulsiveness.

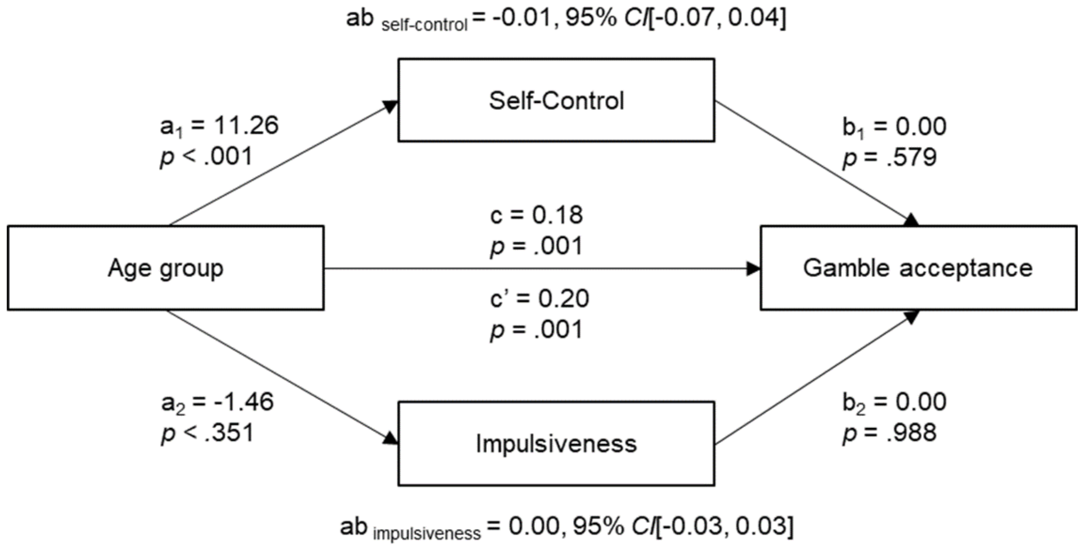

Figure 19. *Mediation analysis on estimation of correct chance in the simplified task, with age group as independent variable, with self-control and impulsiveness as mediators.*

3.5 Discussion

The main aim of this study was to further investigate the role of cognitive ability and risk preference in age differences in risk-taking, similar to study 1. In response to the findings of study 1, we designed a novel decision-making task consisting of two separate task types; one task that is cognitively straining and another with minimal cognitive ability involved. The behavioural task in study 1 had 10 gambles, for this task we included 20 gambles randomized across the two task types. This study also included multiple measures of cognitive ability and risk preference that would allow us to assess which would be the best predictor of task performance.

We hypothesized that older adults would be correct less often on the complex task because of the task's reliance on cognitive abilities that may decrease in older age (hypothesis 1). Older adults were indeed correct less often, and numerical ability significantly mediated the relationship of age group and correct estimation. On the simplified task, the task version in which participants counted the pre-filled box and entered values on the screen, older and younger adults did differ in their risk preference (older adults reported more risk-seeking), as well as working memory performance being negatively associated with older age, but there was no significant mediation by risk preference or cognitive ability on the relationship between age and correct estimation (hypothesis 2).

When looking at risk-taking behaviour, characterized as gamble acceptance, we again looked at the complex and simplified tasks separately. In the complex task, we anticipated that the higher demand on cognition would show in older adults taking more risk, and that their risk-taking would contrast with their reported risk preference (hypothesis 3). We found that older adults' gamble acceptance and reported risk preference did not align, but the disparity was not explained by cognitive ability. Participants' working memory was not related to gamble acceptance, nor did it mediate the age difference in gamble acceptance. In the simplified task, we expected that risk preference would mediate the relationship between age and risk-taking, as the task was designed to remove any cognitive strain (hypothesis 4). We found that older adults accepted more gambles on the simplified task, but age groups did not differ in their self-reported risk preference, and risk preference (or cognitive ability) did not mediate the relationship between age and gamble acceptance.

Overall, most of the findings discussed above were not as hypothesized, but many findings did align with prior research. We found that older adults correctly estimated probabilities less often compared to younger adults, as well as accepting more gambles. Though other behavioural tasks often do not explicitly require participants to estimate the chance of outcomes occurring (i.e. participants are not asked to convert chance to frequency), there is a similar pattern in comprehension. Mamerow et al. (2016) found that older adults accepted riskier options more often than younger adults in unequal trials, despite the lower expected value of the risky option, and reported that older adults took more risk than younger adults, which was likely due to difficulties in calculating the expected value of available outcomes. These findings were similar to the descriptive-only condition in the study by Hess et al. (2018), in which older adults were also correct less often.

Older and younger adults differed in numerical ability, with older adults having lower numerical abilities than younger adults. Consequently, numerical ability partially mediated the relationship between age and correct estimation of probability, as older adults also estimated probabilities correctly less often than younger adults. Numeracy was not found to mediate age differences in gamble acceptance. The mediating effect of numeracy was as predicted, as we expected that older and younger adult differences in risk comprehension would be explained by age-related decline in cognitive abilities. This finding was different from the findings on age differences in numeracy in study 1, as no difference between age groups were found in study 1. Despite the lack of age differences, numeracy was related to risk comprehension on the task in study 1 as well. Prior findings on age differences in numeracy have been mixed, with some studies finding a decrease in numerical ability in older adults (Bruine de Bruin et al., 2015; Delazer et al., 2013; Weller et al., 2013), and some studies finding no difference in numerical ability between age groups (Bruine de Bruin et al., 2017; Eberhardt et al., 2019; Weller et al., 2013).

Why age differences are more often observed in working memory and processing speed, but less in numerical ability, might be because fluid abilities (which encompass working memory and processing speed) are thought to be more sensitive to age-related changes (Li et al., 2013). Numeracy is related to general intelligence, but any damage or decline of non-numerical intelligence can be separate from numerical ability (Peters, 2012). For example, retired financial professionals with age-related decline in non-numerical memory maintained similar numerical memory to younger adults (Castel, 2007). As such, it might be that the mixed results concerning age differences in numeracy simply reflect differences between individuals regardless of any age-related decline. This would explain why some studies will find age differences in numerical ability, often using the same measure, and other studies do not.

In addition, older adults had both lower working memory, and processing speed, which fits prior literature on both abilities (Henninger et al., 2010; Salthouse, 1996; Salthouse & Craick, 2007). An explanation for why working memory and processing speed did not mediate the relationship between age and correct estimation or gamble acceptance on the complex task could be because the task types in this study do not rely heavily enough on cognitive ability for any effects to show. This is not uncommon; the Iowa Gambling Task is an example of a risk-taking task which is often thought to show age-related differences in performance due to age-related decline in cognitive abilities. However, many studies investigating this relationship also reported non-significant results, while studies that did find a relationship between task performance and cognitive ability reported small effect sizes (Toplak et al., 2010). According to Li et al. (2013), working memory is also more affected in complex tasks that require active processing. However, the complex task type in this study does not require participants to retain and recall large chunks of information. Instead, participants made calculations for each probability they estimated, and then moved on to estimating the next outcome probability (while their prior calculation is still visible), instead of having to retain and recall information to be able to complete trials. Processing speed is another ability in which strain is expressed in situations under time pressure and is more affected in complex tasks that require active processing (Li et al., 2013). Prior work has found that older adults often perform worse under tasks with time pressure (Mata et al., 2011), but the current task did not include time pressure, instead allowing participants to take as much time as needed. As such, any age differences in processing speed may not have affected older adults' task performance. An approach to address the current lack of mediation by processing speed and working memory would be to make the task more difficult in terms of time constraints, and by not providing a visual overview of prior answers (i.e. once participants have calculated and entered the number of balls for one type of outcome, to show a blank screen in which they calculate the next outcome, having to remember the outcome they calculated before).

Another reason why cognitive abilities do not mediate age differences in risk-taking might be because of the generally small age differences in description-based decisions. A meta-analysis by Mata et al. (2011) found that age differences in task performance were generally larger when it involved decisions based on experience compared to decisions based on description, with older adults generally taking more risk when making experience-based decisions. As participants are often given full information when making description-based decisions, age differences on these tasks may not be due to differences in cognitive ability, as the cognitive demand is lower compared to experience-based decisions, in which learning processes are often involved (Hess et al., 2018).

We also found age differences on some measures of risk preference. In the analyses involving correct estimation of probability, older adults reported lower willingness to take risk compared to younger adults on the General Risk Propensity Scale. This is similar to other studies on self-reported risk preference, which have been found to elicit risk-averse responses from older adults (Josef et al., 2016; Mamerow et al., 2016; Mata et al., 2016; Rolison et al., 2014). We also used the adjusted Dospert (Blais & Weber, 2006) by Rolison et al. (2019) and found no age differences in risk preference for financial risk-taking. This was the opposite of findings by Rolison et al. (2019), as older adults were less willing to take financial risk in their study.

Risk preference did not mediate the relationship between age and gamble acceptance. These findings were not as expected. However, these findings do add to a growing body of research that show a gap between self-reported risk preference and risk-taking on behavioural tasks when comparing older and younger adults' tendency to take risks. In this study, some of the self-reported risk preference measures showed a similar direction to risk-taking on the task, with those reporting more risk-seeking also accepting more gambles. However, the General Risk Propensity Scale and the New Risk Scale were not related to risk-taking behaviour on the task, whereas the adjusted Dospert was. A reason for this might be due to the difference in domain between the three measures. The adjusted Dospert had only financial items, while the other two scales items more closely related to general risk, with more diverse statements or scenarios beyond financial risk. Despite the relationship between the adjusted Dospert and risk-taking on the task, older and younger adults did not differ in risk preference, while older adults did take more risk on the task. Why this is so may be explained by differences in risk comprehension between younger and older adults. On the task, older adults correctly estimated gamble probabilities less often than younger adults in both task parts, but this difference was most pronounced on the complex task. In the complex task, participants had to calculate the probabilities themselves instead of counting the frequency of outcomes. When looking at the overall pattern of their estimations (see Figure 9), older adult estimations of win probability, when incorrect, were more likely to overestimate the chance to win, whereas loss probabilities were more likely to be underestimated. When looking at gamble acceptance on the complex task, older adults accepted more gambles than younger adults, effectively taking more risk. As such, it appears that misunderstanding of gamble probabilities, partially due to age differences in numerical ability, may explain why older adults reported being more risk averse than younger adults yet taking more risk on the task. Older adults' self-reported risk preference may not align with their task behaviour if there is a lack of comprehension of the risks involved, especially if the gamble's expected value is overestimated (i.e. by overestimating win probability and underestimating loss probability). Older adults may take more risk despite reporting being risk averse, if they do not fully understand the risks associated with the gamble, and if the gamble appears more profitable compared to its actual value.

This study also had its limitations. We used multiple measures of risk preference but not all measures demonstrated excellent internal consistency. The reliability of the Adjusted Dospert was initially insufficient, and was increased after an item was removed, but remained only barely satisfactory. The reliability of most other measures was sufficient (apart from the General Risk Propensity Scale, which showed good internal consistency). As such, interpreting findings of these measures must be done critically. When choosing the best predictor, all measures of risk preference and cognitive ability only had small to medium correlations to both outcome variables. Low, or non-existent, correlations between self-report measures appear common and indicate a problem when relating self-reported risk preference and performance on risk-taking tasks (Frey et al., 2017). In addition, due to an issue with the platform the self-report measures were conducted on, the self-report measures were not randomized. Lastly, in the simplified task part, participants were asked to count the number of coloured balls in the box for each outcome and report these. Due to its simplicity (designed to remove any cognitive strain), age differences were constricted due to a ceiling effect. Both groups were correct most of the time, with a small difference between groups.

To summarize, the study aimed to examine the role of cognitive ability and risk preference in age differences in risk-taking behaviour. We found that the relationship between age group and correct estimation of probability on the complex task was partially mediated by numerical ability, but not by risk preference. When assessing age differences in risk-taking, neither cognitive ability nor risk preference were significant mediators, across both tasks. This may be caused by a lower than required level in which cognition is required to complete the task, and due to the measurement gap between behavioural tasks and self-report measures. In conclusion, the study adds to a growing body of research on age difference in risk-taking and provides further information on the complexities of relaying self-report measures and behavioural measures, as well as the role of cognitive ability in age differences in risk-taking.

CHAPTER 4

Age differences in COVID-19 risk-taking, and the relationship with risk preference and numerical ability [1]

[1] This chapter has received in-principle acceptance and is due to be published at Royal Society Open Science.
Wolfe, K., Sirota, M., & Clarke, A. D. F. (in press). Age differences in COVID-19 risk-taking, and the relationship with risk preference and numerical ability. *Royal Society Open Science*.
https://osf.io/3nv56

4.1 Abstract

Aim. This study aimed to investigate age differences in risk-taking concerning the coronavirus pandemic, while disentangling the contribution of risk preference, objective risk, and numeracy. We tested i) whether older and younger adults differed in taking coronavirus-related health risks, ii) whether there are age differences in coronavirus risk, risk preference and numerical ability, and iii) whether these age differences are related to coronavirus risk-taking behaviour. **Method.** The study was observational, 469 participants reported their risk-taking behaviour measured as misalignment with government guidelines and advanced health measures. They also reported their risk perception, objective risk, risk preference towards health and safety risks, and their numerical ability using a numeracy scale. **Results.** Our findings show that age was significantly related to coronavirus risk-taking, with younger adults taking more risk, and that this was partly mediated by numeracy but not by objective risk or risk preference. Exploratory analyses suggest that there are differences between age groups in risk perception for self and others. **Conclusion.** Findings of this study may help us to better understand why age groups differ in their engagement concerning protective behaviours during a pandemic. This research contributes to the debate whether age differences in risk-taking occur due to decline in abilities or changes in risk preference.

4.2 Introduction

The new coronavirus (SARS-CoV-2; COVID-19) is a highly infectious disease that causes acute respiratory syndrome and has reached most countries around the world. On January 30th, 2020, the World Health Organization (WHO) declared the outbreak a public health emergency of international concern. According to European Centre for Disease Prevention and Control (ECDC), the global number of deaths on September 22nd, 2020, stands at 1,155,235 deaths, of which 44,896 deaths have been recorded in the United Kingdom[2]. The UK government announced a nationwide lockdown on March 23rd, and a series of measures to prevent the spread of the virus. Staying indoors as much as possible, keeping others at a safe distance, exercising outdoors only once a day, and washing hands often with antibacterial soap were measures the public was asked to adhere to in order to prevent further spreading of the virus and protect the National Health Service. Since then, restrictions and lockdown measures have been loosened, but infections are on the rise again, and the highest daily cases since May were reported on Monday 21st of September 2020[3].

Adherence to the government-mandated preventive measures is believed to be critical to curb the spread of the infection but there are individual differences in the extent people apply these preventive measures. Some UK citizens have openly protested the compulsory use of face masks in shops and public transport, with similar protests on mask usage in other countries such as Germany and the United States. A survey conducted on UK citizens during the first week of lockdown found that 60% of respondents reported following government guidelines completely, and

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[2] Since April 13th, 2021, the death toll stands at 2,936,916 deaths globally, of which 127,087 deaths in the UK (World Health Organisation, 2021).

[3] Since then, two further national lockdowns have been in place, as infections, hospitalizations and deaths have continued to increase (when restrictions are loosened).

6% reported following guidelines only half the time or less (“Life under lockdown: coronavirus in the UK”, 2020). Subsequently, a survey by University College London (Covid-19 Social Study, 2020), which includes cross-sectional data from over 10 weeks, showed that guideline adherence in their sample had decreased from 70% at the start of the survey to 50% at the end of May. However, this decline differed between age groups: while more than 6 out of 10 older adults reported following government guidelines entirely, only 4 out of 10 younger adults said to do the same. In studies on behaviour during prior epidemics, researchers found similar results; younger adults reported following guidelines less as well as perceiving less risk compared to their older counterparts, during the SARS epidemic in Canada in 2003 (Blendon et al., 2004). Additionally, a study on the 2009 influenza epidemic in The Netherlands found that older age was associated with higher intention to adopt protective measures (van der Weerd et al., 2011). Since not adhering to guidelines exposes the individual, as well as others, to risk, this behaviour can be considered a form of health-related risk-taking.

It is important to replicate and understand the nature of these age differences for theoretical and practical reasons. Firstly, from a theoretical perspective, investigating the contribution of risk perception, risk preference and numerical ability to age differences in risk-taking adds to a growing body of work on older age and risky decision-making. Older adults are generally considered to be more careful, especially when it comes to their health and safety. However, prior research on age differences and risk-taking has already shown that age-related risk-taking is highly dependent on context, such as framing, learning components, and whether materials are description- or experience-based (Frey et al., 2017; Liebherr et al., 2017; Mata et al., 2011). The current study adds to the existing research as it measures age differences concerning real-life risk during an unprecedented situation in our lifetime. Secondly, there are practical reasons to investigate age differences in risk-taking. With recent spikes in infections and the possibility of a second wave, it is vital to understand what factors play a role in guideline adherence. These findings could benefit risk communication during the remainder of the pandemic as well as after, as it highlights what areas communication should focus on. For instance, if low numerical ability is associated with lower guideline adherence, risk communication could be improved by limiting the use of large, complicated numbers or figures. In addition, if younger adults report a lower likelihood of following government guidelines, communication about the virus can be tailored and sent through channels more specific to that age group to convey the risk of coronavirus more clearly.

We considered four factors, known to differ between older and younger adults, that could account for the observed differences in risk taking between these age groups: objective risk for COVID-19 complications, risk perception, risk preference and numerical ability.

Since the start of the outbreak in December 2019, there have been over 40 million coronavirus infections, and over a million people worldwide have died[4]. To understand the workings of the virus, and identify who is most vulnerable, possible risk factors to COVID-19 are being investigated. Studies on patients with coronavirus in China, where the virus was first reported, report a multitude of risk factors. A meta-analysis by Wang et al. (2020) found that patients with comorbidities such as cardiovascular disease, hypertension, diabetes, and chronic obstructive pulmonary disease (COPD) were more likely to experience severe illness as a result of

[4] The count now stands at 130 million coronavirus infections, and nearly 3 million deaths (April 13th, 2021).

coronavirus infection. These findings are further supported by Zheng et al. (2020), who also found that respiratory illness was common among those with severe illness, and those who had died as a result of COVID-19. Studies on populations outside China found similar results, reporting that diabetes (Atkins et al., 2020; Grasselli et al., 2020; Tenforde et al., 2020; Williamson et al., 2020; Xu et al., 2020), cardiovascular disease (Sousa et al., 2020; Xu et al., 2020), and COPD (Atkins et al., 2020; Grasselli et al., 2020; Sousa et al., 2020; Xu et al., 2020) were risk factors for severe coronavirus complications.

In addition to comorbidities, several personal characteristics have been found to increase the chance of coronavirus complications. For example, men have a higher chance of experiencing severe symptoms or dying as a result of coronavirus than women (Atkins et al., 2020; Grasselli et al., 2020; Xu et al., 2020; Zheng et al., 2020). Ethnicity has also been found to impact the likelihood of complications (Atkins et al., 2020; Tenforde et al., 2020; Williamson et al., 2020). Price-Haywood et al. (2020) found that most patients who were hospitalized (76.9%) or died (70.6%) due to coronavirus complications were Black, despite only making up a little over a third of the study's Louisiana cohort. However, older age appears to be one of the largest risk factors of coronavirus complications and mortality (Atkins et al., 2020; Grasselli et al., 2020; Price-Haywood et al., 2020; Sousa et al., 2020; Tenforde et al., 2020; Williamson et al., 2020; Xu et al., 2020; Zheng et al., 2020), with one study reporting people aged 80 or over having a more than 20-fold-increased risk compared to 50–59-year-olds (Williamson et al., 2020). Those most likely to die from coronavirus are those of older age, especially if they are male and have comorbidities (Zheng et al., 2020).

In the months since the outbreak of the virus, it has been well-documented that the majority of younger adults experience mild symptoms, with only a small proportion needing hospitalization or having died as a result of coronavirus. However, older adults (aged 65 and older) make up the majority of hospitalizations and mortalities. This distinct difference in risk between age groups may (at least in part) explain differences in the adoption of preventive behaviours. It may be that younger adults are less inclined to adopt preventive behaviours as their chance of hospitalization or mortality are much lower than those of older adults.

In addition to objective risk, we also explored people's subjective perception of their risk. While objective risk is an indicator of how likely a negative outcome is to occur, people's perception of their risk can differ from their actual risk. An example of such dissonance was found by Katapodi et al. (2004) in their meta-analysis, in which younger women reported higher risk perception of breast cancer than older women, despite older age being an established risk factor for breast cancer. In the context of the current pandemic, risk perception may play a role in the adopting of preventative behaviours. Someone could view their risk of coronavirus as high, which then increases their likelihood to adhere to guidelines and minimize their chances of contracting the virus, despite their low objective risk. A recent study by Bruine de Bruin & Bennett (2020) found that those who perceived higher risks concerning coronavirus were more likely to adopt protective behaviours. These findings are similar to those of prior pandemics; van der Weert (2011) reported that only risk perception was associated with the intent to adopt protective measures during the influenza A (H1N1) pandemic in the Netherlands.

Risk perception may also explain differences in health behaviours between age groups. Prior research shows that older adults perceived more risk and were more cautious than younger adults concerning health-related activities as well as ethical activities (Bonem et al., 2015), and that self-reported risk perception in social, financial, and recreational domains increased with age (Rolison, 2019). A study on differences in COVID-19 risk perceptions by Bruine de Bruin (2020) found that older adults reported perceiving more risk of mortality if infected with COVID-19 but reported seeing less risk in getting infected or quarantined. These findings demonstrate the effect of people's subjective perception of risk on risk-taking behaviours, regardless of their objective risk. As such, this study will also examine people's perspective of their risk, in addition to objective risk, using exploratory analyses to do so.

Second, individual preferences towards risk can account for the age differences in risk-taking: people become more risk averse as they age. Risk preference can be defined as the degree to which an individual appears to avoid or seek out risky options or behaviours (Weber et al., 2002). Risk preference goes beyond merely risk-taking, which is the likelihood of engaging in risky behaviour, as it incorporates other factors such as the person's perception of risk as well as perceived benefit of the risky activity, and describes a more general disposition towards risk. Although one can have an overall risk preference, indicating that an individual is generally more or less comfortable with risk, there is evidence that risk preference also differs across domains such as health, social, and recreational risk (Josef et al., 2016; Rolison et al., 2014). Though risk preference is considered a stable psychological trait, it may change over time. Past studies have investigated the differences between younger and older adults in terms of risk perception, risk preference and risk-taking behaviour by means of self-reports or through risk-taking in an experimental lab setting. There is evidence that people become more risk averse as they age (Dohmen et al., 2017; Josef et al., 2016), though people's feelings towards risk may vary according to domain. Rolison et al. (2014) found that younger adults reported being more likely to take risks in the social domain, as well as health and safety, compared to older adults. Older adults were found to be more risk avoidant concerning health risks; they reported being less likely to undertake a health or safety risk, saw less benefit in these risks and reported higher risk perception than younger adults. These differences across domains are supported by Josef et al. (2016), who reported declines in financial, driving, health, social and recreational risk-taking in older age, with differing rates of decline. As following guidelines is key to preventing the spread of the virus, risk preferences could provide more information on why people differ in how strict they adhere to guidelines. It may be that those who choose not to follow guidelines completely, whether in part or not at all, have risk-seeking preferences concerning health. These individual differences in behaviour towards coronavirus may be (partly) explained by underlying, more stable personality traits concerning risk-taking.

Third, people’s numerical ability may explain the age differences in risk-taking. At its core, numeracy encompasses the ability to do simple arithmetic operations and compare numerical quantities. However, higher numerical abilities also include logical and quantitative reasoning, and understanding concepts such as fractions, percentages, probabilities and proportions (Reyna et al., 2009). Those with lower numerical ability have been found to experience difficulties in judging risks, reading graphs, and are more sensitive to framing effects (Peters, 2012; Reyna et al., 2009; Weller et al., 2013). When examining the role of numeracy within the context of health-related risk, Petrova et al. (2017) found that the effect of numeracy was a unique predictor to longer decision delays (i.e. time between symptom onset to decision to seek medical care), leading to significant increase in risk for death and serious disability. Participants with low numerical ability were four times more likely to delay critically needed medical treatment. Leiter et al. (2018) found that those with low numeracy skills made worse patient prognostic estimates (participants were given case studies), as well as selecting treatments ill-fitting with patient prognosis (e.g. selecting an aggressive treatment for a 90-year old man with 0% chance of survival or functional independence). Yamashita et al. (2018) investigated numeracy and preventative health behaviours and found that low numerical ability was associated with lower likelihood of dental check-ups in older adults. Additionally, Peters et al. (2014) found that lower numerical ability was associated with a lower willingness to take medication (participants were asked to calculate the likelihood of severe side effects prior to this, with information provided to them).

At this time, daily counts of infections and deaths are given in newspapers and official briefings to inform the public how the virus is spreading and the progress of containment. However, simply providing numbers does not equate to understanding. A recent survey among UK citizens found that more than half of the working-age population has the numeracy level expected of a primary school child (Ipsos Mori, 2019). In the past months, news websites and TV programs have been providing support in understanding what these numbers mean. In BBC's Coronavirus Special (Thomas, 2020), numbers and graphs were explained to the public, as well as other news outlets publishing articles explaining what the coronavirus numbers mean and how to interpret them (Blauw, 2020; "COVID-19: Making sense of all the numbers", 2020; Sanderson et al., 2020). The ability to comprehend these numbers and apply them to calculate a useful statistic may influence people's willingness to take risks. Some may find these numbers confusing or difficult and may make miscalculations, which may cause misconception about the virus' severity, and may influence behaviour towards limiting the spread of the virus. However, this may vary between age groups. Current findings on age differences in numerical ability differ; some research has found no age differences in numeracy (Bruine de Bruin et al., 2017; Eberhardt et al., 2019; Weller et al., 2013), while others have found that older age was associated with higher numerical abilities (Ipsos Mori, 2019), or the opposite (Bruine de Bruin et al., 2015; Delazer; 2013; Weller et al., 2013). As numbers and graphs have been an integral part of risk communication during the pandemic, it may prove vital to understand how people's numerical ability influences their health behaviours during this time.

4.2.1 The present research

As older adults are considered one of the groups most at risk for coronavirus, while younger adults are generally considered to be most risk-taking, it is important to understand how these two age groups differ in their approach to the current pandemic. These differences, if present, may stem from a contrast in risk of for coronavirus complications, their underlying preference towards risk, or their ability to process and transform the numerical information given to them. So far, surveys and studies have been conducted to explore how people have behaved during the pandemic, and how much they have stuck to guidelines. However, no study has investigated what underlying, more stable factors such as risk preference or numerical ability may explain age differences in health behaviours during the pandemic.

This study aimed to investigate how age differences in health-related risk-taking during the COVID-19 pandemic are related to objective risk, risk preference and numerical ability (see Figure 20). This has been addressed by use of an online survey that included items on people's behaviour concerning guidelines, their (objective) risk of severe consequences of COVID-19 infection, and questionnaires on risk preference and numeracy. We hypothesized the following outcomes:

H1: age. Older adults would report following guidelines more often than younger adults, which is reflected in a higher mean in guideline adherence.

H1: objective risk. Those at higher risk of coronavirus complications would be more likely to adhere to COVID-19 guidelines and implement health measures.

H1: risk preference. Those who are more risk averse towards health-related risk would be more likely to adhere to COVID-19 guidelines and implement health measures compared to those who are risk-seeking.

H1: numeracy. Those with higher numerical ability would be more likely to adhere to COVID-19 guidelines and implement health measures compared to those with lower numerical ability.

If H1: age was not confirmed, none of the H2 below would be tested, and we would continue continue with exploratory analyses instead. To test any H2, H1: age and any H1 matching the H2 had to be confirmed. For example, to test whether the effect of age on COVID-19 risk-taking is mediated by objective risk, both H1: age and H1: objective risk had to be confirmed to continue with H2: objective risk, as those hypotheses concern the relationship between these two variables and COVID-19 risk-taking.

H2: objective risk. COVID-19 objective risk would mediate the relationship between age and COVID risk-taking. Older adults would be at higher risk than younger adults, which in turn would lead them to take less risk than younger adults.

H2: risk preference. Risk preference would mediate the relationship between age and COVID-19 risk-taking. Older adults would report being more risk-averse towards health risks than younger adults and would take less risk relating to COVID-

19 due to this.

H2: numeracy. Numeracy would mediate the relationship between age and COVID-19 risk-taking. Older adults having lower numerical ability than younger adults would lead to them taking more risk related to COVID-19 than their younger counterparts.

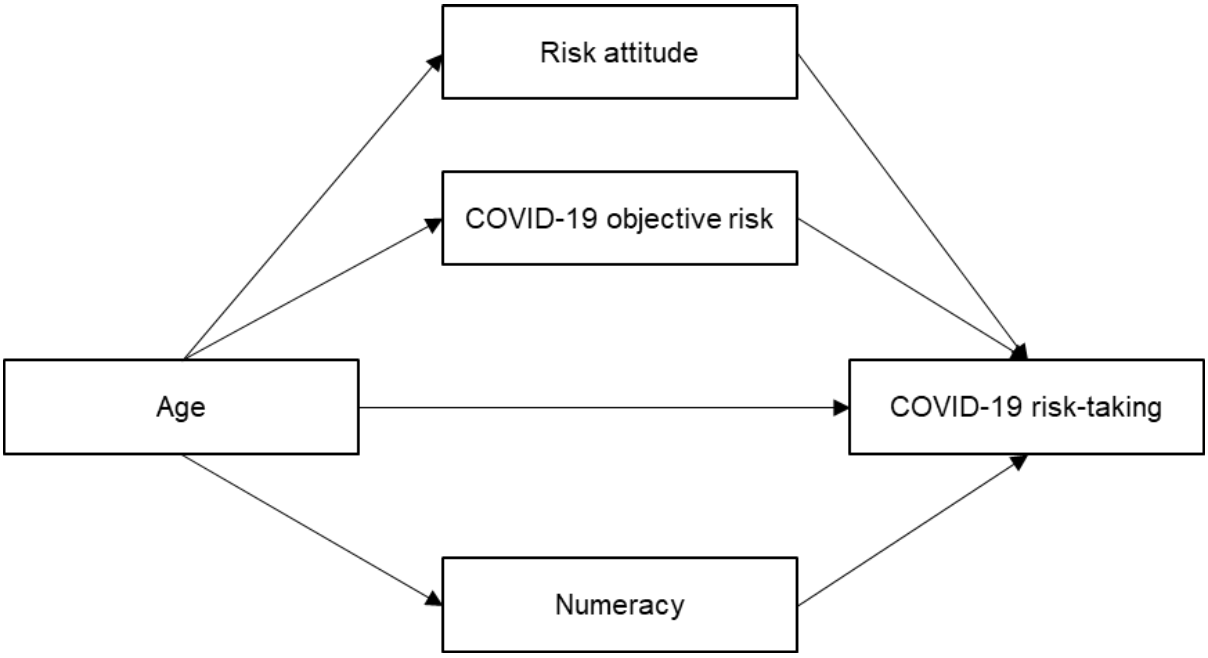

Figure 20. *A visual representation of planned multiple mediation analysis.*

4.3 Method

4.3.1 Participants

We conducted an a-priori power analysis using a simulation-based approach[5]. The direct effect of age group on risk-taking was set to -0.3, with the effects of age group on risk preference and numeracy also set to -0.3, and the effect of age group on objective risk set to 0.3. These three variables (risk preference, numeracy, and objective risk) were assumed to have an effect on risk-taking of 0.3 with the effects of objective risk and numeracy in the opposite direction to that of risk preference (i.e., y = 0.3 x risk preference - 0.3 x objective risk - 0.3 x numeracy). This allowed us to repeatedly simulate a dataset (500 times) for various sample sizes, for us to carry out the planned analysis. Based on these assumptions, and with $\alpha = .05$ and $1- \beta = .95$, a sample size of N=400 should suffice to verify all hypotheses.

Participants consisted of two age groups; the younger adults were aged between 18-35 years, and the older adult group were aged 65 years or older. Groups were of equal size, with a target n = 200 for each group. Participant recruitment was done via Prolific Academic, with participants being paid £1.42 for taking part, with an hourly rate of £5.01 per hour, upon completion of the study. Only participants who i) resided in England, ii) fit the age criteria (aged between 18 - 35 years and aged 65 years or older), and iii) had an approval rate of 90% were eligible to take part. We expected a 20% dropout rate (i.e. participants who have more than one measure incomplete. Therefore, we collected data from 480 participants (target n = 400, the expected dropout rate of 20% is equal to 80 participants) to obtain the analytical sample of n = 400.

[5] Materials relating to this paper, including the power analysis, can be accessed via the Open Science Framework, at https://osf.io/n5y8p/

4.3.2 Materials and procedure

The materials included in the survey were given in a random order and were randomized within materials as well as between. All participants were given the same materials. The survey did not allow participants to skip items, and one item designed as an attention check was also included. All variables included in the study can be found in Table 5. Materials can be found in the appendix or accessed via https://osf.io/n5y8p/

Table 5

Variables included in study

Dependent variable	Independent variable	Descriptive variable
COVID-19 Risk-taking	Age group	Trust in UK government
	COVID-19 Objective Risk	
	COVID-19 Risk perception	COVID-19 numbers usage
	Risk preference	
	Numeracy	

Participants were given a link to the survey via Prolific. In the study description, participants were told the general aim of the study and its prerequisites. Participants were told that they were not eligible to take part if they have been diagnosed with coronavirus. Those confirmed to have, or have had, coronavirus may approach the risks differently as it is widely assumed that antibodies will be present after recovery (for a period of time), and those cannot be infected again, or infect others. For this reason, people who have been confirmed to have (had) coronavirus were not included in the study. Participants were also not able to take part if they have been officially diagnosed with cognitive impairment, which was also communicated in the study description.

At the start of the survey, participants were given an information sheet with the details of the study, as well as a consent form. After providing consent, participants provided demographic information about themselves, including the county they reside in, education level, type of employment and annual household income. They also answered whether they believe they have, or have had, coronavirus, and if they have been officially diagnosed with cognitive impairment. These two items were included as screening items, in case participants did not read the study description on Prolific clearly. If participants answered yes to either of these, they were excluded from the analysis.

Following the demographic items, participants completed the Objective risk stratification tool (Jankowski et al., 2020) to estimate their objective risk for COVID-19 complications. The measure is an existing risk assessment measure, designed for workplace assessment of healthcare workers. The items concern established risk factors for COVID-19, such as ethnicity, age, diabetes, pulmonary illness and cardiovascular disease. Answers to items may differ in the weight of their scoring, depending on the severity of the outlined illness. For instance, having diabetes type 1 or 2 without complications is scored as 1, while diabetes type 1 or 2 with complications (i.e. acute or chronic health problems, such as eye, foot and kidney problems) results in a score of 2, as diabetes complications increase the risk of severe disadvantageous outcomes of COVID-19 infection. Participants' total score is the sum of weights across all items, with higher scores indicating higher risk of severe complications resulting from COVID-19 infection.

Participants then completed 10 items concerning their behaviour in the current pandemic (e.g. "Thoroughly cleaning my hands with hand sanitiser"). Six of the items reflect current government guidelines, such as wearing a mask on public transport and frequent handwashing, and four items concern common recommendations such as utilizing contact-free deliveries (Coronavirus (COVID-19): Accessing food and essential supplies, 2020), not touching your face with unwashed hands and the use of hand sanitizer (Social distancing: what you need to do, 2020). Though these recommendations are not part of official guidelines, the government has often communicated their importance to the public, as they help prevent infection of coronavirus. Participants were instructed, "The next set of questions will present a number of activities and behaviours. You will be asked to report how often you have engaged in these behaviours in the last 2 weeks. Your answers will be fully anonymous, so please answer honestly.". They were then asked to rate how often they engaged in the outlined behaviours on a 5-point Likert scale ranging from 1 to 5 (1 = Never, 2 = Mostly not, 3 = Sometimes, 4 = Mostly yes, 5 = Always). The option "not applicable" is also included. Participants' risk-taking score is the arithmetic mean across all items, with scores near 5 indicating higher levels of risk-taking. As this is a novel measure, and has been designed for this study, we established its reliability using Cronbach's alpha. If we find that the reliability is unsatisfactory (a Cronbach's alpha below 0.7), we will remove items in iterative ways until we reach satisfactory reliability, or use only one item (the item that is the best indicator of COVID-19 risk-taking).

Participants then expressed their perception of COVID-19 risk by completing the COVID-19 Risk Perception Scale (Dryhurst et al., 2020). This 6-item scale is measured as an index, covering affective, cognitive, and temporal-spatial dimensions to provide a holistic measure of risk perception. The COVID-19 Risk Perception Scale includes items concerning participants' perceived seriousness of the COVID-19 pandemic, perceived likelihood of contracting the virus themselves over the next 6 months, perceived likelihood of their family and friends catching the virus, and their present level of worry about the virus. Three of the six items are measured on a 5-point Likert Scale (1 = strongly disagree, 5 strongly agree), the other 3 items are measured on a 7-point Likert Scale (2 items: 1 = not at all likely, 7 = very likely, and 1 item: 1 = not at all worried, 7 = very worried). The pooled Cronbach's alpha across countries was α = .72, the alpha for the United Kingdom sample was α = .80. Participants' risk perception is calculated by transforming the arithmetic mean for the 6 items to a value on a scale from 0 to 1, where higher scores nearest to 1 indicate higher risk perception.

Participants' risk preference was measured by the 30-item Dospert (Blais & Weber, 2006). This version is shorter than the original Dospert (Weber et al., 2002), and applicable to a broader range of ages, cultures, and educational levels. Participants responded to six items concerning health and safety (e.g. "Driving a car without a seatbelt"), with identical items for each of the three subscales of the questionnaire (i.e. likelihood, expected benefits, and risk perceptions). In the Likelihood scale, participants rated the likelihood that they would engage in the given behaviours on a seven-point Likert scale from 1 to 7 (1 = Extremely unlikely, 7 = Extremely likely). In the Benefit scale, participants rated the benefits that they perceived in the outlined behaviours on a seven-point Likert scale from 1 to 7 (1 = No benefits at all, 7 = Great benefits). On the third scale, Risk Perception, participants rated the risk they perceived in undertaking the outlined behaviours on a seven-point Likert scale from 1 to 7 (1 = Not at all risky, 7 = Extremely risky). The internal consistency estimates (i.e., Cronbach's alphas) associated with the 30- item Dospert risk-taking scale ranged from α = .71 to α = .86, and those associated with the risk-perception scale, from α =.74 to α = .83 (Blais & Weber, 2006). Participants' scores on the risk preference questionnaire were calculated by means of regressing the subscales Risk Benefit and Risk Perception on Likelihood for each participant, using corresponding scores from each item which provided a (positive or negative) coefficient for each participant, in line with the recommended approach on the Dospert scoring sheet.

Participants' numerical ability was measured by the Objective Numeracy Scale (Lipkus et al., 2001). Participants were given 11 items for which they were required to calculate the answer to a mathematical problem (e.g. "Imagine that we rolled a fair, six-sided die 1,000 times. Out of 1,000 rolls, how many times do you think the die would come up even (2, 4, or 6)?"). Participants were instructed "You will be shown 11 numerical questions. Each question will require you to calculate your answer. Each question has a few words in front of the answer line to indicate what type of answer is required. You may not use a calculator or any other means of help, except paper and pen for calculations (if needed)". The reliability of the Objective Numeracy Scale, including the additional 3 items by Schwartz et al. (1997), was found by Lipkus et al. (2001) to be α = 0.78. Weller et al. (2013) reported a Cronbach's alpha of α = .76, and Thomson and Oppenheimer (2016) found a Cronbach's alpha of α = .72. Participants' numerical ability score consists of the sum of correct items, ranging from 0 to 11, with scores close to 11 indicating higher numerical ability.

Lastly, participants were given two items on trust in the UK government's policies on coronavirus and how often they checked numbers on coronavirus deaths. These items are descriptive variables and were not included in the planned analyses.

4.3.3 Data processing

Participant data was eliminated if they answered "*yes*" to one or more screening questions at the beginning of the survey (i.e. if participants have been diagnosed with coronavirus or cognitive impairment). Additionally, participants who answered the attention check incorrectly were also excluded. Missing data was treated as follows: if a small number of items (i.e. maximum of 2 items) within a measure had not been completed, the participant's score was calculated over the remaining items (i.e. instead of an average over 8 items, it would be an average over 6 items). If more than 2 items of a specific measure had not been completed the measure was not included. If more than one measure was incomplete, the participant's data was removed entirely. Reliability of the scales used in the study was measured using Cronbach's alpha. If the reliability was unsatisfactory (an alpha below 0.7), we removed the items in iterative ways until we reached satisfactory reliability, or we used a single item instead (the item that is shown to be the best indicator of this measure).

4.3.4 Planned analysis

We planned to conduct regression analyses as part of a multiple mediation analysis. For the primary hypotheses (H1) we used four simple linear regressions with COVID-19 risk-taking as the dependent variable, and age group, COVID-19 objective risk, risk preference and numeracy as predictors. If there was no effect of age group in the primary hypothesis (H1: age), we would stop the planned analysis and run exploratory analyses instead. If any of those primary hypotheses were confirmed, together with age (i.e. we established a direct relationship or a relationship between mediator and dependent variable) we continued analyses to establish the required relationship between age and mediators (risk preference, objective risk and numeracy), to then test the outlined H2 hypotheses in a multiple mediation model.

4.3.5 Exploratory analyses

The overall expectation was that younger and older adults differed in their risk-taking, and that this could be explained by age-related differences in objective risk, risk preference and numerical ability. However, as age differences were an important part of our hypotheses, we proposed exploratory analyses if no age differences were found. We were also interested in further exploring why people differ in their COVID-19 risk-taking and explored the relationship between risk-taking and other possible factors, including additional mediation analyses. One analysis assessed the relationship between age and risk-taking, using people's perception of their risk as a mediator. We then further explored this relationship using risk perception for self and for others as mediators. Another analysis applied a mediation model including numeracy and risk-taking, with risk perception as a mediator.

4.4 Results

4.4.1 Participants

We recruited 489 participants, out of which 20 did not fulfil the pre-registered inclusion criteria (7 participants had incomplete responses, 3 participants reported mild cognitive impairment, 6 participants had received a confirmation of coronavirus infection, 2 participants failed the attention check, and 2 participants reported an age outside of the set limits for younger and older adult age groups. Some participants failed multiple exclusion criteria; they are only counted in their initial exclusion criteria). The final analytical sample was 469 and consisted of 232 younger adults (49.6% identified as female, $M_{younger}$ = 26.52, *SD* = 5.16 years), and 237 older adults (49.8% identified as female, M_{older} = 69.38, *SD* = 3.85 years). In the younger adult group, the majority listed a University undergraduate degree as their highest completed education (39.6%; followed by A-levels, 30%), that they were employed full time (49.6%; followed by student, 25.4%), and had a household income of £30.001 to £50.000 (33.6%; followed by £10.001 to £30.000, 27.6%). Most younger adults reported that they had not been infected with COVID-19 (56%; followed by "I'm not sure, but I don't think so", 26.7%). In the older adult group, the majority also listed a University undergraduate as their highest completed education (29.5%; followed by both secondary school and A-levels, 25.7%), that they were currently retired (78.1%; followed by employed part-time, 10.1%), and reported a household income of £10.001 to £30.000 (43.8%; followed by £30.001 to £50.000, 31.6%). Most older adults also reported that they had not been infected with COVID-19 (79.7%; followed by "I'm not sure, but I don't think so", 26.2%).

4.4.2 Analysis

To assess the reliability of the self-report measures, Cronbach's alphas were computed using the *ltm* package (version 1.1-1), and item total correlations were computed using the *multilevel* package (version 2.6). To choose the best predictors of risk preference and cognitive ability, zero-order correlations were run using the *ggcorrplot* package (version 0.1.3). For the mediation analyses, we used simple linear regressions to establish relationships between variables and used the *mediate* function from the *Psych* package (version 2.0.12) to run the mediation analyses. Each mediation model was run using a bootstrapping approach, with indirect effects computed for 500 bootstrapped samples.

4.4.3 Composite variables

Objective risk

We measured objective risk by means of a series of health questions, with values given in accordance to the severity of the condition's contribution to COVID-19 risk. No changes to the planned approach were made.

Risk preference

The reliability of the risk preference scale was a Cronbach's alpha of $\alpha = 0.72$ (across all subscales), indicating sufficient reliability. Risk preference scores were calculated in line with the provided scoring manual, in which the effect of risk perception and benefit were used to predict likelihood using linear regression. Risk preference is then defined as the regression coefficient for risk perception in this model. A negative coefficient indicates a risk averse preference, whereas a positive coefficient indicates a risk seeking preference, with a larger value (both positive or negative) indicating the extent of risk seeking or risk averse preferences.

Numeracy

We planned to sum the number of correct answers to 11 numerical problems However, the scale's reliability was not sufficient, Cronbach's alpha of α = 0.68. As this was below our stated cut-off, we first removed items in iterative ways, which did not improve the reliability of the scale. We then used an item-total correlation test to establish which of the 11 items was the best suited item of the scale. The third item of the scale correlated most highly with the total score and has been used as an indicator of numeracy for the planned analysis.

Risk-taking

The scale's reliability was satisfactory, with an alpha of α = 0.73. As such, risk-taking was measured as planned, through 10 items on preventative behaviours related to COVID-19.

4.4.4 Deviation from preregistration

Our Stage 1 registered report with preregistered hypotheses and methods can be found at https://osf.io/n5y8p/. Here, we report three minor deviations from our preregistered approach (see Table 6).

Table 6

Overview of deviations from preregistration in attention checks, COVID-19 risk-taking and objective risk.

Measure	**Type of deviation**
Attention check	We preregistered 2 attention checks in the study. Unfortunately, one of the attention checks was accidentally removed (as it was included with a replaced measure) in the last revision round.
COVID-19 risk-taking	We originally included the item “meeting in groups larger than 6 people” but changed this to “meeting indoors with people who are not in your household or bubble”, due to the second lockdown in November 2020. This change was approved by the editor on November 10th, 2020.
Objective risk	The objective measure of risk required to ask about participants sex at birth. However, our item measured their gender. To mitigate this confusion, we cross-checked our measured variable with our set requirements for participation in the Prolific Academic database (which included sex at birth).

4.4.5 Confirmatory tests of hypotheses

Age differences in COVID-19 risk-taking (Hypothesis 1a)

We hypothesized that older adults would be less inclined to take risks than younger adults. Overall, we observed that our participants were not risk-taking, since their mean score was close to the lowest possible value of 1 (see Table 7). Nevertheless, we observed that younger people reported that they took more risks than older adults (see Table 7). Examining the differences at the individual item level, we can see that these were notable for each item with the exception of two items with flooring effects (masks wearing in the shops and public transport) and touching the face item (see Figure 21). To test our hypothesis, we used a simple linear regression, which revealed that age group significantly negatively predicted risk-taking, B = -0.17, $t(467)= -3.77$, $p < .001$. Thus, we confirmed our hypothesis that older adults took less risk than younger adults.

Table 7

Descriptive statistics on risk-taking, objective risk and risk-preference in younger and older adults.

Measures	Mean and standard deviation		
	Overall	Younger adults	Older adults
COVID-19 risk-taking	1.92(0.49)	2.01 (0.51)	1.84 (0.46)
Objective risk	2.54 (2.05)	1.04 (0.94)	4.00 (1.76)
Risk preference	-0.47 (0.71)	-0.50 (0.72)	-0.43 (0.70)

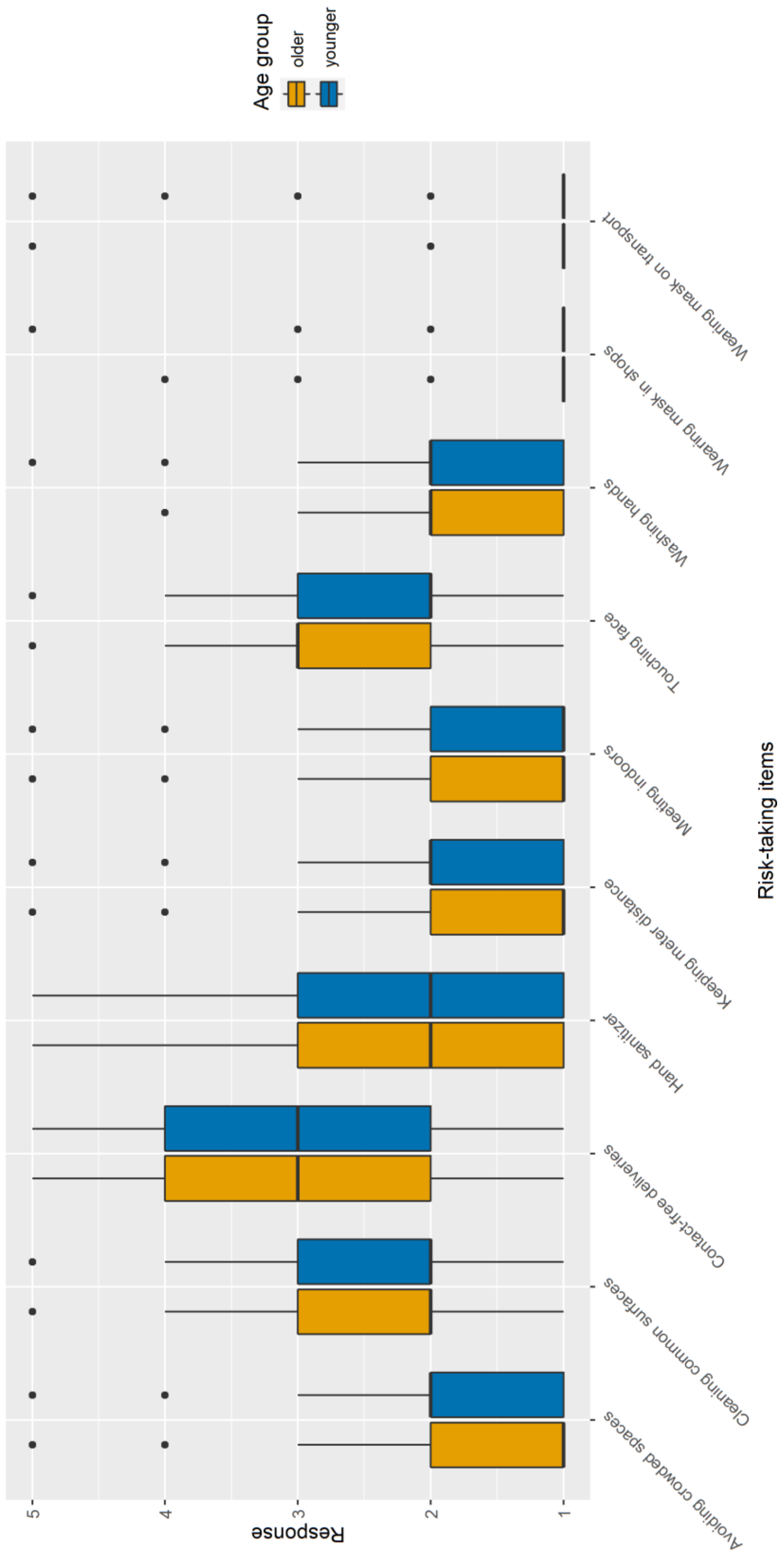

Figure 21. *The distribution of all 10 items of the COVID-19 risk-taking scale, with separate distributions for older and younger adults.*

Objective risk and risk-taking (Hypothesis 1b)

We hypothesized that participants with higher scores in objective risk of experiencing severe illness would be less likely to take coronavirus-related risk than those with lower objective risk. As expected, the mean objective risk was lower for younger adults than older adults (see Table 7). Objective risk was correlated most highly with age group, other correlations were of negligible effect size (see Table 8). To test our hypothesis, we used a simple linear regression, which revealed that objective risk significantly negatively predicted risk-taking, B = -0.03, $t(467) = -2.36$, $p = .019$. Thus, we confirmed our hypothesis that those with higher objective risk took less risky behaviour than those with lower objective risk.

Table 8. *Zero-order correlations between COVID19 risk-taking, age group, objective risk, numeracy, and risk preference.*

Measure	1	2	3	4	5
1. COVID19 risk-taking					
2. Age group	$r = -0.17$ $p < .001$				
3. Objective risk	$r = -0.1$ $p = .019$	$r = 0.72$ $p < .001$			
4. Risk preference	$r = -0.01$ $p = .864$	$r = 0.05$ $p = .284$	$r = 0.05$ $p = .331$		
5. Numeracy	$r = 0.21$ $p < .001$	$r = -0.13$ $p = .007$	$r = -0.05$ $p = .382$	$r = -0.05$ $p = .268$	

Note. $N = 469$; all correlations are Pearson product-moment correlations, except of the point-biserial correlations with numeracy.

Risk preference and risk-taking (Hypothesis 1c)

We hypothesized that those reporting a risk-seeking preference towards health and safety risk would be more likely to take coronavirus-related risk, versus a person with a risk averse preference towards health and safety risk. Overall, we observed that both younger and older adults reported being relatively risk-averse, as both group means were negative (see Table 7). Correlations of risk preference with other variables were very small (see Table 8). To test our hypothesis, we used a simple linear regression, which showed that risk preference did not significantly predict risk-taking, B = -0.01, $t(439) = -0.17$, $p = .865$. Thus, we disconfirmed our hypothesis about the positive relationship between risk-seeking preference and risk-taking.

Numeracy and risk-taking (Hypothesis 1d)

We hypothesized that those with lower numerical ability would be more likely to take coronavirus-related risk. Most participants answered the item correctly, with 62% of participants having given the correct answer. Younger adults were correct more often, with 69% compared to 57% of older adults. There was a small correlation between the numeracy item and risk-taking, other correlations were of minor size (see Table 8). To test our hypothesis, we used a simple linear regression, which showed that numeracy positively predicted risk-taking, B = 0.22, $t(467) = 4.69$, $p < .001$. Participants with higher numerical abilities reported taking more risk (i.e. adopting fewer preventative measures) than those with lower numerical abilities (see Figure 22). The findings did not confirm our hypothesis, as we expected a significant relationship between numeracy and risk-taking but in the opposite direction. For better comparison with the results of other literature, we ran identical analysis with the full 11-item scale. We found that the analysis yielded a similar outcome for this hypothesis, B = 0.05, $t(467) = 4.26$, $p < .001$.

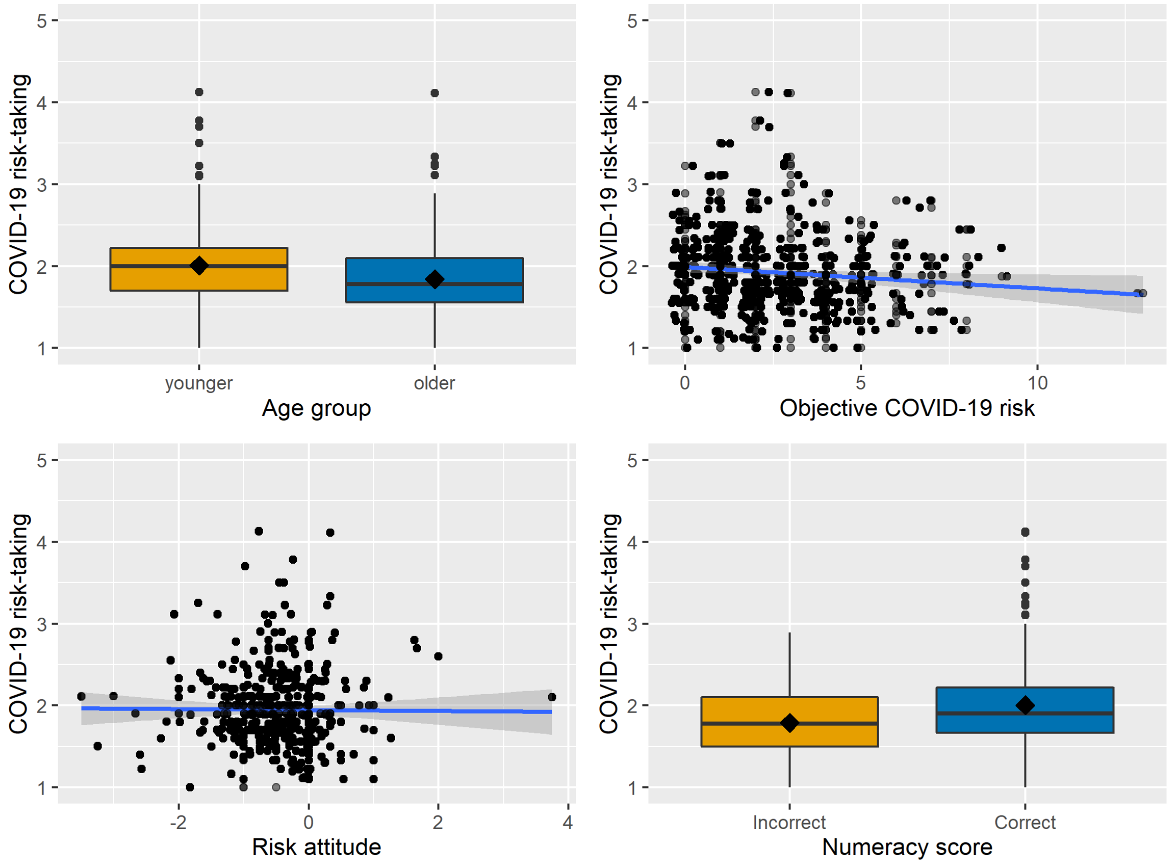

Figure 22. *The relationships between COVID-19 risk-taking and age group, objective risk, risk preference, and numeracy.*

Note. Both the distribution of age group and numeracy are displayed as box plots as these are dichotomous variables. Each boxplot has a line indicating the median risk-taking score, and a diamond shape representing the mean risk-taking score for that age group, or numeracy response. Objective risk and risk preference are displayed as scatterplots, with risk-taking on the y axis, and objective risk or risk preference scores on the x axis. Each scatterplot also includes a regression line indicating the direction of the relationship between risk-taking and objective risk and risk preference.

Age differences in objective risk and risk-taking (Hypothesis 2a)

We hypothesized that older people would be at higher risk of coronavirus complications, resulting in older adults taking less coronavirus related risk than younger adults. The mean objective risk was lower for younger adults than older adults (see Table 7). We first tested our hypothesis of a relationship between age group and objective risk, using linear regression, which revealed that age group significantly predicted objective risk, B = 2.95, $t(467) = 22.50$, $p < .001$. We then tested whether the relationship between age group and risk-taking was mediated by objective risk through multiple linear regression, which also included numeracy as a mediator (Hypothesis 2c). The results showed that objective risk no longer significantly predicted risk-taking. We tested the significance of this indirect effect using a mediation model with objective risk and numeracy as mediators (see Figure 23). The results of the analysis indicated that the indirect effect of age group on coronavirus risk-taking through objective risk was not significant, thus not confirming our hypothesis.

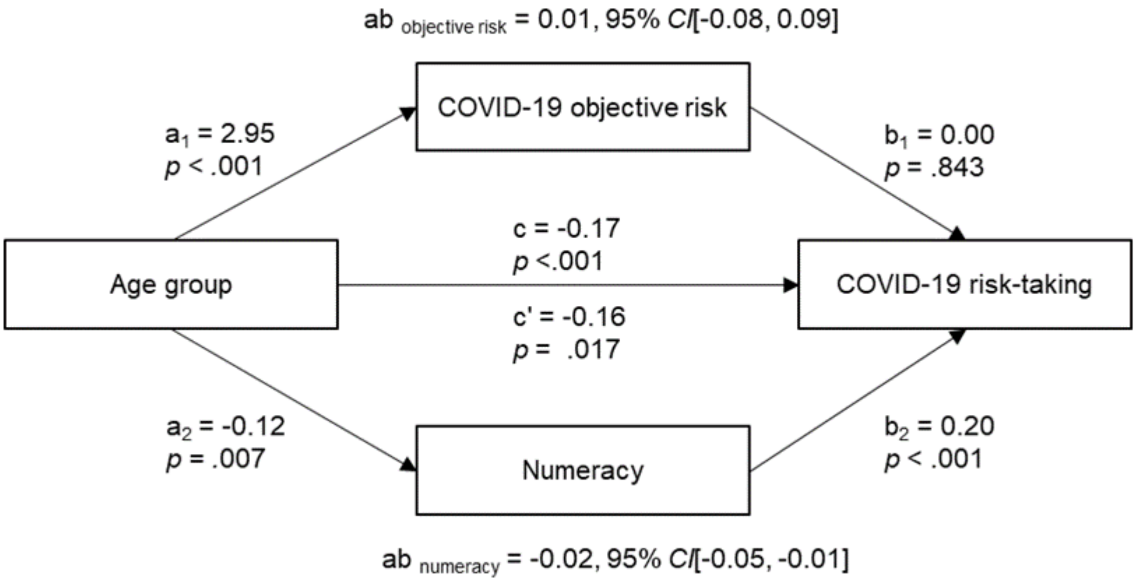

Figure 23. *Mediation analysis on COVID-19 risk-taking, with age group as independent variable, objective risk and numeracy as mediators.*

Note. The *a* path coefficient from independent variable to mediator, *b* path coefficient from mediator to dependent variable, *ab* path coefficient from independent variable to dependent variable via mediator (indirect effect), *c'* path coefficient from independent variable to dependent variable (direct effect), *c* path coefficient from independent variable to dependent variable (total effect). The reported confidence intervals represent 95% bootstrapped confidence intervals.

Age differences in numeracy and risk-taking (Hypothesis 2c)

We hypothesized that numeracy would mediate the relationship between age and COVID-19 risk-taking, expecting lower numerical ability in older adults. To test whether there were age differences in numeracy, we used a simple linear regression, which revealed that older age significantly negatively predicted numeracy, B = -0.12, $t(467) = -2.70$, $p = .007$. We then tested our hypothesis that numeracy would mediate the relationship between age group and risk-taking by using a multiple linear regression, which showed that numeracy significantly predicted risk-taking. We then tested the significance of this indirect effect using a mediation model with objective risk and numeracy as mediators (see Figure 23). The analysis demonstrated a significant indirect effect of age group on coronavirus risk-taking through numeracy, $ab_{\text{numeracy}} = -0.02$, 95% $CI[-0.05, -0.01]$, indicating partial mediation. The findings confirmed our hypothesis.

Again, for better comparison with the literature, we also re-ran the same analyses with the full 11-item scale. We found no age difference in numeracy, nor did numeracy mediate the relationship between age group and coronavirus risk-taking in the mediation model.

4.3.6 Exploratory analyses

In this section, we conducted three sets of exploratory analyses that were not listed as in the planned analysis. First, we focused on subjective risk perception. We were interested in how risk perception is linked with the adoption of preventative measures, and whether this differed between age groups, numerical ability, and types of risk perception (i.e. for self and others). Second, we explored the role of the measured variables played in predicting two types of COVID-19 risk-taking indicators: enforced and unenforced indicators. Some indicators of risk-taking were enforced (i.e. fines or warnings were given to citizens for failing to adhere to preventative behaviours), such as meeting indoors and wearing a facemask, while others were merely recommended such as using hand sanitizer. Third, we included two questions on whether people often checked COVID-19 numbers, such as hospitalizations and deaths, and whether they were dissatisfied with the UK government's coronavirus approach.

Mediation model with numeracy and risk-taking, with risk perception as a mediator.

First, COVID risk-taking was regressed on numeracy and risk perception separately, using a simple linear regression for both. Numeracy was found to positively predict risk-taking, B = 0.22, $t(467) = 4.69$, $p < .001$, while higher risk perception led to less risk-taking, B = -1.10, $t(467) = -9.18$, $p < .001$. Using a simple linear regression, risk perception was then regressed on numeracy. Results showed that numeracy did not significantly predict risk perception, B = -0.00, $t(467) = -0.21$, $p = .84$. The mediation model with numeracy, risk-taking, and risk perception did not have a significant indirect effect, *ab* = 0.00, 95% *CI*[-0.03, 0.04], suggesting that risk perception did not mediate the relationship between numeracy and risk-taking.

Mediation model with age group and risk-taking, with risk perception as a mediator.

We reran the mediation model tested in the planned analysis section but replaced objective risk with subjectively perceived risk to account for the significant relationship between age and risk-taking, B = -0.17, $t(467)$, $p < .001$. Even though higher risk perception significantly negatively predicted risk-taking, B = -1.10, $t(467) = -9.18$, $p < .001$, age group did not significantly predict risk perception, B = -0.02, $t(467) = -1.35$, $p = .180$. We then ran a mediation model to test the significance of this indirect effect. The results of the mediation model suggest that there is no significant indirect effect of age group on risk-taking through risk perception, *ab* = 0.02, 95% *CI*[-0.01, 0.06].

Perception of risk for self and risk for others

The risk perception scale included questions that assessed COVID-19 perception more generally (e.g. "Getting sick with the coronavirus/COVID-19 can be serious"), as well as questions that focused on personal risk of COVID-19 and the risk of others. Older and younger adults may not differ when accounting for all items, but they may differ in personal risk and others' risk. We therefore calculated means for personal and others' risk (Figure 24). Relationships between each type of risk perception and risk-taking differed according to age group (Figure 25). The plots again show visual differences between older and younger adults in terms of risk perception and risk-taking. Due to this, we decided to run two additional analyses using perception of personal risk, perception of others' risk, and COVID-19 risk-taking.

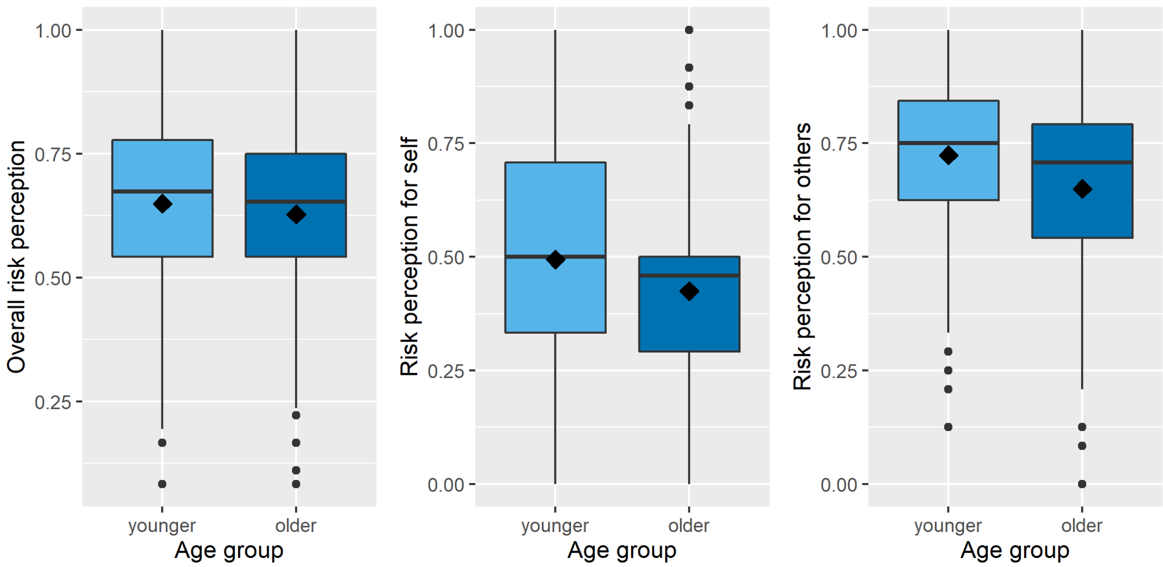

Figure 24. *Age differences in risk perception overall decomposed in perception of own risk and perception of others' risk.*

Note. From left to right: overall risk perception, risk for self, and risk for others. The lines in the middle of the boxplots indicate the median risk perception, the diamond within the boxplot represents the mean risk perception for that specific age group.

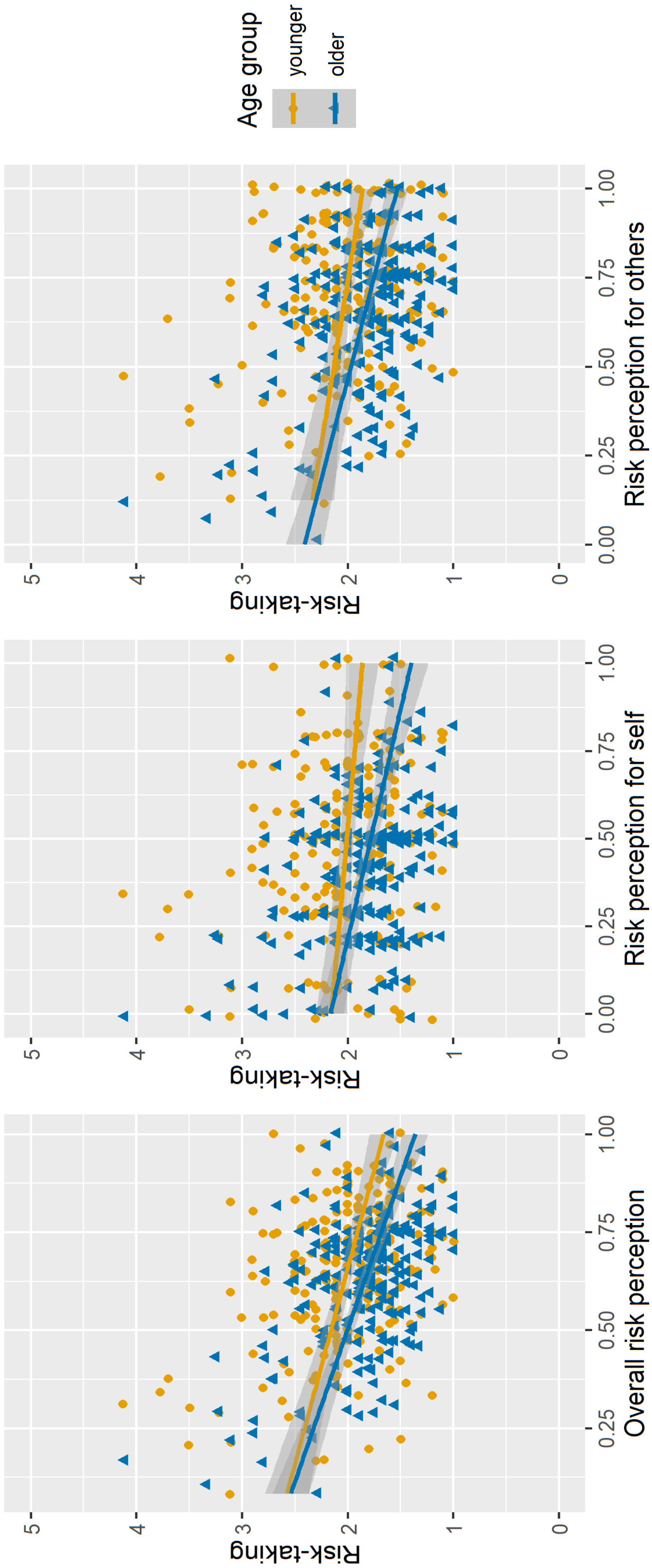

Figure 25. *Three scatter plots on risk-taking and its relationship with risk perception and age group.*

Mediation model with age group and risk-taking, with risk perception of self as a mediator. A simple linear regression on age group and risk-taking showed a significant difference in risk-taking across the two age groups, B = -0.17, *t*(467), *p* < .001, with older adults reporting less risk-taking. We then used a simple linear regression, regression risk-taking onto perception of personal risk. The results suggested that perception of risk for self significantly negatively predicted risk-taking, B = -0.43, *t*(467) = -4.33 *p* < .001. We then regressed risk perception for self on age group, and found age differences in risk perception, B = -0.07, *t*(467) = -3.36, *p* < .001, with older adults reported a lower perception of personal risk. Following this, we ran a multiple mediation analysis with age group and risk perception for self as predictors of risk-taking. Both age group, B = -0.20*,* *t*(467) = -4.60, *p* < *.*001, and personal risk perception, B = -0.50, *t*(467) = -5.08, *p* < .001, remained significant predictors of risk-taking. We then checked for significant mediation effects using a bootstrapping approach, with age group, risk-taking and risk perception of self. Results suggested a significant indirect effect, *ab* = 0.03, 95% *CI*[0.01, 0.06], indicating that risk perception for self partially mediated the relationship between age group and coronavirus-related risk-taking.

Mediation model with age group and risk-taking, with risk perception of others as a mediator. We first regressed risk-taking on both age group and on perception of others' risk, using a simple linear regression, as part of the first step of the mediation analysis. Both age group, B = -0.17, *t*(467)= -3.77, *p* < .001, and perception of others' risk, B = -0.63, *t*(467) = -5.88, *p* < .001, significantly negatively predicted risk-taking. We then used a simple linear regression to regress perception of others' risk on age group. The results indicated that age group negatively predicted perception of others' risk, B = -0.07, *t(*467) = -3.94, *p* < .001. We then proceeded to the mediation analysis. First, we used a multiple linear regression with age group and perception of others' risk as predictors of risk-taking, and found that both age group, B = -0.22, $t(467) = -5.12$, $p < .001$, and perception of others' risk, B = -0.72, $t(467) = -6.86$, $p < .001$, were significant. We then tested for mediation effects using a mediation model with risk perception of others as a mediator for the relationship between age group and risk-taking. The model's indirect effect was significant, $ab = 0.05$, 95% *CI*[0.02, 0.09], suggesting that risk perception for others partly mediates the relationship between age group and coronavirus risk-taking.

Enforced and unenforced preventative measures

In our planned analysis, we found that objective risk was related to adopting more preventive measures (i.e. taking less coronavirus-related risk). However, some of the preventative measures included in this study are more enforced (e.g. wearing facemask on the bus, meeting indoors) and some are simply unenforced recommendations (e.g. cleaning thoroughly, using hand sanitizer). There may be a difference between these two types of measures. To further explore this, we ran two additional analyses on enforced and unenforced preventative measures.

Mediation model with age group, risk-taking of enforced guidelines, and objective risk as a mediator. We first regressed this subset of risk-taking items onto age group and objective risk separately, as we have done in prior analyses. Results of two simple linear analyses that suggest both age group, B= -0.21, $t(467) = -5.12$, $p < .001$, and objective risk, B= -0.04, $t(467) = -3.81$, $p < .001$, are negatively related to coronavirus-related risk-taking, when only including enforced measures. Following this, we used a simple linear analysis to investigate age differences in objective risk. Age group significantly positively predicted objective risk, B= 2.95, *t*(467) = 22.5, *p* < .001. We then ran a multiple linear regression, which showed the effect of objective risk on risk-taking disappearing, while age group was still significantly related to risk-taking with only enforced measures, B= -0.20, *t*(467) = -3.38, *p* < .001. Using a bootstrapping approach to test for mediating effects, the results suggest that the indirect effect of age group on risk-taking (only enforced measures) through objective risk is not significant, *ab* = -0.01, 95% *CI*[-0.09, 0.07].

Mediation model with age group, risk-taking of non-enforced guidelines, and objective risk as a mediator. We then looked at non-enforced measures (e.g. handwashing, thoroughly cleaning common surfaces). Using two simple linear regressions, we regressed risk-taking (only non-enforced guidelines) onto age group and objective risk separately. Results suggested that only age was negatively related to risk-taking in non-enforced measures, B= -0.17, *t*(467) = -3.02, *p* = .003. This suggests that there is no difference between those at lower and higher risk in their adoption of non-enforced preventative measures, but that older adults are more likely to adopt these measures than younger adults.

Coronavirus numbers and dissatisfaction with UK coronavirus approach

Lastly, we examined how often people reported checking coronavirus numbers (i.e. numbers of infection, hospitalisation and deaths relating to coronavirus) and dissatisfaction with UK COVID-19 policies. Checking coronavirus numbers was presented as a statement, with values closer to 1 indicating a higher level of agreement (see Figure 26). An independent sample-test on checking coronavirus numbers showed age differences between groups, *t*(464.79) = 3.32, *p* < .001, with older adults more often reporting that they regularly checked numbers (M_{older} = 2.98) compared to younger adults ($M_{younger}$ = 3.53). When looking at dissatisfaction with the UK's coronavirus approach, an independent sample-test with age group and coronavirus approach showed age differences between groups, $t(457.93) = 4.37$, $p < .001$, with younger adults reporting higher dissatisfaction with the UK government's coronavirus approach ($M_{younger} = 4.94$) than older adults ($M_{older} = 4.33$).

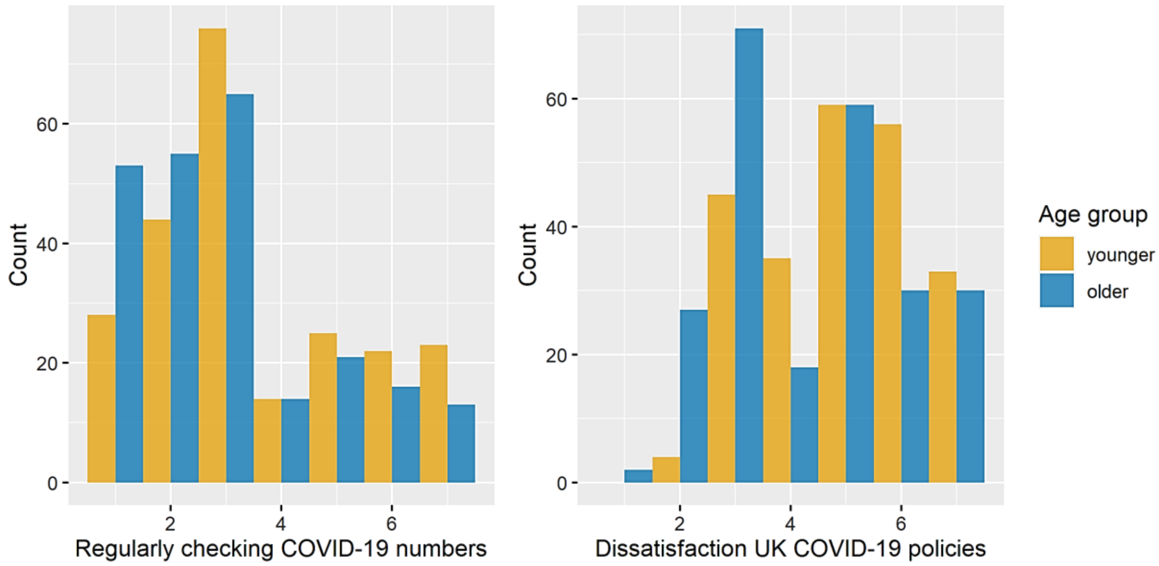

Figure 26. *Dissatisfaction over UK COVID-19 policies (left) and regularly checking COVID numbers (right), separated by age group.*

Note. On the x axis, participants' choice options are displayed, the y axis displays the number of participants who chose the specific options. For dissatisfaction over UK COVID-19 policies (left), the options ranged from 1 ("Extremely satisfied") to 7 ("Extremely dissatisfied"). For regularly checking COVID numbers (right), the options ranged from 1 ("Strongly agree") to 7("Strongly disagree").

Overall, the results suggest that age group, objective risk and numerical ability were all significant predictors of coronavirus-related risk-taking. When included together in a mediation model, the effect of objective risk disappeared, but numeracy partially mediated the relationship between age group and risk-taking. In the exploratory analyses, we found that people's risk perception of COVID-19 was not related to their numerical skills, and that though risk perception was significantly related to risk-taking, overall risk perception did not differ between the age groups. However, when only looking at items that reflected personal risk or risk for others, age groups did differ, with younger adults reported perceiving more risk for themselves as well as others, compared to older adults. We also found that those at higher objective risk were more likely to adopt the enforced preventative measures (e.g. wearing a facemask) but this effect disappeared once objective risk and age group were both included in the model. However, objective risk was not associated with unenforced recommended behaviours such as handwashing or using hand sanitizer, unlike enforced preventative behaviours.

4.5 Discussion

The current COVID-19 pandemic has been a major health risk, claiming 2,936,916 lives worldwide, 127,087 of those lives in the United Kingdom at the time of writing this discussion (April 2021). It is essential to understand the underlying mechanisms of the adoption of protective behaviours to prevent further illness and mortality. We tested the assumption that younger adults take more risk than older adults, while testing three possible explanations for such a difference: differences in objective risk, risk preference and numeracy. The adoption of preventative measures differed between older and younger adults, with younger adults adopting preventative measures less often. While numeracy partly mediated the relationship between age group and risk-taking, objective risk and risk perception did not. In the exploratory section, we also looked at differences in enforced behaviours (e.g. mask wearing), and recommendations (e.g. using hand sanitizer). Though both groups reported adopting the unenforced behaviours less often, older adults adopted them more frequently than younger adults. The same observation was true of the enforced behaviours, where older adults adopted those measures more frequently. This is in line with other findings on the adoption of preventative measures across age groups, in which younger adults were less likely to implement preventative measures (Atchison et al., 2021; Bruine de Bruin & Bennett, 2020; Coroiu et al., 2020; Fancourt et al., 2020; Machida et al., 2020; Park et al., 2020; Roozenbeek et al., 2020).

Why these age groups differ in the coronavirus-related risk they take could be due to the difference in risk of coronavirus complications. That younger adults are less at risk of coronavirus complications has often been communicated through the media (Bazelon, 2020) and government briefings. In the UK, the NHS only lists those aged 70 or older at moderate risk (National Health Service, 2021). In addition, mortality rates provided by the UK government suggest that the proportion of coronavirus-related deaths of people aged between 15 and 44 years accounts for 1 percent of deaths, while the mortality of those aged 65 or older are close to three quarters of total as deaths. The large differences of risk in terms of hospitalization and death as a result of coronavirus infection may lead to younger adults taking more risk by not adopting preventative measures as often, as it is less likely that they will experience serious health-related consequences.

Another possible reason for this finding may be differences in financial status and work environments. Financial concerns, such the loss of current job security or income, are an often-reported concern for younger adults (Fancourt et al., 2020; Park et al., 2020). In the current study, half of those aged between 18 and 35 reported working full-time. The UK government has asked citizens to work from home when possible but has equally allowed companies to decide whether employees are needed on location. Unlike the older age group, who largely reported being retired, it may be that the younger adult group are not able to consistently avoid crowded spaces, such as offices, public transport, schools, or supermarkets, and are unable to consistently socially distance with at least 1 meter between themselves and others at all times. However, it is important to note that age differences in risk-taking were small, and both groups reported relatively low risk-taking.

Risk preference showed no relationship to adopting preventative measures in the study. The Dospert (Blais & Weber, 2006) is a measure of risk preference in which people are asked whether they would engage in risky activities, as well as the benefit and risk they see in those activities. Items in the questionnaire are hypothetical situations, such as taking a ride in a taxi without a seatbelt. Though the negative consequences of those hypothetical situations can be severe, they are more everyday situations, in contrast to the current coronavirus pandemic. In addition, the coronavirus-related preventative measures in this study were communicated by the government and many of these measures are enforced, such as wearing a face mask on public transport. It may be that the risk preference items are too distinct from the non-hypothetical risk posed by coronavirus to explain preventative behaviours during the pandemic. For future research, it could be beneficial to include a risk preference measure that more closely resembles the decisions or behaviours people experience during an international health crisis such as COVID-19.

Objective risk was found to be significantly related to COVID-19 risk-taking, which was in line with our expectations. However, when closer examining enforced guidelines (such as mask wearing) and recommendations (such as using hand sanitizer) we found that those at higher objective risk were more inclined to adopt measures that were enforced guidelines, but not measures that were recommendations. The recommendation items were also hygiene-related, such as cleaning common surfaces with disinfectant and washing hands for at least 20 seconds. Prior research has found that hygiene-related measures were adopted least of all preventative measures (Machida et al., 2020), which seems to be the case in this study as well, overall and when considering objective risk. Other studies, such as the COVID-19 Social Study (Fancourt et al., 2020), reported that those at higher objective risk did not adopt preventative measures more often than those at low risk of coronavirus-related complications (Roozenbeek et al., 2020; Sobkow et al., 2020). Further research is needed to investigate why those at higher risk do not appear to adopt unenforced preventative measures more often than those at low risk.

Numerical abilities were a significant predictor of COVID-19 related risk-taking, with those having higher numerical ability taking more coronavirus risk. This finding was the opposite of what we expected, as prior research has found that low numeracy was related to poorer health outcomes and decisions (Leiter et al., 2018; Peters et al., 2014; Petrova et al., 2017; Yamashita et al., 2018). When looking at numeracy and COVID-19 health behaviours specifically, other studies found that numeracy was not significantly related to adopting preventative measures (Roozenbeek et al., 2020; Sobkow et al., 2020). We also found that older adults had lower numeracy. This finding is not surprising, as there have been other studies in which older adults had lower numerical abilities (Bruine de Bruin et al., 2015; Delazer; 2013; Låg et al., 2014; Weller et al., 2013).

Risk perception was a significant predictor of adopting preventative measures, which is in line with previous findings (Bruine de Bruin, 2020; Dryhurst et al., 2020).

Despite older adults taking less risk (i.e. they adopted more preventative measures), there were no age differences in COVID-19 risk perception. However, when only examining items on personal risk and risk of others, younger adults reported perceiving more risk for both themselves and for others such as family and friends. As such, it is likely that other factors, beyond those included in this study, are involved in why younger adults adopted preventative measures less despite their high perception of risk. As stated previously, this may be due to differences in circumstances associated with this age group such as work environment or their well-being. According to the Office of National Statistics (2020), younger adults reported that they felt lonely more often than those aged 60 years and over, as well as reporting that COVID-19 had affected their work through reductions in hours worked and concerns about health and safety at work. A quarter of those young adults reported concerns on the impact of COVID-19 on their well-being. Other studies found similar findings, including older adults reporting less concern about their finances and mental well-being compared to younger adults (Bruine de Bruin, 2020; Fancourt et al., 2020; Li & Wang, 2020). Despite the high perception of risk for themselves and others, it may be that younger adults' perception of other stressors, such as their mental well-being or finances, drives these age differences in coronavirus-related risk-taking, despite younger adults' higher risk perception for themselves and others.

The exploratory analyses highlight several interesting findings, such as the effect of age group on risk perception and COVID-19 protective behaviours. Initially, risk perception did not seem to differ between age groups. However, when exploring perception of personal risk and risk for others, younger adults appeared to perceive more risk for themselves and for others, compared to other adults. In addition, when separating COVID-19 preventative measures by enforced measures and unenforced recommendations, those at higher risk of coronavirus complications seemingly adopted enforced behaviours more often, but not unenforced recommendations such as handwashing. Future studies should explore which other variables underlie age differences in COVID-related risk-taking, and why those at higher risk of COVID-19 consequences are similar in adopting unenforced recommendations to those at objectively lower risk of COVID-19 complications.

Limitations

Of course, this study is not without its limitations. Firstly, adoption of preventative behaviours was self-reported, real-life behaviour may differ from participants' self-reported behaviour due to social-desirability bias. Secondly, some of the items were designed with generalizability in mind, such as “avoiding crowded spaces", as being too specific could make it difficult to answer or the item would be not applicable. This also had its limitations. For instance, it is not possible to determine whether participants indicated that they are not avoiding crowded spaces due to a lack of concern, or whether that is due to a lack of possibility to do so (e.g. public transport to work). Lastly, although we found significant relationships that explained differences in adopting preventative measures, it is likely that additional factors exist beyond those included in the study, and we suggest that future research explores these further.

Conclusion

We aimed to further the understanding of whether age differences in COVID-19 risk-taking, characterized by the adoption of preventative measures, are related to risk preference, numeracy, objective risk, and COVID-19 risk perception. As COVID-19 is predicted to be present for the foreseeable future, we will have to rely on preventative measures such as social distancing to keep ourselves and others safe. Understanding what factors play a role in adopting preventative measures, and whether these mechanisms differ across age groups is crucial to prevent further illness and mortality.

CHAPTER 5

GENERAL DISCUSSION

5.1 Overview

Across adulthood, people face increasingly more impactful and high-risk decisions, such as medical interventions. Decisions on medical treatment and interventions are often made in older age, as older adults are more likely to have multiple chronic conditions and health-related accidents. These kinds of decisions are often complex, offering multiple treatments with varying outcomes and side effects. As such, understanding how ageing affects risky decision-making is essential.

Generally, older adults are widely assumed to be risk-averse and therefore prefer to avoid any risk-taking. However, research on age differences in risk-taking has mixed findings. In some studies, older adults took more risk, in other studies they took less risk, and some studies found no age differences in risk-taking at all. The conflicting findings may be explained by the measures used to assess risk-taking across adulthood, and to what extent cognitive abilities are involved in decision-making on these measures. Self-report measures are often used to gauge a person's risk preference, asking participants to imagine a hypothetical scenario of risk or respond to a given statement on risk or on themselves. Alternatively, behavioural tasks are used to measure risk-taking behaviour, and risk-taking behaviour is assumed to reflect a person's underlying preference towards risk (i.e. whether they are risk averse or risk-seeking individuals). Behavioural tasks often measure risk-taking through lotteries, sure versus risky options, or other financial incentivized scenarios of risk. These behavioural tasks often rely more heavily on cognitive abilities, as people must be able to compare options, learn on the task to be able to avoid or take more risk, or calculate expected values of outcomes. Some cognitive abilities required to make optimal decisions on these tasks are known to be sensitive to age-related decline. As such, age-related decline of cognitive abilities may interfere with older adults' decision-making on behavioural tasks and may lead to unintentional risk-taking. As such, age differences in risk-taking may not be due to age differences in their underlying risk preference but could be due to age differences in cognitive ability instead.

The studies reported in this thesis have explored the role of cognitive ability and risk preference in age differences in risk-taking behaviour across different scenarios and with various methods. The first two studies have investigated risk-taking on behavioural tasks with financial incentives, similar to existing behavioural tasks, but were adjusted to specifically investigate the role of cognitive ability and risk preference. Initially, in response to the findings of the first two studies, a third study was designed that examined age differences in road risk, with an adapted driving task. Unfortunately, the coronavirus pandemic led to the closure of testing facilities and working with older adults at the time would put them at unnecessary risk. However, this situation also provided a unique opportunity to investigate age differences concerning real-life risk during an unprecedented situation in our lifetime. As such, we adapted to the circumstances and conducted an online study on how younger and older adults differed in risk-taking during the pandemic, measured by their misalignment to preventative health behaviours that were communicated by the UK government.

By drawing on a range of methods and scenarios, the studies have identified factors that may explain age differences in risk-taking. The findings of the three studies highlight how the measurement of risk-taking across adulthood is complex and depends on many factors, including the type of measurement, its reliance on cognitive ability, and the importance of design features including risk domain. These findings could be applied to future research on the topic in the measurement of risk-taking, informing the financial sector on how older adults make financial decisions, and inform health campaigns on preventative behaviours of age differences in adoption of behaviours and its determinants.

5.2 Summary of findings

5.2.1 Age differences in risk-taking

Across three chapters, 3 studies have examined risk-taking differences between younger and older adults. In Chapter 2, participants were given a physical behavioural task in which they were asked to convert gamble probabilities to frequencies over the course of 20 hypothetical times that this gamble would be played. If participants estimated the outcomes correctly, the task would give the expected value of the gamble over being played 20 times, designed to help participants decide whether the gamble would be worth playing in real life. If outcomes were estimated incorrectly, the task's feedback would represent the expected value based on the frequencies of outcomes provided by the participant instead. Contrary to expectations, there were no age differences, as older and younger adults did not differ in their risk-taking on the task. Both age groups accepted a similar number of gambles.

In response to the findings of Chapter 2, the study in Chapter 3 used an adjusted design of the task in Chapter 2, having been computerized and expanded to two task types instead of one. The two task types, a complex and simplified task type, allowed for comparison of how cognitive demand would affect task performance and the role of cognitive ability and risk preference across the two task types. It was predicted that older adults' comprehension on the complex task would be affected by the age-related decrease in cognitive abilities, and that this effect would cause them to take more risk on the complex task. However, the absence of cognitive demand on the simplified task was expected to exclude any effects of cognitive ability and therefore risk-taking would reflect participants' risk preference. Expectations on risk-taking across the task types were partially confirmed, as older adults took more risk on the complex task (as well as having lower comprehension), but unlike expected, this pattern persisted in the simplified task version.

In the third study, discussed in Chapter 4, we looked at age differences in risk-taking during the current COVID-19 pandemic. In this study, participants were asked about their behaviour in the past 2 weeks, and how often they had adopted the preventative measures that were either enforced or highly recommended by the UK government. Behaviours included keeping at least 1 metre distance from others, wearing a facemask on public transport, and regularly washing hands with water and soap for at least 20 seconds. We expected that older adults would be less likely to take risk (adopting preventative behaviours more often), as prior research showed that older adults reported being less likely to take health risks. In line with expectations, older and younger adults differed in how much health risk they took, with older adults adopting preventative measures more often.

In summary, two of the three studies reported age differences in risk-taking. These mixed findings (i.e. no age differences in one study and age differences in opposite directions) likely resulted from variations in design and risk domain across the three studies. In the studies discussed in Chapters 2 and 3, the design of the tasks was similar, but had slight differences. In the first study, the task consisted of 10 gambles and was a physical task, whereas the task in study 2 had two types (i.e. complex and simplified task), included 20 gambles, and was computerized. Despite the differences between tasks, a large component of why study 2 did show age differences in risk-taking whereas study 1 did not, was likely due to the difference in older adult participants who took part in the study. In the first study, older adult participants were largely recruited through an existing participant pool, and many had taken part in Psychological studies on ageing before. In comparison, almost all participants in the second study had been recruited from the local community, through the distribution of flyers and online advertisement, and most had never taken part in a study before. If older adults were signed up to the participant pool, only those who had limited to no experience with Psychological studies were approached. As such, the sample of the second study was more representative of the older adult population, and without any (possible) confounding effect of prior knowledge of the measures, learning or bias involved.

Despite age differences varying between Chapters 2 and 3, another pattern did emerge. Though there were no age differences in risk-taking in the first study, risk-taking on the task in study 1 was directly associated with overestimating wins and underestimating losses. Yet, older and younger adults were similar in their correct estimations of probability, as well as their risk-taking. In study 2, older adults were correct less often compared to younger adults, indicating more difficulty in converting probability to frequency, and they also took more risk. The distribution of older adults' estimations showed an inclination to overestimate wins and underestimate losses once more. On these types of tasks, it can be said that risk-taking is associated with overestimating the value of the associated gambles, and this pattern remained when age differences in risk-taking did occur, with older adults' estimations showing the same pattern.

In the third study, older adults reported taking less risk than younger adults, which was characterized by them adopting more preventative measures to avoid coronavirus infection. Differences between older and younger adults in terms of their adoption of preventative measures had been found in prior research, both in similar situations of health risk before the coronavirus pandemic (Blendon et al., 2004; van der Weerd et al., 2011) as well as during (Atchison et al., 2021; Bruine de Bruin, 2020; Coroiu et al., 2020; Fancourt et al., 2020; Machida et al., 2020; Park et al., 2020; Roozenbeek et al., 2020). Unlike in the first two studies, the risk (i.e. becoming sick with coronavirus) had been clearly communicated to older adults, as they had been strongly advised to stay indoors during the period in which the study was conducted. In addition, this type of risk-taking was in a different domain than in the first two, as study 1 and 2 looked at financial risk-taking, whereas study 3 looked at health-related risk-taking behaviours. Prior research has found that older adults generally are more risk averse concerning health risk (Dohmen et al., 2011; Josef et al., 2016; Rolison et al., 2014), likely due to the increased likelihood of complications associated with ageing.

Though findings of the three studies show a clear image of how differences in risk-taking between adult age groups depend on a number of factors, such as domain and comprehension, the studies involved also had some limitations that may limit any inferences drawn from their findings. As discussed prior in this section, the participants in study 1 had experience in psychological tasks, especially those concerning the measurement of cognitive abilities, and as such may have been more experienced with the task and other tests, leading to different results than if an inexperienced sample had been used. In the second study, performance on the simplified task encountered a ceiling effect, preventing any further differences between age groups to appear. In the third study, participants reported on their behaviour in the past two weeks. As adoption of preventative measures was expected and often communicated by the UK government and international health organisations, participants may have given desirable answers in terms of their behaviour. The issue posed in study 1 concerning a potential biased sample had been addressed in study 2 and can generally be avoided by recruiting participants from the local community that have no prior experience with Psychological studies. The ceiling effect found in study 2 could be addressed by using a different paradigm for a simplified task, in which participants are more able to show their understanding of gamble probabilities while maintaining a design that requires minimal cognitive strain. Lastly, the potential presence of socially desirable answers in study 3 can be difficult to address, as the topic of adopting these behaviours may be sensitive. However, keeping the study’s aims as vague as possible, making sure that participants are aware that their entries are anonymous (by stating this clearly in the information sheet and consent form) and are not asked for any identifying information, and providing statements to (dis)agree with instead of questions are helpful design features that minimize social-desirability bias. In addition, one can decide to include a social desirability scale to establish how likely participants are to provide a desirable answer and as possible exclusion tool.

Overall, the findings on risk-taking across the three studies highlight the importance of risk domain, as older adults may feel differently about taking risk in one area compared to another (e.g. financial risk compared to health risk). It also underlines the importance of using a sample that is as representative of the population as possible, and limiting prior experience with Psychological studies,

5.2.2 The role of cognitive ability

To investigate the role of cognitive ability in age differences in risk-taking, multiple measures of cognitive ability were included in the design of the studies discussed in this thesis. Chapter 2 and 3 included three measures of cognitive ability: numeracy, working memory and processing speed. These three abilities were chosen as they are often considered to be related to task performance and have been measured in past research. In Chapter 4, only numeracy was included due to the study having to be conducted online and as numeracy appeared to be most relevant concerning risk-taking during the coronavirus pandemic.

Numeracy

Due to the numerical information provided in all studies, numeracy was included as a measure of cognitive ability. In the first two studies, numeracy was included due to the mathematical design of the task. In Chapter 2, numeracy was used to measure whether older and younger adults differed in numerical ability and whether it explained differences in estimations of probability and gamble acceptance, especially concerning age differences. It was hypothesized that older adults would have worse numerical ability than younger adults, and that this would result in being correct less often and having larger distances from the actual probability. Results showed that there were no age differences in numeracy. However, numeracy was related to task behaviour, as it was negatively associated with correct estimations and predicted risk-taking on the task.

In Chapter 3, the design of the prior task was adjusted to create two task types that would allow better comparison of the role of cognitive ability and risk preference under different circumstances. In line with expectations, the results indicated that older adults' numerical ability was worse than those of younger adults, and older adults took more risk in both task types. As expected, numeracy partially mediated the relationship between age and correct estimation on the complex task.

In Chapter 4, numeracy was used due to the numerical information often presented to UK citizens to discuss the development of coronavirus (i.e. common use of graphs and figures, proportional chance of infection, hospitalization and death, and the R number). Older adults were found to have lower numerical ability than younger adults, numeracy was positively related to risk-taking, and numeracy partially mediated the relationship between age group and risk-taking. These findings were partially in line with prior expectations, as age differences were hypothesized, but the direction of the relationship between numeracy and risk-taking was the opposite of what was predicted. Similar to Chapter 3, the findings indicate that though there are differences in numeracy across age groups and those with higher numerical abilities take more risk, another variable likely also explains why older and younger adults differ in risk-taking.

Overall, the three studies have found mixed findings on numeracy, both in terms of age differences and its relationship to correct probability estimations and risk-taking. In Chapters 2 and 4, numeracy was directly related to risk-taking (this was not the case in Chapter 3, though it did predict how often people correctly estimated gamble probabilities). However, the direction of the effect was the opposite in Chapters 2 and 4; in Chapter 2, higher numerical ability led to less risk-taking, whereas higher numerical ability led to more risk-taking in Chapter 4. Similar to age differences in risk-taking, these differences are likely due to variations in design and domain. Firstly, the behavioural task used in study 1 included gambles with varying expected values. Higher numerical ability was associated with better estimations of probability, and better estimations will have meant that participants were better informed of the gamble's expected value, which will likely have impacted their risk-taking (i.e. overestimating win probability and underestimating loss probability were associated with taking more risk). Higher numerical ability in study 1 will likely have led to better estimations of which gamble would be profitable, thereby being able to separate profitable and non-profitable gambles. Despite numerical information being communicated in study 3, this may not have the direct link to risk-taking as it does in study 1, where the task relied on using numerical abilities to convert probability into frequencies correctly, thus informing the participant about the gamble's risk. Secondly, the domains between studies differed, with the first study assessing financial risk-taking and the third study assessing health-related risk-taking. Numerical abilities likely serve a different purpose for the different types of decisions people make in those situations. In a financial setting, better numerical skills improve the understanding of the given information, and therefore the risks involved. When considering health-risk, numeracy may improve understanding of numerical information and provided figures, but it may not explain risk-taking directly (as evidenced by the non-significant indirect path of age differences in coronavirus risk-taking via numeracy).

When assessing age differences in numeracy, there were no differences between younger and older adults in study 1, whereas older adults did show lower numerical ability in the second and third study. The difference in age effects between the first two studies may be caused by the difference in the sample of both studies, as the first study's sample consisted of participants with more experience in psychological testing measures. When study 2 did include members from the community with no prior experience, age differences in numeracy did emerge. This pattern fits with the findings of study 3, in which older adults' numerical ability was lower than that of younger adults. In these studies, as well as prior research, age differences in numeracy are mixed and may depend on other factors, such as the selection procedure of participants and their motivation (Bruine de Bruin et al., 2015).

Working memory

Working memory and its relation to age differences in risk-taking was assessed in Chapter 2 and 3. In Chapter 2, working memory was measured using a subscale of the Wechsler Adult Intelligence Scale III (WAIS III; Wechsler, 1997), the Digit Span Backward. Unlike hypothesized, older and younger adults performed similarly, indicating that there were no differences in working memory. Results showed that working memory also was not associated with risk-taking behaviour on the task, which was not as expected.

In Chapter 3, working memory was assessed using the Shortened Symmetry Span, a computerized test. In line with expectations, older adults did perform worse on the span task, showing signs of age-related decline in working memory. In the study, older adults were expected to have age-related decline in working memory, which would then lead to increased risk-taking on the task. However, working memory was found not to be related to risk-taking on the behavioural task, despite older adults also taking more risk, nor did it mediate the relationship between age and risk-taking behaviour.

As to why age differences in working memory were found in Chapter 3, but not in Chapter 2, this is likely due to the difference in materials used to measure working memory. The Digit Span Backward is more sensitive to age-related decline compared to its simpler version, Digit Span Forward, but performance on other working memory measures show more decline as a function of age (Bopp & Verhaeghen, 2005; Elliott et al., 2011; Hale et al., 2011), such as spatial tasks (Myerson et al., 2003; Park et al., 2002). In addition, working memory tasks can be sensitive to the education level of participants. In response to the findings in Chapter 2, the Shortened Symmetry Task was chosen as a working memory measure for

Chapter 3, as the test is suitable for higher educated samples and more difficult due to the addition of distractor blocks (Draheim et al., 2018; Foster et al., 2015).

In both studies, working memory was not related to risk-taking behaviour. This is equally similar (Figner et al., 2009) and dissimilar (Zamarian et al., 2008) to the findings of other studies, as findings on the relationship between working memory and risk-taking are mixed. In the current study, cognitive ability may not have been related to risk-taking as the designed task may not have imposed enough strain on working memory for any effect to show. Li et al. (2013) found that working memory is more affected in complex tasks that require active processing. Both tasks in Chapter 2 and 3 (the task in Chapter 3 consisted of two types) in this study did not require participants to retain and recall large chunks of information. Instead, participants made calculations for each probability they estimated, and then moved on to estimating the next outcome probability (while their prior calculation is still visible), instead of having to retain and recall information to be able to complete trials. Information on the gamble was freely available throughout the trial, and they were given feedback to facilitate decision-making. As such, working memory may not have been involved to such an extent that it affected performance on the behavioural task.

Overall, the findings on working memory in Chapters 2 and 3 indicate that age differences in working memory are likely a product of which measure is used to assess working memory. When investigating the relationship between working memory and risk-taking on behavioural tasks, future research is encouraged to use a task that relies more heavily on key aspects of working memory (i.e. having to manipulate information, or retain and recall information on the gamble to make an optimal decision in the task) to assess its effect on (age differences in) risk-taking.

Processing speed

Like working memory, the effect of processing speed on age differences in risk-taking was investigated in Chapters 2 and 3. In Chapter 2, processing speed was assessed using the Digit Symbol Coding, a subtest of the WAIS III. In line with expectations, older adults performed worse on the Digit Symbol Coding, indicating a slower processing speed compared to younger adults. However, processing speed was not related to risk-taking on the behavioural task, which was unexpected.

In Chapter 3, the same measure as in Chapter 2 was used to assess processing speed. In this study, correlations were used to establish the best predictor of risk-taking out of all included cognitive measures. The correlation between processing speed and risk-taking was small, and as such, working memory was chosen as a predictor of risk-taking of both task types instead. In a pattern similar to that of the study in Chapter 2, processing speed was not related to risk-taking behaviour in Chapter 3.

Processing speed is another ability that is more affected in complex tasks that require active processing (Li et al., 2013). Past studies have found that older adults often perform worse under tasks with time pressure (Mata et al., 2011) due to the age-related decline in processing speed. However, Chapters 2 and 3 did not include tasks that featured response time measurements or a deadline for participants to decide within, instead allowing participants to take as much time as needed. As such, any age differences in processing speed may not have affected older adults' task performance in Chapters 2 and 3.

Overall, the findings on processing speed in Chapters 2 and 3 indicate that older adults do show age-related decline in processing speed. However, age differences in this ability did not seem to affect task performance, which is likely due to the task's lower-than-required reliance on processing speed. As such, the findings indicate that though this ability decreases in age, its effect on risk-taking depends on the design of the behavioural measure. Future research should focus on including a task with higher demands on processing speed, through the use of deadlines or judgment based on participants' response time, to assess if processing speed does affect age differences in risk-taking on a behavioural task with higher reliance on this ability.

5.2.3. The role of risk preference

Across the three studies, measures of risk preference were included to establish whether risk-taking behaviour did reflect risk preferences, and whether age groups differed in their preference towards risk.

In Chapter 2, we included the financial and health and safety domains of the Dospert (Blais & Weber, 2006), adjusted by Rolison et al. (2019). As expected, the results in Chapter 2 indicated that younger adults rated themselves as more likely to take risks, seeing more benefit in the risky activities and perceiving less risk in health and safety risk than older adults. There were no age differences in the perception of financial risk. This finding is similar to those of prior research, especially concerning health and safety risk (Dohmen et al., 2011; Josef et al., 2016; Mamerow et al., 2016; Rolison et al., 2014). Despite age differences in risk preference, further analyses on risk-taking behaviour showed that risk preference was not a predictor of participants' risk-taking. Why risk preference and risk-taking were not related could be due to the relatively low risk posed by the behavioural task compared to the risk preference measure. Whereas the Dospert asked participants about investing or gambling a specific amount of their pay, and therefore larger sums could be lost if the investment went badly, the task allowed participants to gamble with smaller amounts as well as knowing their losses would be capped. As such, it's likely that gambling on the task did not invoke the same response as their imagined scenario of losing a large portion of their pay or savings.

In study 2, we used multiple measures of risk preference to establish the best predictor of risk-taking among them, including the adjusted Dospert, General Risk Propensity Scale, and a risk preference measure specifically made for study 2. Older and younger adults differed in their risk preference across the three measures; there were no age differences on the adjusted Dospert, whereas older adults reporting being risk averse on the General Risk Propensity Scale, but risk-seeking on the measure designed for the study (which involved taking risks when already placed in an environment where risk was present, such as a casino). Why there were age differences on some measures of risk preference but not others, is likely due to the difference in domains being measured. There has been evidence that risk preference can be conceptualized as a general construct, that can encompass both domain-specific (i.e. recreational risk) as well as general preferences towards risk (Frey et al., 2017; Hertwig et al., 2019; Weber et al., 2002). However, differences in some specific domains may still be present, as these differ psychologically in perceptions of associated risks and benefits by participants (Charness et al., 2013; Frey et al., 2017; Weber et al., 2002). Participants differed in their appraisal of the risks posed in the three risk preference measures in study 2, and the measures each touch on a different aspect of risk. The General Risk Propensity Scale asked participants to rate the extent to which they agreed with statements about themselves, whereas the financial domain of the adjusted Dospert specifically asked about financial risk only and suggested risky activities instead of using personal statements. The measure designed for the study was slightly different, and asked people about the likelihood that they'd take a risk after being put in a situation where the risk was already present (e.g. attending a birthday party at a casino). As such, it's likely that age differences, or lack thereof, differed between measures, as well as their direction. Of the three risk preference measures in study 2, the adjusted Dospert was found to be most highly correlated with risk-taking and was therefore included in the analysis. However, it was not significantly related to risk-taking on the behavioural task. Similar to study 1, participants' reported risk preference may not have been related to their risk-taking behaviour due to differences in the self-report measure, in which larger amounts could be lost with higher impact to participants' wellbeing, than the risk posed in the study, of which participants were informed had limited impact.

In the last study, discussed in Chapter 4, we used the health and safety domain of the Dospert (Blais & Weber, 2006) to measure whether people's risk preference towards health and safety risk would be related to coronavirus-related risk-taking. We found that this was not the case, as the Dospert failed to predict risk-taking. The correlation between age and risk preference was very small and not significant, indicating that younger and older adults did not differ in their preferences towards health and safety risk. In the case of study 3, the topic was highly uncommon, as most citizens had not experienced a health crisis of this scale before. Younger and older adults differed in their risk-taking during the pandemic, but the difference between groups was rather small, and the relatively low group means indicated that both age groups mostly adopted preventative measures. In addition, many of the preventative behaviours were clearly communicated as essential or highly recommended by the UK government, and some were enforced (i.e. people would be fined if they were caught not adhering to the communicated guidelines, such as not receiving visitors indoors). This may explain why the relative difference between age groups was small, and why self-reported risk preference did not reflect risk-taking behaviour during the coronavirus pandemic.

Overall, the results of all three studies did not show a relationship between risk preference and risk-taking, despite age difference in some measures. This is not as hypothesized, but it is not specific to this study. Prior research has found that self-reported risk preference does not necessarily align with risk-taking on behavioural tasks (Frey et al., 2017; Mamerow et al., 2016; Mata et al., 2018). Several studies have reported that self-reported risk preference measures are generally reliable and are able to capture individual risk preferences in general and across domains (Frey et al., 2017; Hertwig et al., 2019). This is not the same for behavioural tasks. Frey et al. (2017) ran a large study involving 1507 participants, who completed an extensive battery of self-report measures and behavioural tasks. Results showed that self-report measures were not related to behavioural tasks, nor were the 8 behavioural tasks related to one another. Behavioural tasks differ in their complexity and thus their demand on cognitive ability, which cognitive abilities are involved, and what strategies participants need to apply for optimal task performance. These large differences in task design may cause a lack of cohesion among behavioural tasks but may also create difficulty in relating behavioural tasks to self-reported risk preference, as the design of the two types of measurements are distinct from one another. Whereas self-report measures apply a common method across questionnaires (i.e. using hypothetical situations, statements), the elicitation methods of behavioural tasks are not as uniform. As such, behavioural tasks may measure participants' temporary approach to risk (as a reflection of the circumstance of the task or environment), while self-report measures rely on people's experience to estimate risk preference, which has shown to be a more stable approach (Hertwig et al., 2019; Mata et al., 2018).

Another potential reason why the behaviour on types of measures do not align might be the importance of the circumstances and environments in which these measures are conducted. It may be that people's risk-taking on a behavioural task reflects the circumstance in which they are completing the task, instead of their risk preference. Studies on risk-taking using behavioural tasks are generally conducted in a specific environment, in which the limitations of risk are clearly communicated to participants (i.e. participants are aware of how much of their earnings they can lose, as well as knowing that any discomfort surrounding the risk or study allows them to stop taking part without consequences). As such, the experience of risk may be limited. In contrast, when using a self-report measure of risk preference, participants are usually given a hypothetical situation or a statement, in which they are asked to imagine or recall a risky situation. This imagined or recalled scenario is distinct from the environment or circumstances in which the self-report is provided. As such, the circumstances around how preferences and behaviours are measured may have more impact on behavioural tasks than on self-report measures.

Also, when taking a closer look at behavioural tasks to capture risk-taking behaviour, most tasks apply monetary scenarios such as safe versus risky options, playing cards or pumping a balloon to increase earnings. As the majority of behavioural tasks measure risk-taking in a financial setting only, an approach to the current problem could be to use tasks that assess risk-taking in a different domain, as the gap between self-reported risk preference and risk-taking on tasks may be specific to the task domain. In addition, financial tasks are often incentivized, while self-report risk preference measures are not. Charness et al. (2013) argue that for a risk preference measure to be associated with risk-taking, the risk preference measure should also be incentivized to ensure that the underlying risk preference and risk-taking behaviour are as similar as possible. As such, perhaps the self-reported risk preference measure should be equally specific, and apply directly to the scenario that the risk-taking task measures (i.e. if the task measures gambling behaviour, the self-report risk preference measure should equally measure risk preference towards gambling).

5.2.4. The role of other factors associated with risk-taking

All three chapters in the thesis aimed to investigate the role of both cognitive ability and risk preference in age differences in risk-taking. However, other factors associated with age and risk-taking emerged from these studies. In this section, some of these factors will be discussed.

In Chapters 2 and 3, behavioural tasks were used to assess age differences in risk-taking. In these tasks, participants were asked to estimate probabilities correctly and decide whether they wanted to gamble once in real-life. As well as cognitive measures and risk preference measures, other factors were included in the analysis. In study 1, though there were no age differences in correct estimations of probability, when incorrect, older adults' distance from the actual probability was larger. This indicates that when incorrect, older adults made larger mistakes. Age was not related to risk-taking, but overestimating win probability and underestimating loss probability was associated with taking more risk. This pattern in estimations of probability was similar in study 2. Unlike the first study, study 2 did find age differences in both correct estimation and gamble acceptance, with older adults being correct less often and taking more risk. When looking at older adults' estimations on the complex task (see Figure 9 in Chapter 3), the estimations of loss probability showed a tendency to underestimate, whereas the opposite happened when estimating win probability. On the simplified task, this occurrence was less prevalent, but the pattern was still visible. Older adults' miscomprehension of probabilities and expected value have been found in prior studies, and were found to be associated with their increased risk-taking on behavioural tasks (Mamerow et al., 2016; Weller et al., 2011). As cognitive ability and risk preference were found not to be related to risk-taking, the pattern across the two studies suggests that overestimating a gamble's expected value is likely to be associated with increased risk-taking, whether in general (study 1) or in combination with age (study 2).

In study 3, health-related risk-taking during the coronavirus pandemic was measured by the lack of adopting preventative behaviours. As well as numeracy and self-reported risk preference, a measure on coronavirus risk perception was also included. In the exploratory section of Chapter 4, risk perception was negatively related to risk-taking, but age groups did not differ in risk perception. However, when the items of the risk perception scale were separated by perception of risk for others and perception of risk for self (items on general perception of coronavirus, neither for others nor self, were purposely excluded), age differences did appear. Younger adults reported perceiving more risk for themselves and for others compared to older adults. Both the perception of risk for self and perception of risk for others mediated the relationship between age and risk-taking during the coronavirus pandemic.

These findings indicate two gaps between perception and behaviour of both age groups. The first gap is the disconnect between older adults' objectively higher risk of hospitalization and death resulting from COVID-19 infection, yet the lower perception of risk for themselves. This disconnect has been found by other studies (Bruine de Bruin, 2020; Guastafierro et al., 2021), who also reported older adults' lower risk perception of coronavirus. In the study by Guastafierro et al. (2021), older adults reported perceiving less risk concerning coronavirus compared to illnesses such as the flu or cancer. This may be due to how much the prevention of such an illness can be personally controlled. During the pandemic, older adults were advised to shield by staying at home, others were advised to stay away from older friends or relatives, and adjustments to services were made to prioritize the safety of older adults (e.g. shopping hours solely for the elderly, delivery slots specifically for vulnerable citizens). As such, feelings of coronavirus risk being controllable (i.e. by staying home and adhering to guidelines) may in turn have affected risk perception. In addition, older age is often associated with optimism and a decrease in worrying (Chowdhury et al., 2014; Hanoch et al., 2019; Jiménez et al., 2017), with older adults being less likely to update their belief when presented with undesirable information that affects their future (Chowdhury et al., 2014).

The second gap concerns the misalignment between younger adults' higher risk-taking, yet higher perception of risk for themselves and for others. Despite perceiving more risk, younger adults may report adopting preventative behaviours less often due to other reasons. Unlike the older age group, who were mostly retired, it may be that the younger adult group was not able to consistently avoid crowded spaces, such as offices, public transport or supermarkets, and are thus unable to consistently socially distance with at least 1 meter between themselves and others at all times. In addition, younger adults have reported higher rates of loneliness (Office of National Statistics, 2020), mental illness, concerns about finances (Bruine de Bruin, 2020; Fancourt et al., 2020; Li & Wang, 2020, Park et al., 2020), and higher job losses. As such, adopting preventative behaviours may also have negative consequences attached, leading younger adults to not consistently adopt preventative behaviours to avoid losses in other areas of their lives, such as their well-being or financial security. Though age differences in risk-taking were found, the difference in risk-taking between age groups was rather small. Older adults did avoid risk more than younger adults, but both group means were low, indicating that adherence in both groups was generally good. This, combined with younger adults' higher risk perception for themselves and others somewhat dispel the assumption of younger adults having little risk perception and being a driving factor in the increase in cases due to their lack of adherence to guidelines, as often reported in the news during the first year of the pandemic (Mercer, 2020; Polakovic, 2020; Rosney, 2020; Whiteside, 2020).

5.3 Future research

There are several areas of future research that may build on the findings discussed in this thesis. For example, comparisons between the findings of Chapters 2 and 3 highlight the importance of recruiting a representative sample for the older adult population. Psychological research in general has conducted studies with existing participants pools, such as university students, but using an existing participant pool for older adult research may impact results, as many measures used in older adult research may be sensitive to learning effects if participants have encountered these measures before. Thus, it is recommended not to rely on existing participant pools to examine age differences in risk-taking, risk preference and cognitive ability, and instead recruit community members who are not personally familiar with Psychological research.

The findings of Chapter 3, in which all cognitive abilities were related to age and (some) to behaviour on the two tasks, but did not mediate age differences in risk comprehension or risk-taking, indicate that cognitive abilities are involved, yet do not explain age differences in risk-taking. Future studies designing a behavioural task with the aim of assessing the role of cognitive ability should include design features that rely more heavily on cognitive abilities to capture any mediating effects. For instance, if wanting to assess the role of working memory, participants could be shown the probabilities associated with a gamble in the very beginning before commencing the calculation of probabilities, but not throughout the trial (as done in the tasks in Chapters 2 and 3). Another option would be to remove any feedback after completing probability estimations, and have participants rely on their estimations given for all outcomes.

The results of study 4 indicate once more how risk-taking differences between age groups are largely determined by factors other than risk preference or cognitive ability. Younger and older adults are likely to experience the risk differently due to the circumstances associated with their age, which is indicated by the gap between their perception of risk for themselves and others and their risk-taking behaviour. As risk-taking (characterized by not adopting preventative measures) during a worldwide pandemic is a highly unusual situation, future research is advised to include other measures more specific to the circumstances around the pandemic (e.g. isolation, job losses, the move to online learning) that may explain these age differences in risk-taking during COVID-19. Based on this chapter and prior research, those materials could include measures of optimism, fear of dying, trust in the government, or measurements on financial concerns and mental health.

Overall, the findings on age differences in risk-taking across this thesis are mixed. As such, there is a lot of opportunity/space to explore this area further. For future research, two general approaches to studying this phenomenon are recommended. Firstly, most to all behavioural tasks measure risk-taking solely in the financial domain. Participants are expected to understand or calculate (directly or indirectly) probabilities and expected values to take or avoid risk. As such, risk-taking is a reflection of people's ability to understand and work with financial information, while it is known that people may differ in risk-taking across domains. Where self-report measures of risk preference reflect this and have many options for general or domain-specific risk-taking, behavioural tasks are still largely only in the financial domain. As such, future research is recommended to apply behavioural tasks that measure risk-taking in other domains, such as social risk-taking or safety risk (such as driving), to measure age differences in risk-taking behaviour. Lastly, research on age differences in risk-taking often measures age differences by testing younger and older adults, either treating them as binary variables or continuous, but longitudinal data on ageing and risk-taking is scarce. Thus, currently information on how ageing affects one's risk-taking behaviour on an individual level is unavailable but would be very beneficial to the area of research. Future research would be advised to consider using a longitudinal design to assess how ageing affects risk-taking and assess the role of cognitive ability and risk preference in these age-related changes.

5.4 Final comments

To date, there has been little research dedicated to understanding the role of both cognitive ability and risk preference in age differences in risk-taking. As such, the findings in this thesis provide a worthwhile contribution to this area of research.

The present work demonstrates that age differences in risk-taking are complicated and dependent on many factors, such as the type of measurements used for risk-taking, cognitive ability and risk preference, and the risk domain. Older adults' working memory performance differed across measures, and differences in numeracy were found in study 2 but not in study 1 (despite using the same measure for both). This pattern was similar for risk preference, as age differences did or did not appear depending on the type of measure used, domain, and across studies. These findings align with those of prior research, further highlighting the reasons behind these mixed findings and the dependency of age differences on the design of task, test, and self-report measures.

Despite studies not consistently finding the same effect in terms of cognitive ability or risk preference, this thesis found other factors associated with age or risk-taking. On the financial tasks in Chapters 2 and 3, overestimating wins and underestimating losses was associated either directly with risk-taking (when there was no age difference), or with the increased risk-taking of older adults. As such, risk comprehension, whether generally or age-related, seems to drive risk-taking behaviour on the financial behavioural task.

In Chapter 4, initially older and younger adults appeared to perceive coronavirus risk similarly, but separating items showed that younger adults perceived more risk for others and themselves, despite reporting higher risk-taking. This finding indicates that age differences in risk-taking are not due to younger adults' lower risk perception but are likely due to other factors such as well-being and financial circumstance.

In conclusion, the current work adds to the growing body of research on age differences in risk-taking, highlighting how age differences are dependent on other factors, instead of older and younger adults inherently differing in their risk-taking propensity. It has also contributed other factors beyond cognitive ability and risk preference, such as the importance of risk perception, and how these affect younger and older adults' risk-taking behaviour.

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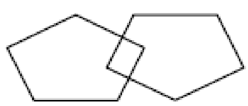
APPENDIX

Mini-Mental State Examination (Chapter 2 and 3)

Mini-Mental State Examination (MMSE)

Patient's Name: ____ Date: _____________

<u>Instructions:</u> Ask the questions in the order listed. Score one point for each correct response within each question or activity.

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day of the week? Month?"
5		"Where are we now: Country? County? Town/city? Building? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible. Number of trials: ___________
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, …) Stop after five answers. Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

(Adapted from Rovner & Folstein, 1987)

Participant instructions for the physical decision-making task (Chapter 2)

In this task you will be given gambles that we will ask you to evaluate. All the gambles have a chance of winning money, a chance of losing money and a chance of neither winning nor losing. Here is an example of one of the gambles you will be offered:

"Imagine you are offered the following gamble: You win £1 with a chance of 25%, you lose £1 with a chance of 15%. Your chance of breaking even, neither winning nor losing, is 60%."

This means that every time you play the gamble, you either win, lose, or neither win nor lose. The gamble does not change, and the odds and amounts remain the same whether you play the gamble 1 time or 100 times. Imagine it's like playing a fruit machine in the casino. The first time you play, you might win money, while the second time you play you might lose money.

We'll ask you to mimic the gamble using a wooden box. The box has 20 compartments, and the compartments each represent an outcome of playing the gamble (i.e., win, lose, neither win nor lose). We want to know your perception of what the chances of each outcome mean.

Place the balls in the compartments to mimic the chances of each outcome described in the gambles, so that, after 20 selections, the outcome mimics the instructions on the card. There are three types of coloured balls that represent each possible outcome; the green balls are wins, red are losses and yellow are neither winning nor losing.

After you have finished placing the balls in the boxes and I have told you how much you believe you would have earned or lost had you experienced those outcomes I will ask you to decide whether you wish to accept to play the gamble once with real consequences. If you accept to play the gamble, my computer will decide whether you have won or lost.

At the end of the study, if you have won money overall then you will leave with your winnings. If by the end of the study, you haven't won any money overall you will leave with your payment of £5. If you have lost money it will be subtracted from your participation payment.

PANAS X (Chapter 2)

This scale consists of a number of words and phrases that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this way right now. Use the following scale to record your answers:

1	2	3	4	5
Very slightly or not at all	A little	Moderately	Quite a bit	Extremely

1. ______ enthusiastic
2. ______ nervous
3. ______ excited
4. ______ upset
5. ______ happy
6. ______ sad
7. ______ content
8. ______ frustrated

Adjusted Dospert scales (Likelihood, Benefit and Risk Perception), each having Financial and Health and Safety items (Chapter 2 and 3)

For each of the following statements, please indicate the **likelihood** that you would engage in the described activity or behavior if you were to find yourself in that situation.

	Extremely Unlikely			Not Sure			Extremely Likely
1. Starting a new intense exercise routine	-3	-2	-1	0	1	2	3
2. Investing in a speculative but potentially lucrative stock on the stock market	-3	-2	-1	0	1	2	3
3. Using your credit card to pay for an item on an unfamiliar website	-3	-2	-1	0	1	2	3
4. Taking a ride home in a taxi that does not have seatbelts	-3	-2	-1	0	1	2	3
5. Betting a day's income or savings at the horse races	-3	-2	-1	0	1	2	3
6. Investing some of your savings in the stock market on the recommendation of your financial advisor	-3	-2	-1	0	1	2	3
7. Betting on the outcome of a sporting event	-3	-2	-1	0	1	2	3
8. Using a sunbed in a tanning studio to top up your vitamin D levels	-3	-2	-1	0	1	2	3
9. Investing a small amount of your income or savings in a potentially highly lucrative new start-up firm	-3	-2	-1	0	1	2	3
10. Joining a weekly high energy exercise class at the local gym	-3	-2	-1	0	1	2	3
11. Taking an unfamiliar medication while on holiday abroad	-3	-2	-1	0	1	2	3
12. Drinking heavily on a weeknight	-3	-2	-1	0	1	2	3

For each of the following statements, please indicate the **benefits** you would obtain from each situation.

	No benefits at all						Great benefits
1. Betting on the outcome of a sporting event	0	1	2	3	4	5	6
2. Drinking heavily on a weeknight	0	1	2	3	4	5	6
3. Joining a weekly high energy exercise class at the local gym	0	1	2	3	4	5	6
4. Investing a small amount of your income or savings in a potentially highly lucrative new start-up firm	0	1	2	3	4	5	6
5. Betting a day's income or savings at the horse races	0	1	2	3	4	5	6
6. Investing some of your savings in the stock market on the recommendation of your financial advisor	0	1	2	3	4	5	6
7. Starting a new intense exercise routine	0	1	2	3	4	5	6
8. Using a sunbed in a tanning studio to top up your vitamin D levels	0	1	2	3	4	5	6
9. Taking a ride home in a taxi that does not have seatbelts	0	1	2	3	4	5	6
10. Using your credit card to pay for an item on an unfamiliar website	0	1	2	3	4	5	6
11. Taking an unfamiliar medication while on holiday abroad	0	1	2	3	4	5	6
12. Investing in a speculative but potentially lucrative stock on the stock market	0	1	2	3	4	5	6

People often see some risk in situations that contain uncertainty about what the outcome or consequences will be and for which there is the possibility of negative consequences. However, riskiness is a very personal and intuitive notion, and we are interested in **your gut level assessment of how risky** each situation or behaviour is for you. For each of the following statements, please indicate **how risky you perceive** each situation **for you personally** if you were to find yourself in that situation.

	Not at all risky						Extremely risky
1. Using a sunbed in a tanning studio to top up your vitamin D levels	0	1	2	3	4	5	6
2. Investing in a speculative but potentially lucrative stock on the stock market	0	1	2	3	4	5	6
3. Joining a weekly high energy exercise class at the local gym	0	1	2	3	4	5	6
4. Investing a small amount of your income or savings in a potentially highly lucrative new start-up firm	0	1	2	3	4	5	6
5. Drinking heavily on a weeknight	0	1	2	3	4	5	6
6. Investing some of your savings in the stock market on the recommendation of your financial advisor	0	1	2	3	4	5	6
7. Starting a new intense exercise routine	0	1	2	3	4	5	6
8. Betting on the outcome of a sporting event	0	1	2	3	4	5	6
9. Taking a ride home in a taxi that does not have seatbelts	0	1	2	3	4	5	6
10. Using your credit card to pay for an item on an unfamiliar website	0	1	2	3	4	5	6
11. Taking an unfamiliar medication while on holiday abroad	0	1	2	3	4	5	6
12. Betting a day's income or savings at the horse races	0	1	2	3	4	5	6

Luck and Luckiness Scale (Chapter 2)

To what extent do you personally agree or disagree with the following statements?

	Strongly Disagree				Strongly Agree
1. I believe in good and bad luck	1	2	3	4	5
2. I try hard to be nice	1	2	3	4	5
3. I mostly have bad luck	1	2	3	4	5
4. There is no such thing as good or bad luck	1	2	3	4	5
5. It's hard to be nice	1	2	3	4	5
6. I'm not lucky	1	2	3	4	5
7. Good and bad luck really do exist	1	2	3	4	5
8. I generally have good luck	1	2	3	4	5
9. I'm nice if I try	1	2	3	4	5
10. Luck doesn't affect what happens to me	1	2	3	4	5
11. I consider myself a lucky person	1	2	3	4	5
12. Belief in luck is completely sensible	1	2	3	4	5
13. It's nice to try hard	1	2	3	4	5
14. Bad luck happens to me often	1	2	3	4	5
15. Luck only exists in peoples' minds	1	2	3	4	5
16. I'm usually lucky	1	2	3	4	5

Objective Numeracy Scale with 3 additional items (Chapters 2 and 3)

You will be shown 15 numerical questions. Each question will require you to calculate your answer. Each question has a few words in front of the answer line to indicate what type of answer is required. You may not use a calculator or any other means of help, except paper and pen for calculations (if needed).

1. Imagine that we rolled a fair, six-sided die 1,000 times. Out of 1,000 rolls, how many times do you think the die would come up even (2, 4, or 6)?

Rolls out of 1,000 ____________________

2. In the BIG BUCKS LOTTERY, the chance of winning a $10 prize is 1%. What is your best guess about how many people would win a $10 prize if 1,000 people each buy a single ticket to BIG BUCKS?

Persons out of 1,000 ____________________

3. In the ACME PUBLISHING SWEEPSTAKES, the chance of winning a car is 1 in 1,000. What percent of tickets to ACME PUBLISHING SWEEPSTAKES win a car?

% ____________________

4. Which of the following numbers represents the biggest risk of getting a disease?

1 in 100 1 in 1,000 1 in 10

5. Which of the following numbers represents the biggest risk of getting a disease?

1% 10% 5%

6. If Person A's risk of getting a disease is 1% in ten years, and Person B's risk is double that of A's, what is B's risk?

% ____________________

7. If Person A's chance of getting a disease is 1 in 100 in ten years, and Person B's risk is double that of A's, what is B's risk?

% ____________________

8. If the chance of getting a disease is 10%, how many people would be expected to get the disease out of 100 people?

Persons out of 100 ____________________

9. If the chance of getting a disease is 10%, how many people would be expected to get the disease out of 1,000 people?

Persons out of 1,000 ____________________

10. If the chance of getting a disease is 20 out of 100, this would be the same as having what chance of getting the disease:

% ____________________

11. The chance of getting a viral infection is .0005. Out of 10,000 people, how many of them are expected to get infected?

Persons out of 10,000 ____________________

12. If three elves can wrap three toys in 1 hour, how many elves are needed to wrap six toys in 2 hours?

Needed elves ____________________

13. Jerry received both the 15^{th} highest and the 15^{th} lowest mark in the class. How many students are there in the class?

Amount of students in class ____________________

14. In an athletics team, tall members are three times more likely to win a medal than short members. This year the team has won 60 medals so far. How many of these have been won by short athletes?

Amount of medals won____________________

Digit Span Backward (Chapter 2)

8. Digit Span

DISCONTINUE RULE
Digits Forward & Backward:
Score of 0 on both trials of any item.
For both Digits Forward & Backward, administer both trials of each item even if Trial 1 is passed. Administer Digits Backward even if examinee scores 0 on Digits Forward.

SCORING RULE
Each Trial: 0 or 1 pt. for each response
Item score = Trial 1 + Trial 2

START

Digits Forward Trial Item/Response		Trial Score	Item Score (0,1 or 2)
1.	1 1-7		
	2 6-3		
2.	1 5-8-2		
	2 6-9-4		
3.	1 6-4-3-9		
	2 7-2-8-6		
4.	1 4-2-7-3-1		
	2 7-5-8-3-6		
5.	1 6-1-9-4-7-3		
	2 3-9-2-4-8-7		
6.	1 5-9-1-7-4-2-8		
	2 4-1-7-9-3-8-6		
7.	1 5-8-1-9-2-6-4-7		
	2 3-8-2-9-5-1-7-4		
8.	1 2-7-5-8-6-2-5-8-4		
	2 7-1-3-9-4-2-5-6-8		
	Digits Forward Total Score (Maximum = 16)		

Digits Backward Trial Item/Response		Trial Score	Item Score (0,1 or 2)
1.	1 2-4		
	2 5-7		
2.	1 6-2-9		
	2 4-1-5		
3.	1 3-2-7-9		
	2 4-9-6-8		
4.	1 1-5-2-8-6		
	2 6-1-8-4-3		
5.	1 5-3-9-4-1-8		
	2 7-2-4-8-5-6		
6.	1 8-1-2-9-3-6-5		
	2 4-7-3-9-1-2-8		
7.	1 9-4-3-7-6-2-5-8		
	2 7-2-8-1-9-6-5-3		
	Digits Backward Total Score (Maximum = 14)		

Forward	+	Backward	=	(Maximum = 30)

Digit Symbol Coding (Chapter 2 and 3)

Digit Symbol—Coding

1	2	3	4	5	6	7	8	9
—	⊥	⊐	└	⊔	○	Λ	×	=

Sample Items

2	1	3	7	2	4	8	2	1	3	2	1	4	2	3	5	2	3	1	4

5	6	3	1	4	1	5	4	2	7	6	3	5	7	2	8	5	4	6	3

7	2	8	1	9	5	8	4	7	3	6	2	5	1	9	2	8	3	7	4

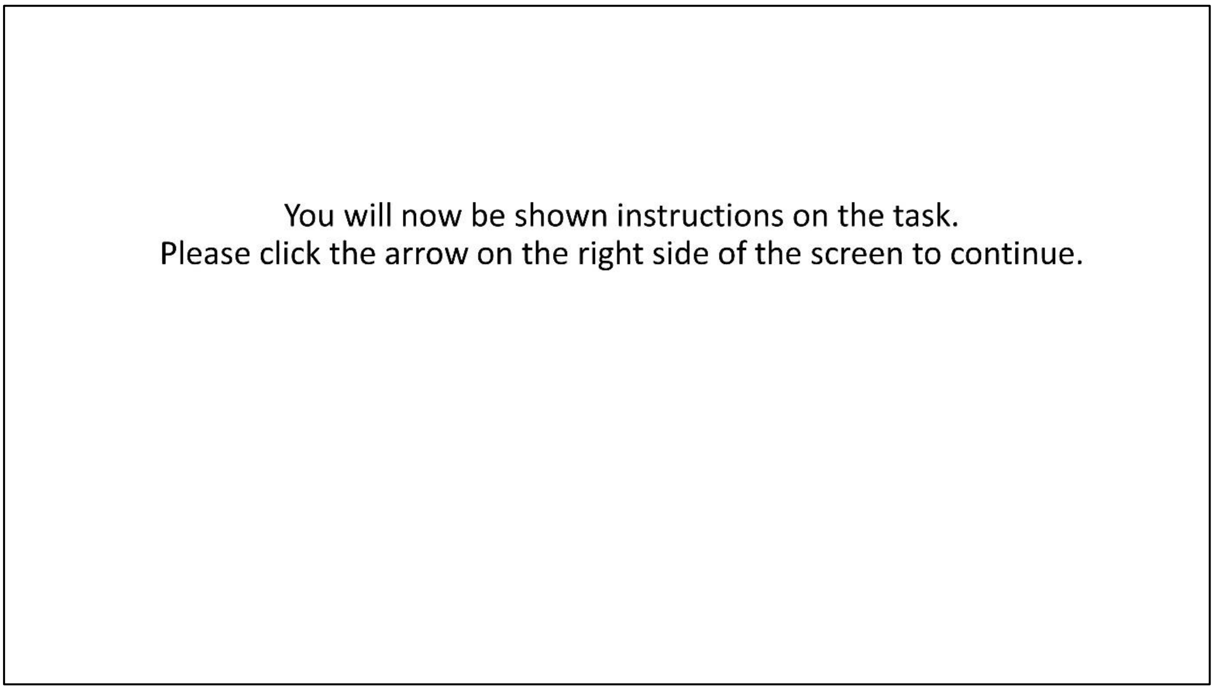
6	5	9	4	8	3	7	2	6	1	5	4	6	3	7	9	2	8	1	7

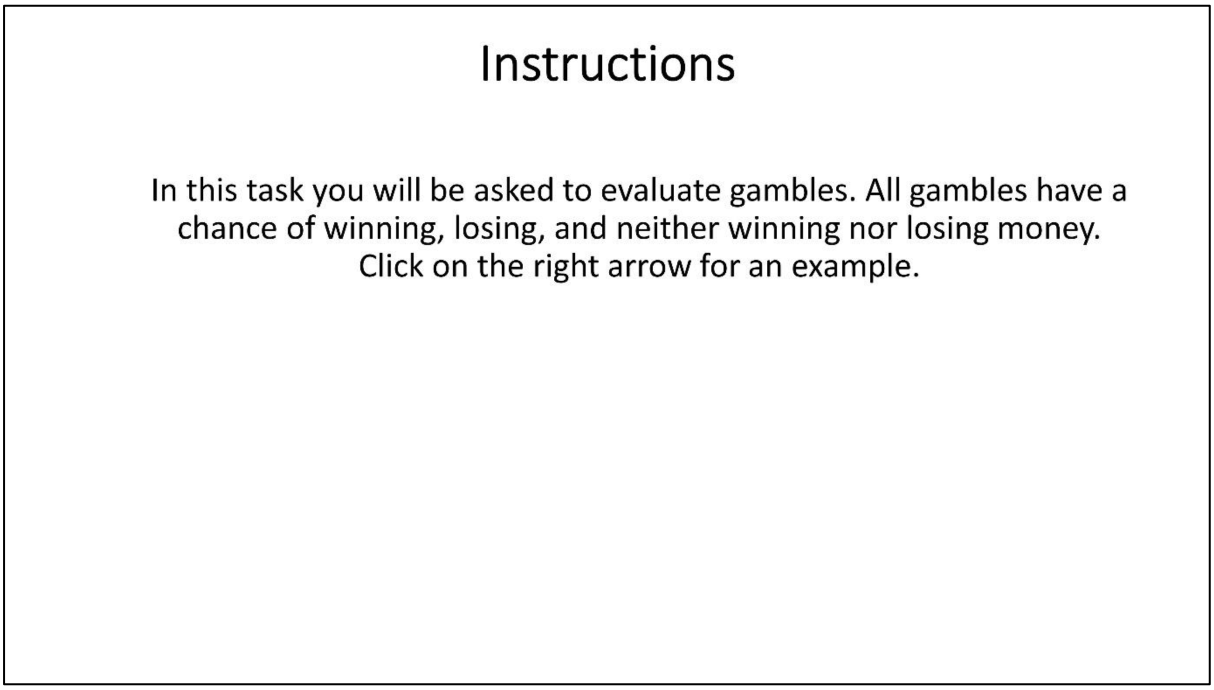
9	4	6	8	5	9	7	1	8	5	2	9	4	8	6	3	7	9	8	6

2	7	3	6	5	1	9	8	4	5	7	3	1	4	8	7	9	1	4	5

7	1	8	2	9	3	6	7	2	8	5	2	3	1	4	8	4	2	7	6

Instructions Complex Task (Chapter 3)





Instructions

In this task you will be asked to evaluate gambles. All gambles have a chance of winning, losing, and neither winning nor losing money.
Click on the right arrow for an example.

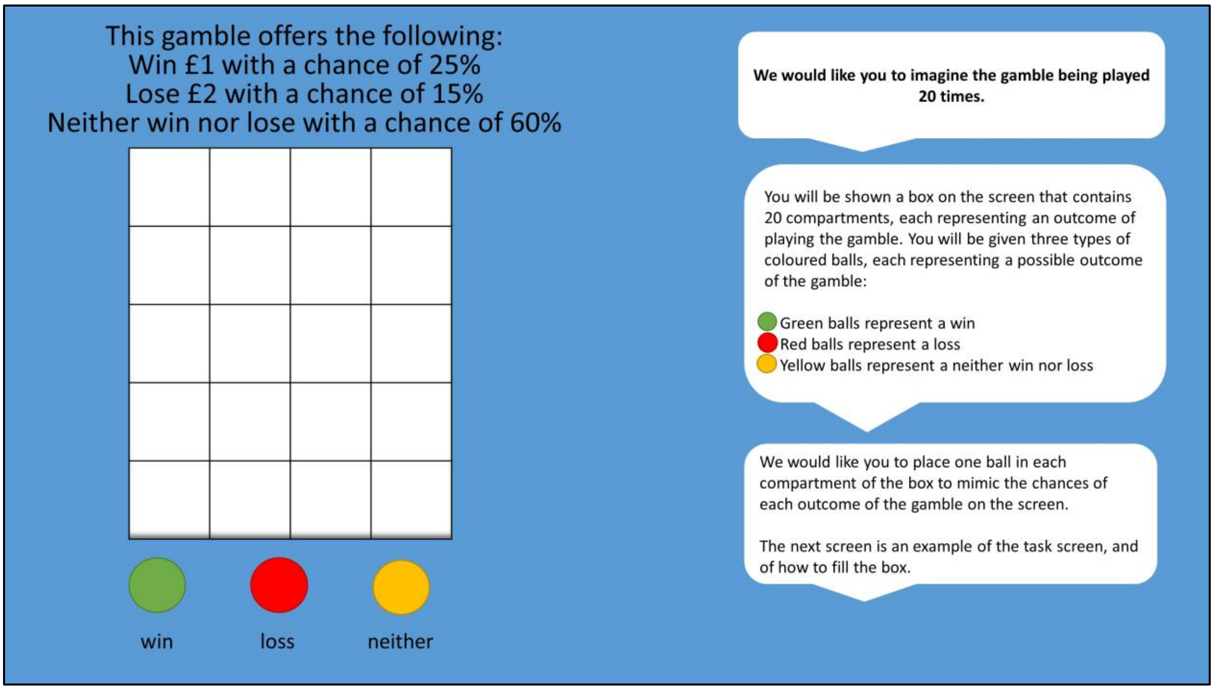
Win £1 with a chance of 25%,
Lose £2 with a chance of 15%.
Neither winning nor losing with a chance of 60%.

If you were to play the gamble, you would either win, lose, or neither win nor lose.

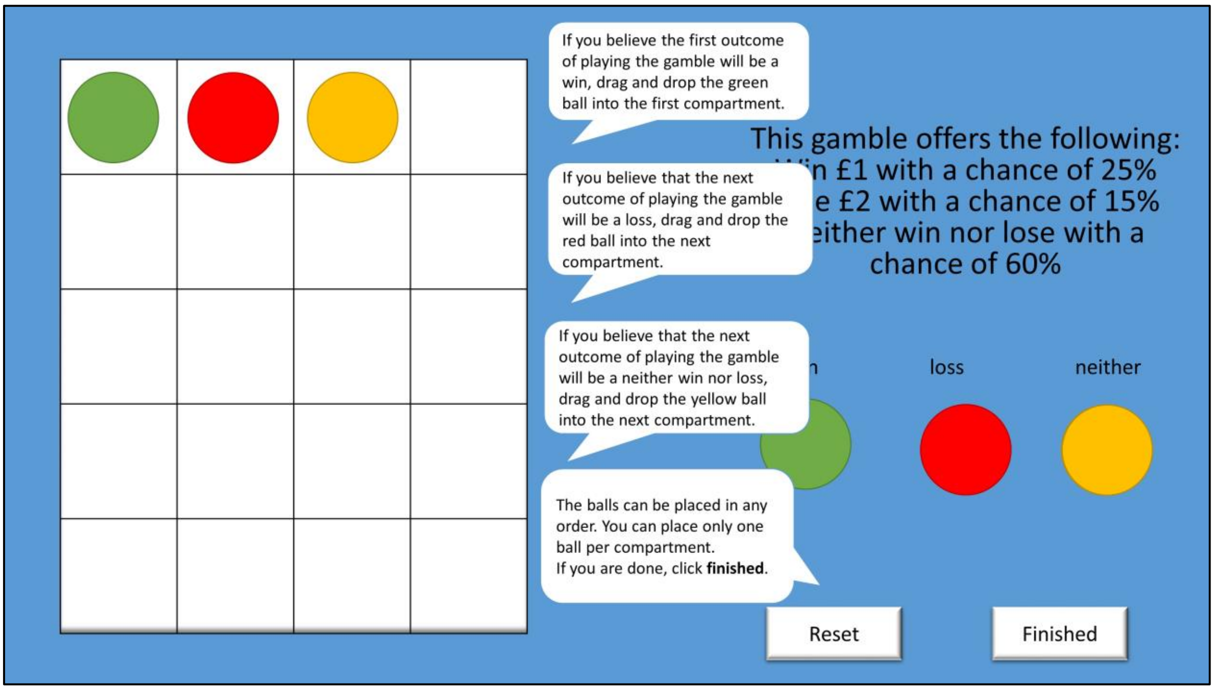
Instructions

Win £1 with a chance of 25%,
Lose £2 with a chance of 15%.
Neither winning nor losing with a chance of 60%.

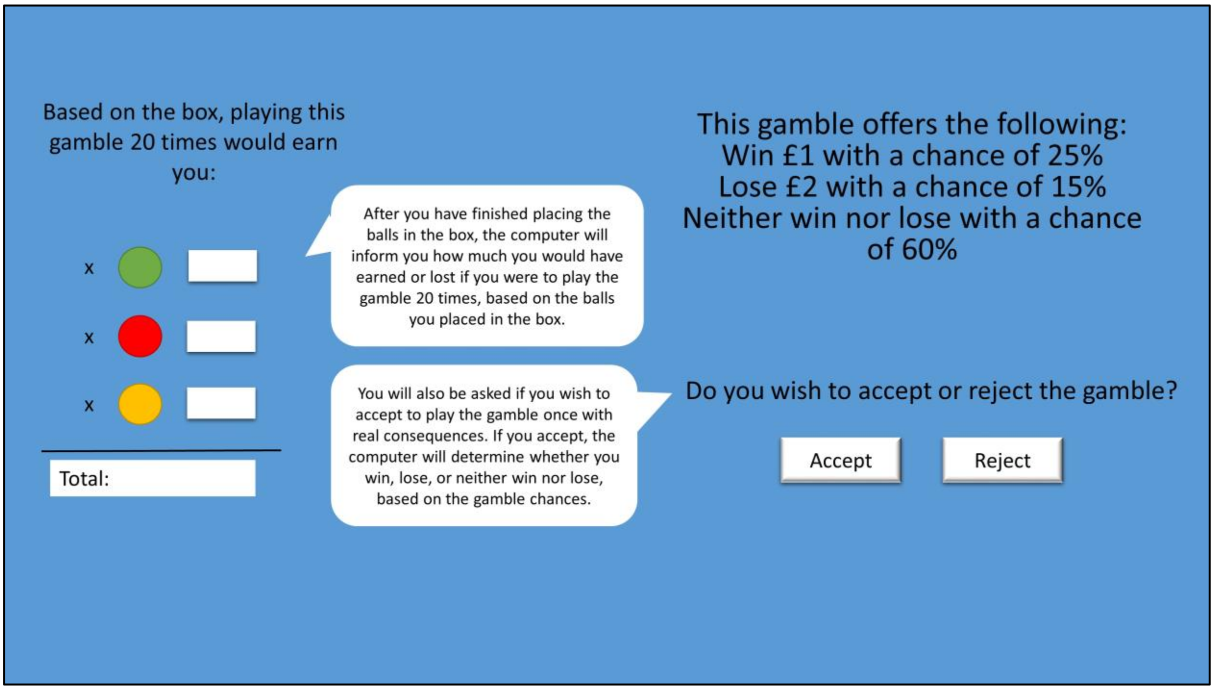
To help you understand these chances, you can think of a bag containing 100 tokens, of which 25 are green, 15 are red, and 60 yellow. Imagine drawing one of the tokens from the bag without looking. If you draw one of the 25 green tokens, you win £1. If you draw one of the 15 red tokens, you lose £2. If you draw one of the 60 yellow tokens, you neither win nor lose.

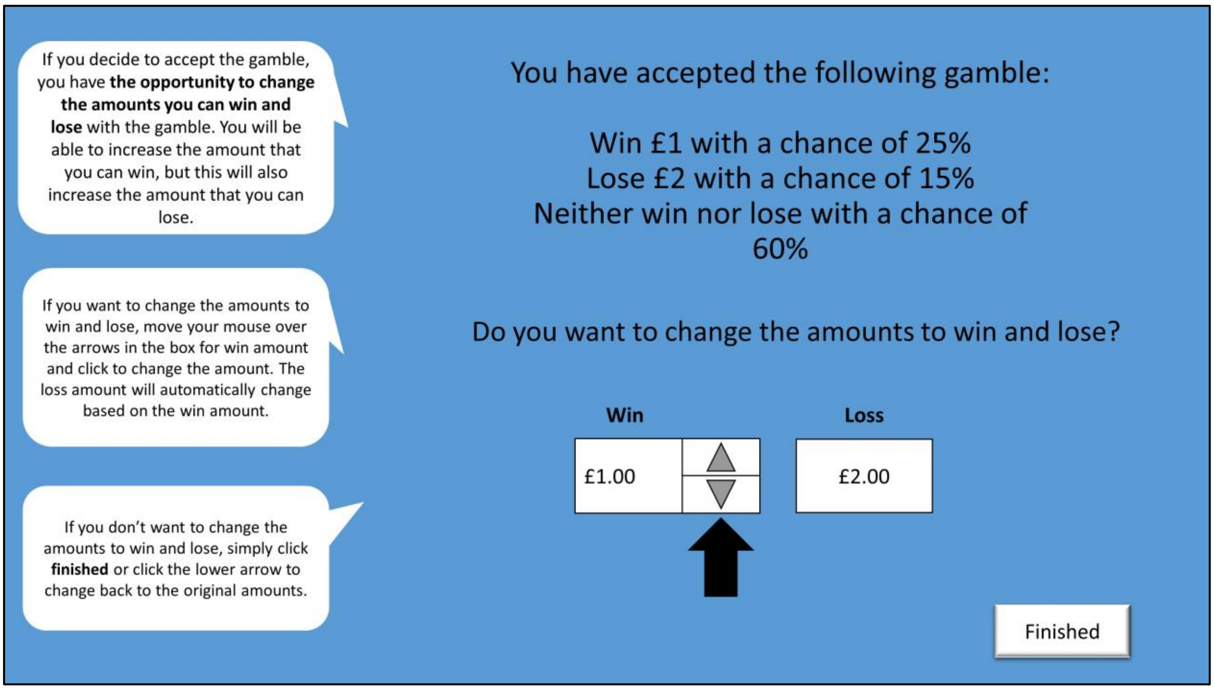


This gamble offers the following:
Win £1 with a chance of 25%
Lose £2 with a chance of 15%
Neither win nor lose with a chance of 60%
win
loss
neither
We would like you to imagine the gamble being played 20 times.
You will be shown a box on the screen that contains 20 compartments, each representing an outcome of playing the gamble. You will be given three types of coloured balls, each representing a possible outcome of the gamble:
Green balls represent a win
Red balls represent a loss
Yellow balls represent a neither win nor loss
We would like you to place one ball in each compartment of the box to mimic the chances of each outcome of the gamble on the screen.
The next screen is an example of the task screen, and of how to fill the box.



If you believe the first outcome of playing the gamble will be a win, drag and drop the green ball into the first compartment.
If you believe that the next outcome of playing the gamble will be a loss, drag and drop the red ball into the next compartment.
If you believe that the next outcome of playing the gamble will be a neither win nor loss, drag and drop the yellow ball into the next compartment.
The balls can be placed in any order. You can place only one ball per compartment.
If you are done, click **finished**.
This gamble offers the following:
n £1 with a chance of 25%
e £2 with a chance of 15%
either win nor lose with a
chance of 60%
loss
neither
Reset
Finished


Based on the box, playing this gamble 20 times would earn you:
x
x
x
Total:
After you have finished placing the balls in the box, the computer will inform you how much you would have earned or lost if you were to play the gamble 20 times, based on the balls you placed in the box.
You will also be asked if you wish to accept to play the gamble once with real consequences. If you accept, the computer will determine whether you win, lose, or neither win nor lose, based on the gamble chances.
This gamble offers the following:
Win £1 with a chance of 25%
Lose £2 with a chance of 15%
Neither win nor lose with a chance of 60%
Do you wish to accept or reject the gamble?
Accept
Reject


If you decide to accept the gamble, you have **the opportunity to change the amounts you can win and lose** with the gamble. You will be able to increase the amount that you can win, but this will also increase the amount that you can lose.
If you want to change the amounts to win and lose, move your mouse over the arrows in the box for win amount and click to change the amount. The loss amount will automatically change based on the win amount.
If you don't want to change the amounts to win and lose, simply click **finished** or click the lower arrow to change back to the original amounts.
You have accepted the following gamble:
Win £1 with a chance of 25%
Lose £2 with a chance of 15%
Neither win nor lose with a chance of 60%
Do you want to change the amounts to win and lose?
Win
Loss
£1.00
£2.00
Finished

Instructions

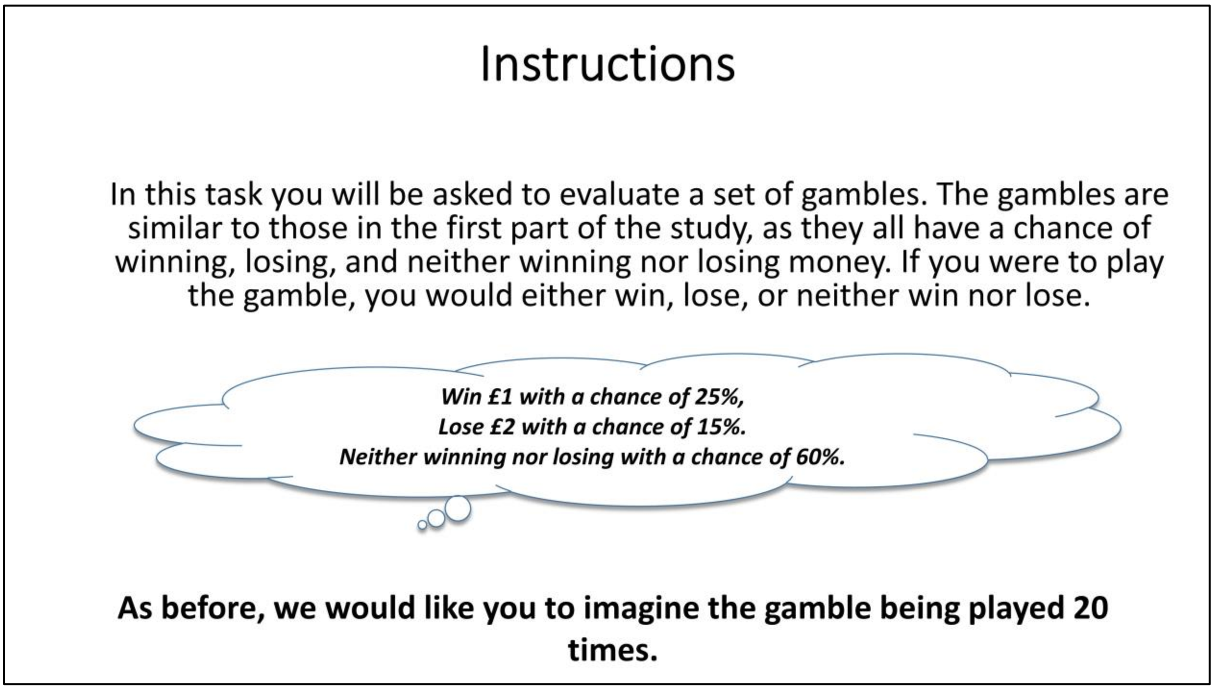
You will be shown multiple gambles, and for each you will be asked to fill the box and whether you want to play the gamble. If you decide to gamble once or more throughout the task, you could win or lose money:

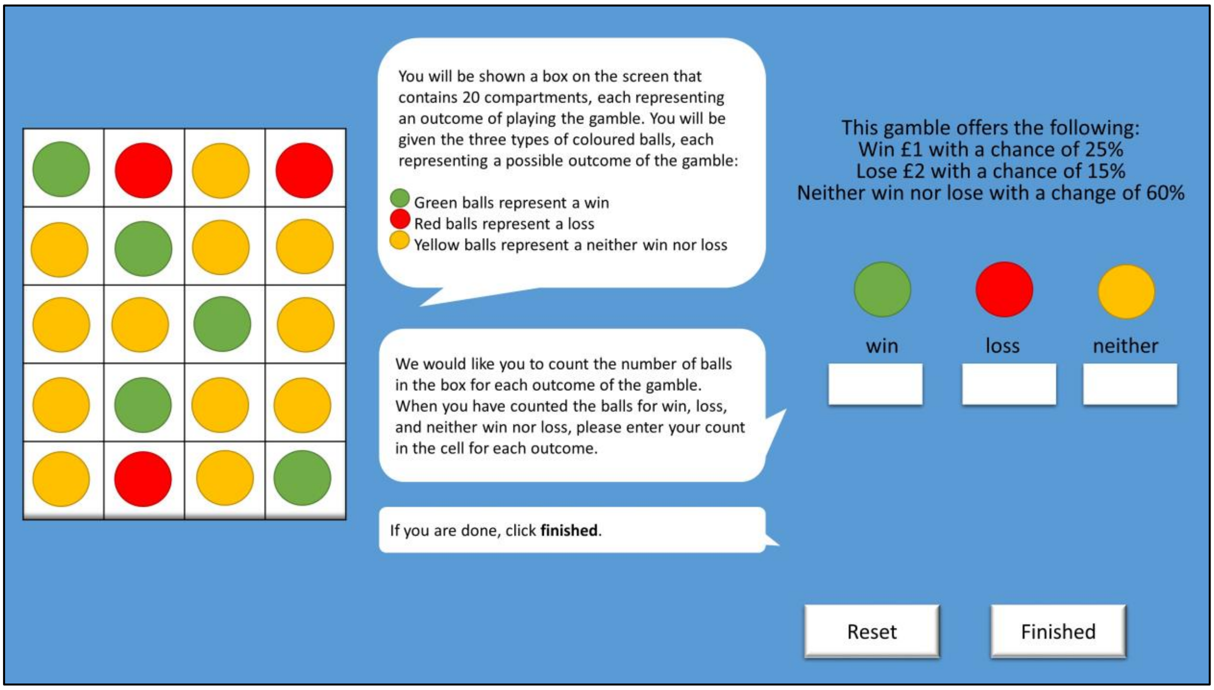
- In case of an overall win, anything earned during the task will be added to your participant payment.
- In case of an overall loss, the loss will be subtracted from your participant payment.*

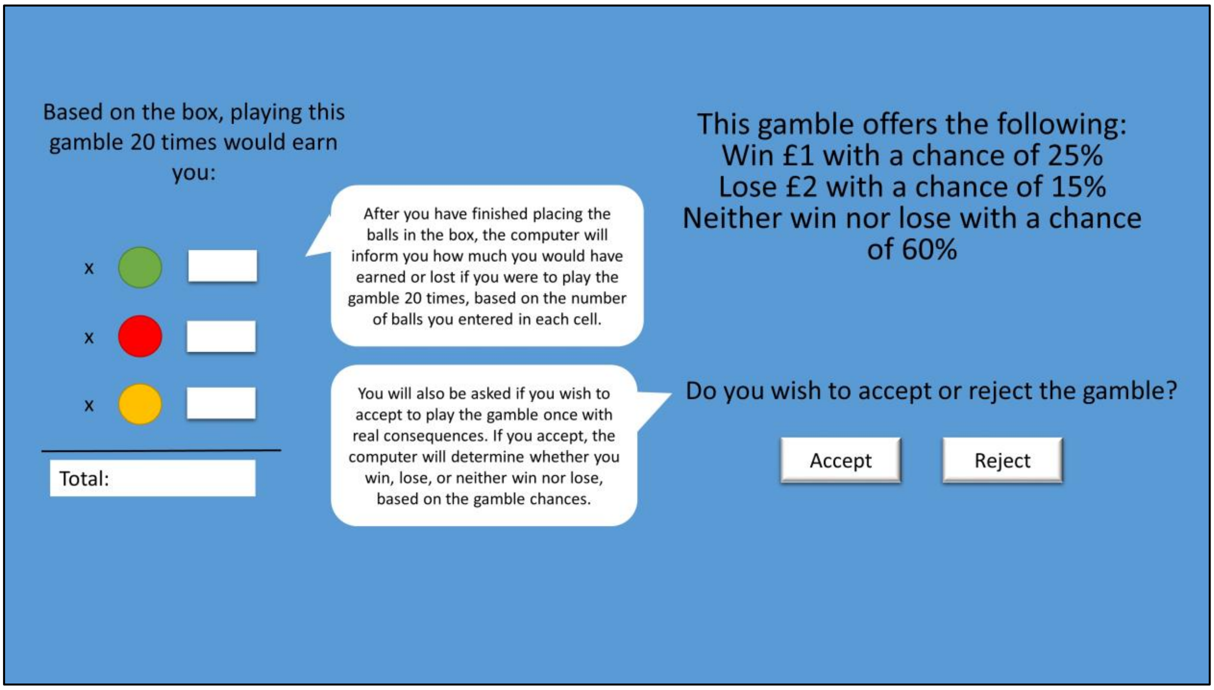
*If your loss is greater than your participant payment the loss will be capped, and you will leave with a payment of £0.

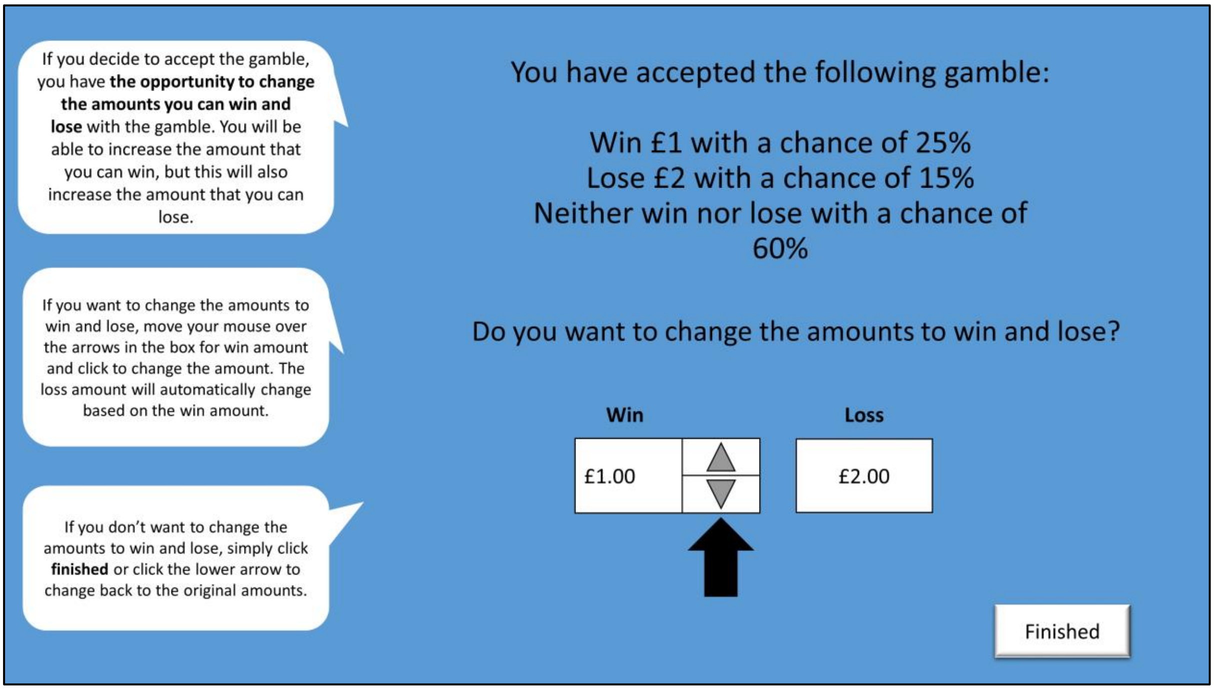
When you are ready, click on the right arrow to start the task

Instructions Simplified Task (Chapter 3)






Based on the box, playing this gamble 20 times would earn you:
x
x
x
Total:
After you have finished placing the balls in the box, the computer will inform you how much you would have earned or lost if you were to play the gamble 20 times, based on the number of balls you entered in each cell.
You will also be asked if you wish to accept to play the gamble once with real consequences. If you accept, the computer will determine whether you win, lose, or neither win nor lose, based on the gamble chances.
This gamble offers the following:
Win £1 with a chance of 25%
Lose £2 with a chance of 15%
Neither win nor lose with a chance of 60%
Do you wish to accept or reject the gamble?
Accept
Reject


If you decide to accept the gamble, you have **the opportunity to change the amounts you can win and lose** with the gamble. You will be able to increase the amount that you can win, but this will also increase the amount that you can lose.
If you want to change the amounts to win and lose, move your mouse over the arrows in the box for win amount and click to change the amount. The loss amount will automatically change based on the win amount.
If you don't want to change the amounts to win and lose, simply click **finished** or click the lower arrow to change back to the original amounts.
You have accepted the following gamble:
Win £1 with a chance of 25%
Lose £2 with a chance of 15%
Neither win nor lose with a chance of 60%
Do you want to change the amounts to win and lose?
Win
Loss
£1.00
£2.00
Finished

Instructions

You will be shown multiple gambles, and you will be asked for each gamble whether you want to play the gamble once. If you decide to gamble once or more throughout the task, you could win or lose money:

- In case of an overall win, anything earned during the task will be added to your participant payment.
- In case of an overall loss, the loss will be subtracted from your participant payment.*

*If your loss is greater than your participant payment the loss will be capped, and you will leave with a payment of £0.

When you are ready, click on the right arrow to start the task

New Risk Scale (Chapter 3)

You will now see a series of items, consisting of situations. For each of the following items, please indicate the likelihood that you would engage in the described activity or behaviour if you were to find yourself in that situation.

-3	-2	-1	0	1	2	3
Extremely unlikely			Not sure			Extremely likely

1. You're at the casino for a birthday party. Would you take some gambles at the slot machines or some other gamble at the casino?

2. You are watching a football game with friends when they suggest a wager. The amount is the small size bill in your wallet.
Would you take part?

3. Your friends have taken you to the dog racing to spend an evening. Would you place a bet whilst at the tracks?

4. You have been saving money for expensive home repairs. Your partner asked for a birthday present that is rather expensive, but you refused due to the cost. They then asked for a different gift that is cheaper but still rather pricey. Would you buy this gift?

5. You have signed up for a research study in which you can gamble to increase your payment. You could also lose your payment if you gamble. The payment is £10. Would you gamble during the study?

6. You’re travelling to a new city shortly and have already booked transportation. While booking for a place to stay you find accommodation for a low price that looks too good to be true. Would you book your stay there?

7. A friend has taken you to the horse racing track.
Would you place a bet at the races?

8. A good friend, not always reliable, lost their job and had to ask you for financial support. The first amount they asked for was too much for you to spare, but they said they found a way to cover most of their bills but still need a smaller amount.
Would you lend them the money?

9. A stranger approaches you at the train station asking for your help to buy a train ticket to go home because they have been mugged.
You don’t have the amount they’re asking for in cash, but you have half of what they asked. Would you give them at least a quarter of the money asked?

10. You are spending your evening at a charity event, when they call out that they are having a raffle. A bundle of 5 is being sold for £5.
Would you take part in the raffle?

Barratt Impulsiveness Scale (Chapter 3)

Using the scale provided, please indicate how much each of the following statements reflects how you typically are.

1	2	3	4
Rarely/never	Occasionally	Often	Almost always/always

1. I plan tasks carefully
2. I do things without thinking
3. I make up my mind quickly
4. I am happy-go-lucky
5. I don't "pay attention"
6. I have "racing thoughts"
7. I plan trips well ahead of time
8. I am self controlled
9. I concentrate easily
10. I save regularly
11. I "squirm" at plays or lectures
12. I am a careful thinker
13. I plan for job security
14. I say things without thinking
15. I like to think about complex problems
16. I change jobs
17. I act on "impulse"
18. I get easily bored when solving thought problems
19. I act on the spur of the moment
20. I am a steady thinker

21. I change residences
22. I buy things on impulse
23. I can only think about one thing at a time
24. I change hobbies
25. I spend more or charge more than I earn
26. I often have extraneous thoughts when thinking
27. I am more interested in the present than the future
28. I am restless at the theatre
29. I like puzzles
30. I am future oriented.

Self-Control Scale (Chapter 3)

Using the scale provided, please indicate how much each of the following statements reflects how you typically are.

1	2	3	4	5
Not at all				Very much

1. I am good at resisting temptation.
2. I have a hard time breaking bad habits.
3. I am lazy.
4. I say inappropriate things.
5. I never allow myself to lose control.
6. I do certain things that are bad for me, if they are fun.
7. People can count on me to keep on schedule.
8. Getting up in the morning is hard for me.
9. I have trouble saying no.
10. I change my mind fairly often.
11. I blurt out whatever is on my mind.
12. People would describe me as impulsive.
13. I refuse things that are bad for me.
14. I spend too much money.
15. I keep everything neat.
16. I am self-indulgent at times.
17. I wish I had more self-discipline.
18. I am reliable.
19. I get carried away by my feelings.
20. I do many things on the spur of the moment.

21. I don't keep secrets very well.

22. People would say that I have iron self- discipline.

23. I have worked or studied all night at the last minute.

24. I'm not easily discouraged.

25. I'd be better off if I stopped to think before acting.

26. I engage in healthy practices.

27. I eat healthy foods.

28. Pleasure and fun sometimes keep me from getting work done.

29. I have trouble concentrating.

30. I am able to work effectively toward long-term goals.

31. Sometimes I can't stop myself from doing something, even if I know it is wrong

32. I often act without thinking through all the alternatives.

33. I lose my temper too easily.

34. I often interrupt people.

35. I sometimes drink or use drugs to excess.

36. I am always on time.

General Risk Propensity Scale (Chapter 3)

For each of the following statements, please use the scale indicate the degree to which you agree or disagree with the statement.

1	2	3	4	5
Strongly agree				Strongly disagree

1. Taking risks makes life more fun
2. My friends would say I am a risk taker
3. I enjoy taking risks in most aspects of my life
4. I would take a risk even if it meant I might get hurt
5. Taking risks is an important part of my life
6. I commonly make risky decisions
7. I am a believer of taking chances
8. I am attracted, rather than scared, by risk

Power analysis (Chapter 4)

Data Simulation

We will write a function to generate some synthetic data for a sample size of n.

We will assume three cts variables, a, b and x. All are distributed $N(0,1)$. All three have a medium effect on y (i.e., 'g_fx_a', 0.3).

We will assume that a, b, x are correlated, with some r.

importantly, there is also a two-level grouping factor, which impacts a, b, x. The effect size of g on the other variables is g_fx_a/b/x

The effect of g on y is g_fx_y and set to -0.3.

```
gen_synth_data <- function(n, r = 0.1) {

 g_fx_a = -0.3
 g_fx_b =  0.3
 g_fx_x = -0.3

 a_fx_y = 0.3
 b_fx_y = -0.3
 x_fx_y = -0.3
 g_fx_y = -0.3

 coefs <- list(
  g = g_fx_y,
  a = a_fx_y,
  b = b_fx_y,
  x = x_fx_y,
  ab  = 0,
  sigma = 1)

  X <- rnorm_multi(
   n = n,
   vars = 3,
   mu = c(0, 0, 0),
   sd = c(1, 1 ,1),
   r = r,
   varnames = c("a", "b", "x"))

  g <- rep(c("group o", "group y"), each=n/2)

  d <- tibble(
   g = g,
   a = X$a, b = X$b, x = X$x) %>%
   mutate(
    g = as_factor(g),
```

```
    a = if_else(g == "group o", a + g_fx_a/2, a - g_fx_a),
    b = if_else(g == "group o", b + g_fx_b/2, b - g_fx_b),
    x = if_else(g == "group o", x + g_fx_x/2, x - g_fx_x),
  y = rnorm(n,
          coefs$g * (g == "group o") +
          coefs$a * a +
            coefs$b * b +
            coefs$x * x,
          coefs$sigma))

 return(d)
 }
```

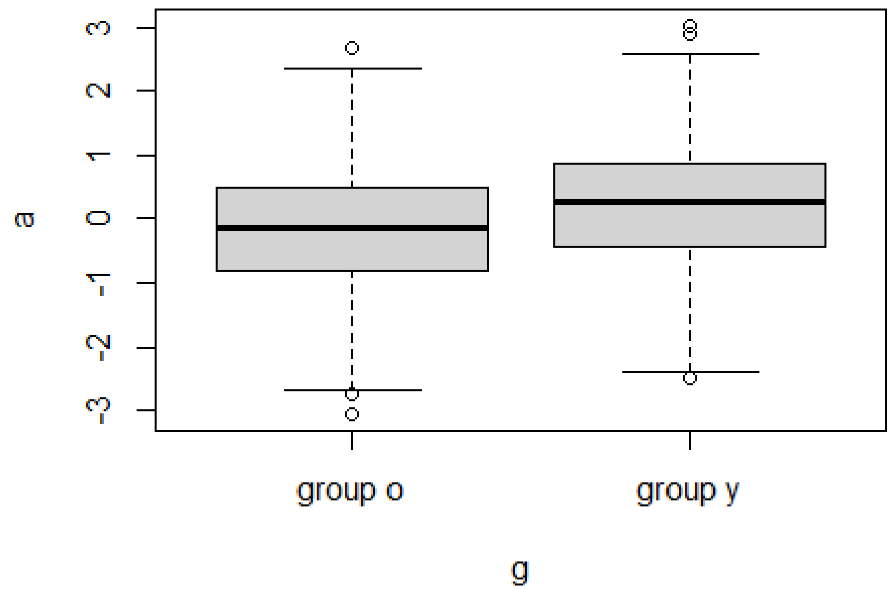
Check Simulation Looks Sensible

Generating synthetic data.

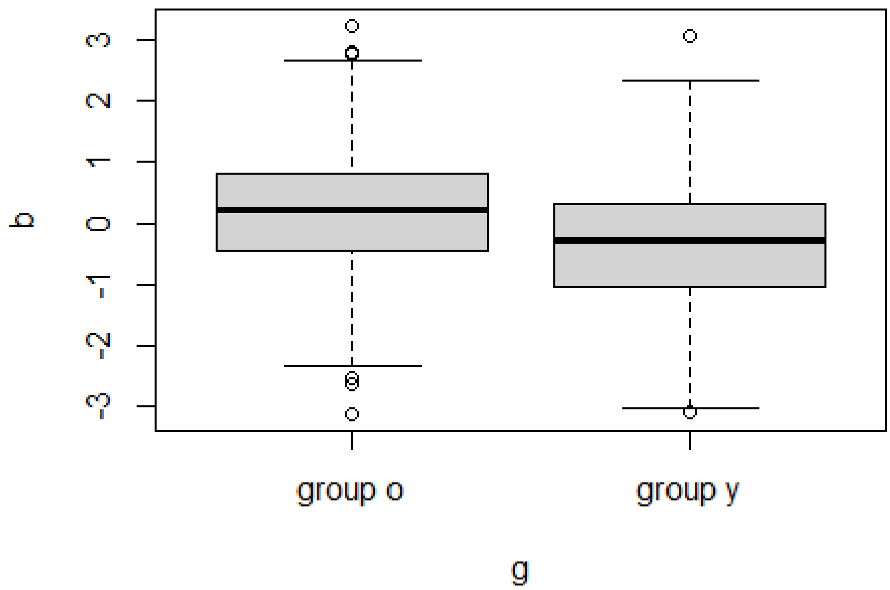
```
d <- gen_synth_data(1000, 0) %>% glimpse()

## Rows: 1,000
## Columns: 5
## $ g <fct> group o, group o, group o, group o, group o, group o, group o, gr...
## $ a <dbl> -1.146, -0.692, -0.473, 0.847, -1.224, 0.649, 0.859, 0.197, 1.517...
## $ b <dbl> 0.2729, -1.2199, 0.5778, -1.1763, 1.1042, 1.2348, 1.9209, -0.4438...
## $ x <dbl> -2.611234, -0.482501, 0.698284, -1.721335, 0.471132, 0.874867, 1....
## $ y <dbl> 1.13907, 0.50851, -1.22882, 0.02135, -2.64889, 0.00611, -0.10290,...

cor.test(d$a, d$b)

##
##  Pearson's product-moment correlation
##
## data:  d$a and d$b
## t = -0.7, df = 998, p-value = 0.5
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.0837  0.0402
## sample estimates:
##     cor
## -0.0218
```

Plots to check a (risk attitude), b (risk perception) and x (numeracy).

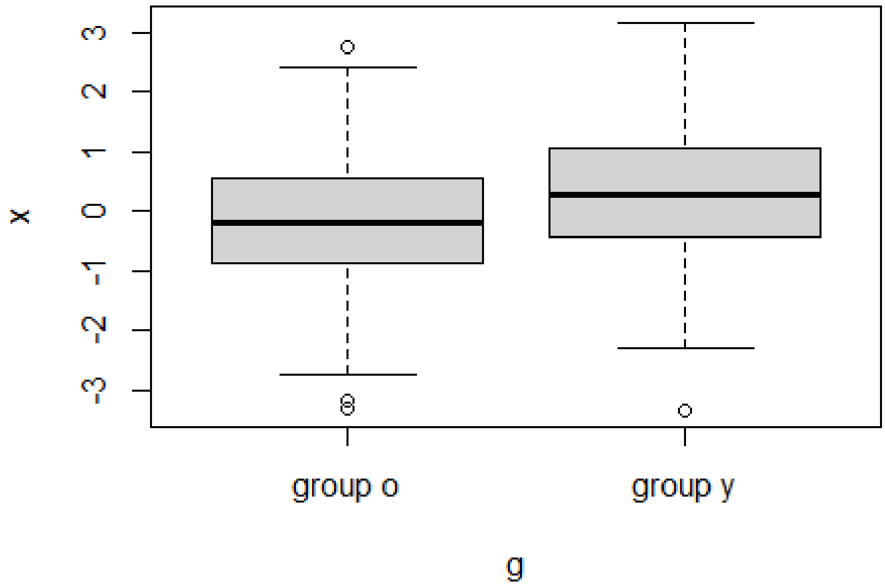
```
boxplot(a ~ g, data=d)
```




```
boxplot(b ~ g, data=d)
```



```r
boxplot(x ~ g, data=d)
```

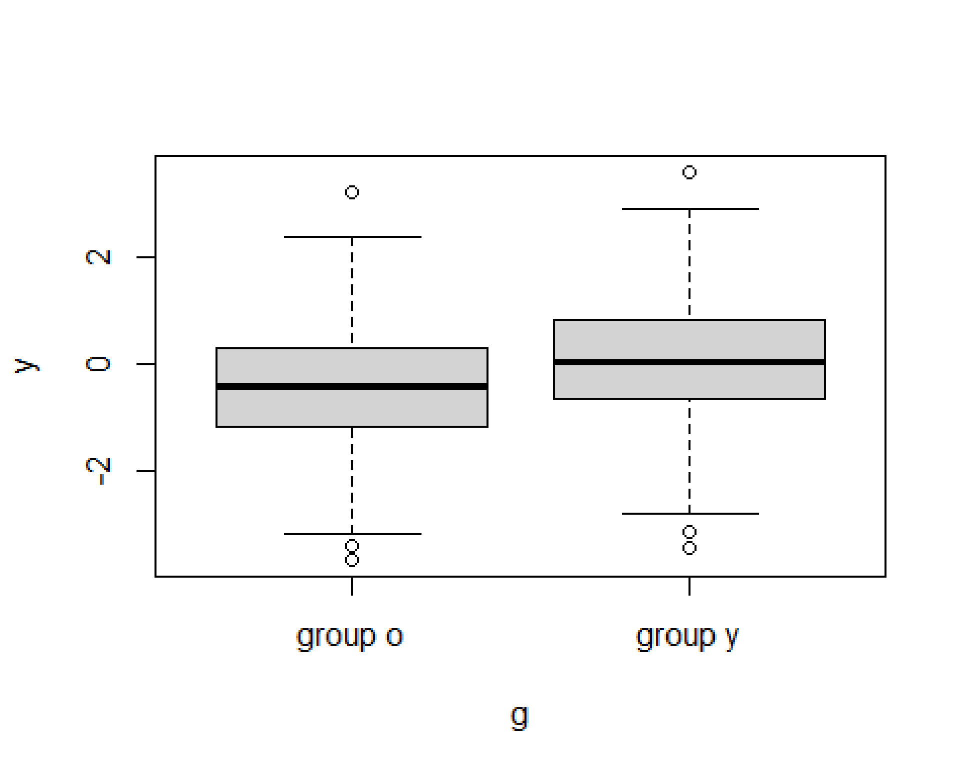


Planned Analysis

Hypothesis 1

H1: g (the effect of age on risk-taking)

```
boxplot(y ~ g, data=d)
```




```
summary(lm(y ~ g, data = d))
```

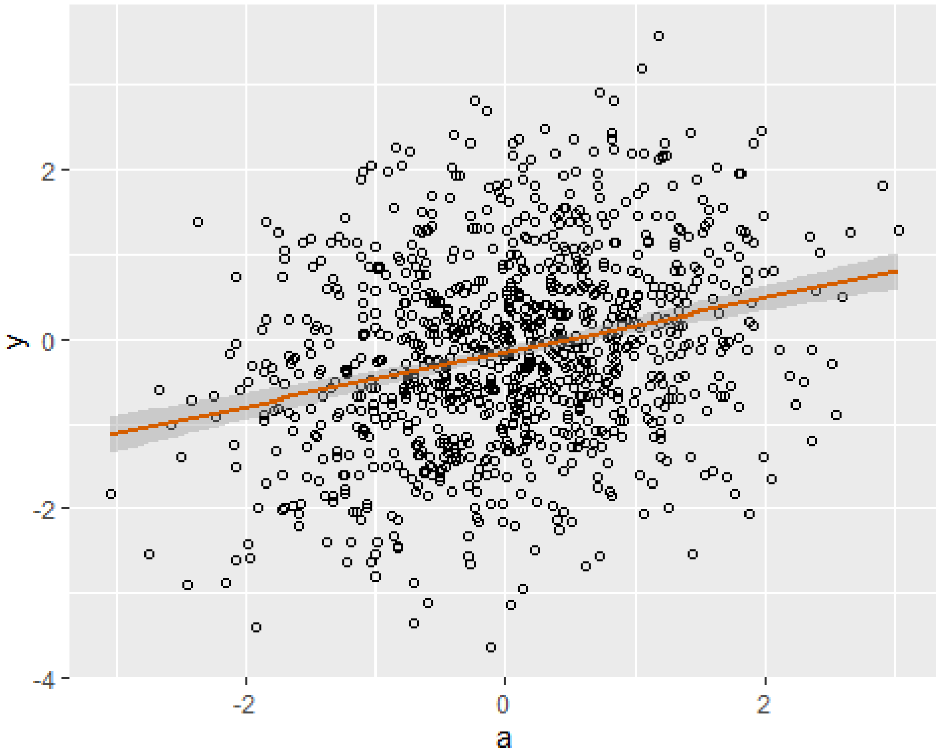
```
##
## Call:
## lm(formula = y ~ g, data = d)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -3.513 -0.749 -0.032  0.725  3.575
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -0.3807     0.0495   -7.69  3.6e-14 ***
## ggroup y      0.4796     0.0701    6.85  1.3e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.11 on 998 degrees of freedom
## Multiple R-squared:  0.0449, Adjusted R-squared:  0.0439
## F-statistic: 46.9 on 1 and 998 DF,  p-value: 1.31e-11
```

So our original main effect of g is:

```
gh1_beta <- summary(lm(y ~ g, data = d))$coefficients[2,1]
```

H1: a (The effect of risk attitude on risk-taking)

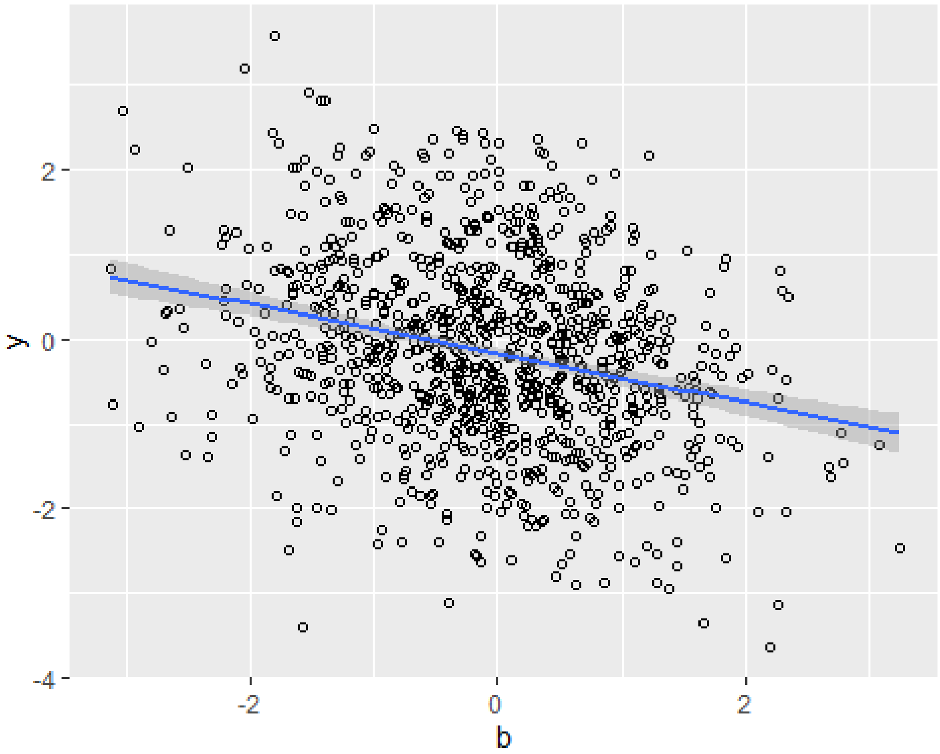
```
ggplot(d, aes(x=a, y=y)) +
  geom_point(shape=1) +
  geom_smooth(method=lm, colour = "#D55E00" )

## `geom_smooth()` using formula 'y ~ x'
```




```
summary(lm(y ~ a, data = d))

##
## Call:
## lm(formula = y ~ a, data = d)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -3.446 -0.730 -0.037  0.664  3.369
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -0.1557     0.0345   -4.52    7e-06 ***
## a             0.3191     0.0350    9.13   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.09 on 998 degrees of freedom
## Multiple R-squared:  0.0771, Adjusted R-squared:  0.0761
## F-statistic: 83.3 on 1 and 998 DF,  p-value: <2e-16
```

H1: b (the effect of risk perception on risk-taking)

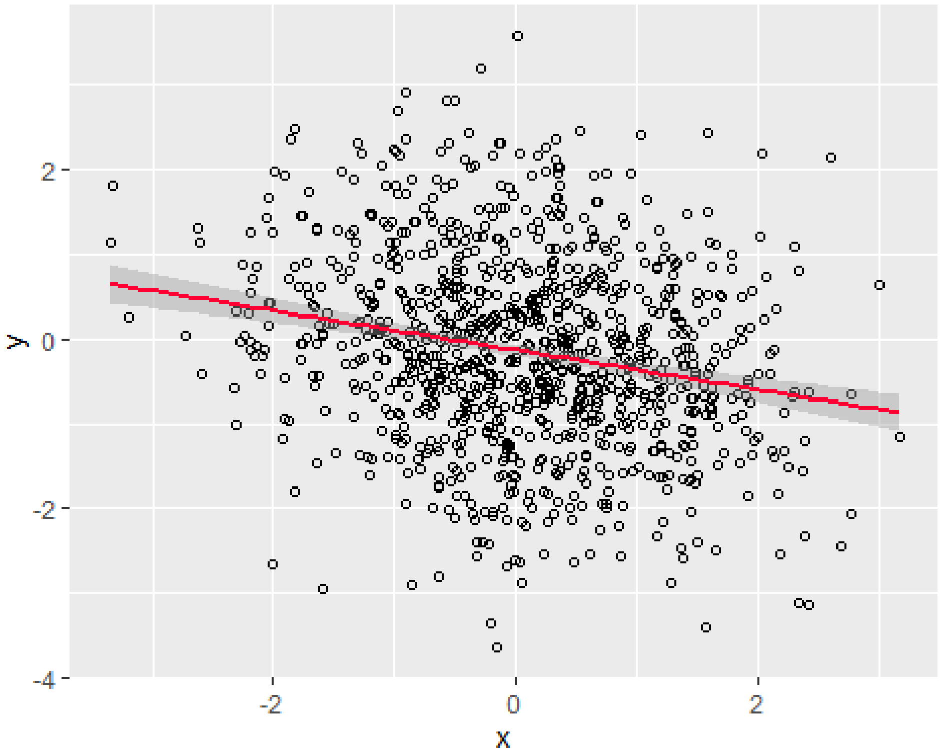
```
ggplot(d, aes(x=b, y=y)) +
  geom_point(shape=1) +
  geom_smooth(method=lm)

## `geom_smooth()` using formula 'y ~ x'
```




```
summary(lm(y ~ b, data = d))

##
## Call:
## lm(formula = y ~ b, data = d)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -3.706 -0.715 -0.025  0.688  3.233
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -0.1669     0.0347   -4.81  1.8e-06 ***
## b            -0.2904     0.0337   -8.61  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.09 on 998 degrees of freedom
## Multiple R-squared:  0.0691, Adjusted R-squared:  0.0681
## F-statistic: 74.1 on 1 and 998 DF,  p-value: <2e-16
```

H1: x (the effect of numeracy on risk-taking)

```
ggplot(d, aes(x=x, y=y)) +
  geom_point(shape=1) +
  geom_smooth(method=lm, colour = "#FF0033")

## `geom_smooth()` using formula 'y ~ x'
```




```
summary(lm(y ~ x, data = d))

##
## Call:
## lm(formula = y ~ x, data = d)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -3.549 -0.687 -0.054  0.704  3.720
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -0.1288     0.0350   -3.68  0.00025 ***
## x            -0.2338     0.0331   -7.06  3.2e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.11 on 998 degrees of freedom
## Multiple R-squared:  0.0475, Adjusted R-squared:  0.0466
## F-statistic: 49.8 on 1 and 998 DF,  p-value: 3.17e-12
```

Hypothesis 2 (H2)

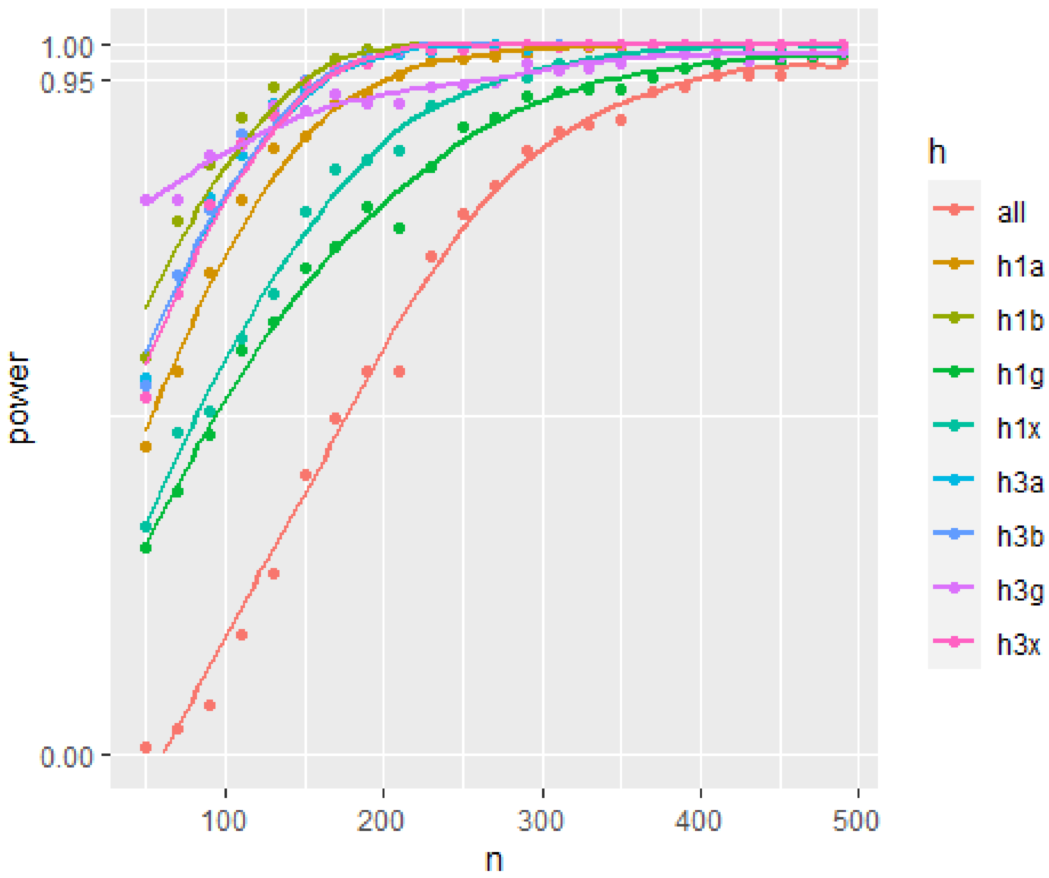
In H2, we are applying multiple mediation. In this follow-up from H1, all variables expected to mediate the relationship between age and risk-taking are included (i.e. risk attitude, risk perception and numeracy).

```
summary(lm(y ~ g + a + b + x, data = d))

##
## Call:
## lm(formula = y ~ g + a + b + x, data = d)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -2.818 -0.677 -0.023  0.657  2.788
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -0.3480     0.0458   -7.60  7.0e-14 ***
## ggroup y      0.3737     0.0687    5.44  6.6e-08 ***
## a             0.2881     0.0329    8.76  < 2e-16 ***
## b            -0.2450     0.0319   -7.67  4.1e-14 ***
## x            -0.2913     0.0308   -9.46  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1 on 995 degrees of freedom
## Multiple R-squared:  0.222,  Adjusted R-squared:  0.219
## F-statistic:   71 on 4 and 995 DF,  p-value: <2e-16

check_for_fx <- function(n, r=0.2, alpha = 0.05) {
  d<- gen_synth_data(n, r)
  # check that H1 is true
  # i.e., the p-value < alpha
  h1g <- summary(lm(y ~ g, data = d))$coefficients[2,4] < alpha
  b1_g <- summary(lm(y ~ g, data = d))$coefficients[2,1]
  h1a <- summary(lm(y ~ a, data = d))$coefficients[2,4] < alpha
  h1b <- summary(lm(y ~ b, data = d))$coefficients[2,4] < alpha
  h1x <- summary(lm(y ~ x, data = d))$coefficients[2,4] < alpha
  # Now check the H2, checking that the new variable is sig and the effect of g has d
ecreased
  m3 <- summary(lm(y ~ g + a + b + x, data = d))$coefficients
  h3a <- m3[3, 4] < alpha
  h3b <- m3[4, 4] < alpha
  h3x <- m3[5, 4] < alpha
  h3g <- m3[2, 1] < b1_g
  d_out <- tibble(
    h = c("h1g", "h1a", "h1b", "h1x", "h3g", "h3a", "h3b", "h3x"),
    n = n,
    r = r,
    p = c(h1g, h1a, h1b, h1x, h3g , h3a, h3b, h3x))
```

```r
  d_out <- add_row(d_out, h = "all",n= n, r = r, p = mean(d_out$p)==1)
  return(d_out)
}
```

Now let us do this lots of times for different values of n.

```r
iter <- 500
n_min <- 10
n_max <- 250
sims <- map_dfr(rep(seq(50, 500, 20), 500), check_for_fx, r = 0.1)

sims %>% group_by(h, n, r) %>%
  summarise(power = mean(p)) %>%
  mutate(r = as.factor(r)) %>%
  ggplot(aes(x = n, y = power, colour = h, group = h)) +
  geom_point() + geom_smooth(se = FALSE) +
  scale_y_continuous(breaks = c(0, 0.95, 1), limits = c(0, 1))

## `geom_smooth()` using method = 'loess' and formula 'y ~ x'

## Warning: Removed 138 rows containing missing values (geom_smooth).
```



Objective Risk Stratification tool (Chapter 4)

Table 3: Suggested objective risk stratification (ORS) tool for individuals not already identified as "vulnerable" by the NHS Digital Shielded Patient List

Risk factor	Indicator	Adjustment
Age	>50	1
	>60	2
	>70	4
	>80	6
Sex at Birth	Female	0
	Male	1
Ethnicity	Caucasian	0
	Black African descent	2
	Indian Asian descent	1
	Filipino descent	1
	Other (including Mixed race)	1
Diabetes and Obesity	(Type 1 or Type 2) uncomplicated*	1
	(Type 1 or Type 2) complicated*	2
	BMI≥35kg/m^2	1
Cardiovascular disease	Angina, previous MI, stroke or cardiac intervention	1
	Heart failure	2
Pulmonary disease	Asthma	1
	Non-Asthma chronic pulmonary disease	2
	Either above requiring oral corticosteroids in previous year	1
Malignant neoplasm	Active malignancy	3
	Malignancy in remission	1
Rheumatological conditions	Active treated conditions	2
Immunosuppressant therapy	Any indication	2

Interpretation	Score
Low Risk	<3
Medium Risk	3-5
High Risk	≥6

COVID-19 risk-taking (Chapter 4)

The next set of questions will present a number of activities and behaviours. You will be asked to report **how often you have engaged in these behaviours in the last 2 weeks.**

Your answers will be fully anonymous, so please answer honestly.

Always	Mostly yes	Sometimes	Mostly not	Never	Not applicable

1. Thoroughly cleaning my hands with hand sanitizer.
2. Touching my face with unwashed hands.
3. Regularly washing my hands with soap and water for at least 20 seconds.
4. Practising social distancing by avoiding crowds in confined and poorly ventilated spaces.
5. Regularly cleaning common surfaces with disinfectant.
6. Wearing a face mask when I am inside shops.
7. Wearing a facemask when I am on public transport.
8. Meeting indoors with people who are not in your household or bubble.
9. Keeping at least a 1 metre distance from others when outside my home.
10. Relying solely on contact-free deliveries for essentials and other shopping.

COVID-19 Risk perception (Chapter 4)

How worried are you personally about the following issues at present?
- Coronavirus/COVID-19

1	2	3	4	5	6	7
Not at all worried						Very worried

How likely do you think it is that you will be directly and personally affected by the following in the next 6 months?
- Catching the coronavirus/COVID-19

1	2	3	4	5	6	7
Not at all likely						Very likely

How likely do you think it is that your friends and family in the country you are currently living in will be directly affected by the following in the next 6 months?
- Catching the coronavirus/COVID-19

1	2	3	4	5	6	7
Not at all likely						Very likely

How much do you agree or disagree with the following statements?
- The coronavirus/COVID-19 will NOT affect very many people in the country I'm currently living in

1	2	3	4	5	6	7
Strongly disagree						Strongly agree

How much do you agree or disagree with the following statements?
- I will probably get sick with the coronavirus/ COVID-19

1	2	3	4	5	6	7
Strongly disagree						Strongly agree

How much do you agree or disagree with the following statements?
- Getting sick with the coronavirus/COVID-19 can be serious

1 Strongly disagree	2	3	4	5	6	7 Strongly agree

Dospert Likelihood, Risk Perceptions and Benefit scales (Chapter 4)

Domain-Specific Risk-Taking (Adult) Scale – Risk Taking

For each of the following statements, please indicate the **likelihood** that you would engage in the described activity or behavior if you were to find yourself in that situation. Provide a rating from *Extremely Unlikely* to *Extremely Likely*, using the following scale:

1	2	3	4	5	6	7
Extremely unlikely	Moderately unlikely	Somewhat unlikely	Not sure	Somewhat likely	Moderately likely	Extremely likely

1. Drinking heavily at a social function.
2. Engaging in unprotected sex.
3. Driving a car without wearing a seat belt.
4. Riding a motorcycle without a helmet.
5. Sunbathing without sunscreen.
6. Walking home alone at night in an unsafe area of town.

Domain-Specific Risk-Taking (Adult) Scale – Risk Perceptions

People often see some risk in situations that contain uncertainty about what the outcome or consequences will be and for which there is the possibility of negative consequences. However, riskiness is a very personal and intuitive notion, and we are interested in **your gut level assessment of how risky** each situation or behavior is.

For each of the following statements, please indicate **how risky you perceive** each situation. Provide a rating from *Not at all Risky* to *Extremely Risky*, using the following scale:

1	2	3	4	5	6	7
Not at all risky	Slightly risky	Somewhat risky	Moderately risky	Risky	Very risky	Extremely risky

1. Drinking heavily at a social function.
2. Engaging in unprotected sex.
3. Driving a car without wearing a seat belt.
4. Riding a motorcycle without a helmet.
5. Sunbathing without sunscreen.
6. Walking home alone at night in an unsafe area of town.

Domain-Specific Risk-Taking (Adult) Scale – Expected Benefits

For each of the following statements, please indicate the benefits you would obtain from each situation. Provide a rating from 1 to 7, using the following scale:

1	2	3	4	5	6	7
No benefits at all			Moderate benefits			Great benefits

1. Drinking heavily at a social function.
2. Engaging in unprotected sex.
3. Driving a car without wearing a seat belt.
4. Riding a motorcycle without a helmet.
5. Sunbathing without sunscreen.
6. Walking home alone at night in an unsafe area of town.

Objective Numeracy Scale (Chapter 4)

You will be shown 15 numerical questions. Each question will require you to calculate your answer. Each question has a few words behind the answer line to indicate what type of answer is required. You <u>cannot</u> use a calculator or any other means of help, but you can use paper and pen for calculations.

1. Imagine that we rolled a fair, six-sided die 1,000 times. Out of 1,000 rolls, how many times do you think the die would come up even (2, 4, or 6)?

Rolls out of 1,000 ____________________

2. In the BIG BUCKS LOTTERY, the chance of winning a $10 prize is 1%. What is your best guess about how many people would win a $10 prize if 1,000 people each buy a single ticket to BIG BUCKS?

Persons out of 1,000 ____________________

3. In the ACME PUBLISHING SWEEPSTAKES, the chance of winning a car is 1 in 1,000. What percent of tickets to ACME PUBLISHING SWEEPSTAKES win a car?

% ____________________

4. Which of the following numbers represents the biggest risk of getting a disease?

1 in 100   1 in 1,000   1 in 10

5. Which of the following numbers represents the biggest risk of getting a disease?

1%   10%   5%

6. If Person A’s risk of getting a disease is 1% in ten years, and Person B’s risk is double that of A’s, what is B’s risk?

% ____________________

7. If Person A’s chance of getting a disease is 1 in 100 in ten years, and Person B’s risk is double that of A's, what is B’s risk?

% ____________________

8. If the chance of getting a disease is 10%, how many people would be expected to get the disease out of 100 people?

Persons out of 100 ____________________

9. If the chance of getting a disease is 10%, how many people would be expected to get the disease out of 1,000 people?

Persons out of 1,000 ____________________

10. If the chance of getting a disease is 20 out of 100, this would be the same as having what chance of getting the disease:

% ____________________

11. The chance of getting a viral infection is .0005. Out of 10,000 people, how many of them are expected to get infected?

Persons out of 10,000 ____________________

Descriptive items (Chapter 4)

1. How satisfied are you with the policies of the UK government to slow the spread of corona virus?

Extremely satisfied	Very satisfied	Somewhat satisfied	Neither satisfied nor dissatisfied	Somewhat dissatisfied	Very dissatisfied	Extremely dissatisfied

2. I regularly check the numbers of infection, hospitalisation and deaths relating to corona virus.

Strongly agree	Moderately agree	Somewhat disagree	Neither agree nor disagree	Somewhat disagree	Moderately disagree	Strongly disagree