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Age differences in the effects of metacognition on financial decision-making (Alternative Format Thesis)

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Age differences in the effects of metacognition on financial decision-making

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Abstract

Previous literature has acknowledged that ageing is associated with declines in cognitive ability and deliberative processes and predicted that older adults could more likely exhibit decision biases. Hence, older adults could find increasingly challenging the delineation of their financial plan and make inappropriate choices when faced with financial decisions. Accordingly, it seems relevant to investigate the processes that underlie decision-making and can counteract the misleading tendencies that drive people's behaviour. This project focuses particularly on the relevance of having awareness concerning the way individuals decide and explores how age-related variance in metacognitive abilities impacts upon financial decision-making. This thesis introduces a novel experimental method to investigate metacognition in decision-making tasks and reports the results of a series of empirical studies assessing the age-related effects that metacognition has on financial choice behaviour and risk preferences at the individual level and on strategic interactions at the social level, so as to explore metacognitive processing in simulated real-world decision scenarios. Considering that metacognition can be broken down into subprocesses, this project also aims to ascertain which particular processes are affected by age and which may act as buffers against cognitive decline. This goal is achieved by exploring both self-reported measures on the functioning of these subprocesses and data gathered with the electroencephalography (EEG), directly measuring the neural markers of metacognitive processes. Taken together, the results suggest that metacognition has a crucial role in decision-making. More precisely, the main findings explain under which conditions high metacognitive skills act as moderators of other psychological variables that influence choice behaviour and when social non-cooperative interactions benefit, in terms of wellbeing, from the presence of social metacognitive competences.

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Introduction

In the last decades, most countries in the world have experienced an increase in the proportion of older persons in the population and the pace of population ageing is expected to accelerate in the coming years. According to the data provided by the United Nations (2017), the population aged 60 years or over increased worldwide from 382 million in 1980 to 962 million in 2017 and is projected to more than double its size again by 2050, growing to nearly 2.1 billion. The number of people aged 60 years or over worldwide is growing faster than the number of individuals in all younger age groups and is expected to increase from one in eight people recorded in 2017 to one in five people projected by 2050.

Many benefits for individuals, families, and society are associated with this greater longevity. For instance, older adults can support their families providing assistance in childcare and can benefit societies contributing to the labour force or taking part in volunteering and civic engagement activities. Nevertheless, being one of the main social transformations of the twenty-first century, population ageing has important implications in different sectors of society (United Nation, 2015). From an economic perspective, the labour market and the demand for commodities will face a substantial shift in their structures, whereas the supply of services and social protection in general should account for a higher demand.

The Madrid International Plan of Action on Ageing (MIPAA) on which 159 governments agreed in 2002 recognises that older individuals contribute to the development of societies and governments should commit to promote their wellbeing by designing policies aimed to anticipate and deal with this fast ongoing change in the composition of the population. Sectors such as employment, pensions, health care, and infrastructure require an urgent plan of new initiatives (United Nation, 2015).

Similar and complementary to the economic changes, there will be a radical change in the financial market. On the one hand, given population ageing, a change in the risk preferences on society as a whole is forecastable. On the other hand, given the importance of high-quality judgements and decision-making in later adulthood, it emerges the necessity of defining interventions to ensure that appropriate financial decisions are taken by individuals. In fact, age-related declines in cognitive processes could, in principle, increase the difficulties related to the choice of optimal financial management (Li et al., 2015). Due to the complexity and uncertainty that characterise today's world and in particular the financial instruments, the ability to maintain high decision-making abilities can be difficult even for experts in the sector and, often, it oversteps the knowledge of the 'average individual' (E Peters, Finucane, MacGregor, & Slovic, 2000). Consequently, the aim of this PhD project is to design and conduct research aimed at better understanding the mechanisms that underlie choice behaviour in our ageing population, identifying areas of vulnerability and areas in which older adults unveil high levels of competence.

Since choice behaviour is affected by individual differences that change with age, one method of understanding decision-making is to study the influence that the psychological processes that underlie choice behaviour have on decision outcomes. Whereas many researchers have explored the relationship between age and financial choices, and the underlying emotional and cognitive processes, there are still some gaps in understanding how other variables – such as metacognition – interact with cognitive and emotional processes when making decisions. This thesis explores how metacognition – i.e., the ability to monitor and control one's own cognitive processing (Flavell, 1979) – is involved in decision-making and whether it can offset age-related cognitive declines. This study answers the question: how is financial decision-making behaviour influenced by metacognition? With a focus on the age-related processes, the main findings can then be used to guide policy making and the design of interventions focused on metacognition and aimed at skill development in older adults' decision-making.

Theoretical Background

Researchers from different disciplines ranging from economists to psychologists and philosophers have extensively studied decision-making, but its understanding is far from fulfilled. Experts agree in defining it as a cognitive process influenced by different factors such as age, attitudes, values, expertise, and judgements. However, researchers have identified metacognition as an equally important variable in the decision process (McCormick, Miller, & Pressley, 1989). Schraw and Dennison (1994) have defined cognition as the act of knowing and metacognition as the ability to reflect upon and monitor such knowledge.

Metacognition is the awareness of one's own cognitive activity and of the skills that are necessary for a given situation, knowledge of the strategies to regulate one's own cognitive processes, and a command for active planning, monitoring, evaluating and revising of cognitive performance (Brown, 1987; McCormick et al., 1989). The main focus of this research is understanding the different dimensions of metacognition when making financial decisions. The relevance of studying this higher cognitive function is fuelled by research showing that metacognition is a teachable skill (e.g., Bailey, Dunlosky, & Hertzog, 2010; Schraw, 2001). Individuals with little knowledge or poor proclivity for finance may be able to compensate for their lacks with the acquisition of a broader repertoire of metacognitive strategies, which can be learned. The potential implication for older adults is the possibility to compensate for the decline in cognitive abilities and maintain high decision-making skills by using metacognitive strategies. There is evidence that individuals with high metacognitive abilities have better performance at problem-solving tasks (Garner & Alexander, 1989; Pressley &

Ghatala, 1990). Furthermore, scholars have highlighted the relevance for investors of being aware of potential investment mistakes and error of judgements (Shefrin, 2000).

According to Olsen (1998), one of the aims of the whole discipline of behavioural finance is to understand and anticipate systematic behaviour, with the final aim of helping investors make more accurate decisions. Existing research has shown that individuals can make suboptimal decisions and be overconfident about them, ignoring their wrong beliefs and the existence of biases that can be misleading. Colombo, Iannello, and Antonietti (2010) have stressed the need to help individuals develop metacognitive strategies able to counteract the biased tendencies that drive people's behaviour. The acquisition of metacognitive competences would improve the knowledge of the psychological mechanisms activated during the decision (Dinsmore, Alexander, & Loughlin, 2008). In turn, this enrichment in the control over one's own mental activity would enhance the ability to correct inappropriate tendencies and result in more appropriate decisions.

A further observation that supports the rationale of this thesis and the investigation of metacognition in decision-making derives form strategic interactions. Game theorists postulate that one of the key processes in social decision-making is the ability to make inferences about other people's beliefs, intentions, and actions. From a psychological perspective, this assumption refers to the fundamental process underlying social metacognition, which enables individuals to form expectations and anticipate others' thoughts and behaviour. However, individuals can have mistaken beliefs about what others will do, which might lead them astray from optimal decision-making (Colombo et al., 2010). Further investigation of the role of metacognition could be beneficial for single individuals and for the society as a whole, as it proves to help individuals correct these misleading biases and judgements.

These considerations provide additional motivation for the work made in this thesis and the particular focus on older adults. Previous research has shown that deliberative processes and fluid intelligence (e.g., working memory, processing speed, inhibitory function) decline with age (e.g., Baltes, Staudinger, & Lindenberger, 1999) and such decline increases the likelihood that older adults exhibit decision biases (Kennedy & Mather, 2007; E. Peters, Hess, Vastfjall, & Auman, 2007). Whereas cognitive function is the most studied variable in the attempt of explaining the underlying processes of decision-making, metacognition is another important component, as it consists in the ability to select and apply appropriate strategies to guide one's own reasoning and decision-making (Schraw & Dennison, 1994). Nevertheless, little effort has been spent to examine the role of metacognition in decision-making and how it changes across the lifespan. Previous studies have used mainly perceptual and memory tasks, and have focused almost exclusively on specific metacognitive experiences, obtaining mixed results in terms of age differences.

The research reported in this thesis answers questions about the variability of financial decision-making in younger and older adults. The main purpose is to better understand the role of metacognition in financial decision-making, both at the individual and the social level, and explain how this relationship changes with ageing.

Significance of the Research Project

This study focuses on one of the burning issues that older adults are facing today: financial decisions. The rationale for focusing on financial decision-making is the need for research able to provide strategies to develop skills in choice behaviour and improve financial management.

The results will potentially benefit two strands of research: the economics and the adult learning literature. The main hypothesis suggests a positive relationship between metacognitive awareness and financial decision-making. The economics and management literature can account for an additional variable – metacognition – which can explain different individuals' attitudes. They will benefit from this study by better understanding how metacognition influences financial decision-making. The adult learning literature could use the results of this research as a platform for the development of aids and interventions based on the improvement of metacognition. Learning models and aids based on metacognition already exist in the educational domain to support students. However, many less programs have been develop to support older adults, especially in the context of decision-making.

Aims and Rationale

Previous research in decision science has extensively studied the outcome of decision-making, whereas there are still gaps in understanding the mental processes that underlie choice behaviour and are used to determine the decision outcome. Particularly, there is a lack of research investigating the relationship between metacognitive strategies and measures of success related to financial decisions and the associated age-related differences. In the attempt of fostering the understanding of these processes, the research project discussed in this thesis aims at investigating some of the psychological processes that are used during decision-making to determine the final outcome; i.e., the decision. More precisely, considering the issues and the gaps in the literature outlined above, this thesis aims at studying age-related differences in the extent to which metacognition influences financial decision-making, using the enriched model of metacognition proposed by Efklides (2008) as reference.

One of the purposes of this thesis is to understand whether higher metacognitive competences are associated with enhanced decision-making abilities and verify the differences in metacognitive processes used by older versus younger individuals when making financial decisions. If metacognitive capabilities are predictive of successful decisions, then individuals can likewise learn metacognitive strategies able to buffer the cognitive decline that comes with ageing and improve their decision-making performance.

This research will add to the existing literature by providing additional considerations and findings that will be beneficial in the following aspects:

1. Gaining an understanding of the decision-making process and the main psychological processes that underlie choice behaviour (Chapters 1 and 2).
2. Developing and testing a specific methodology to assess metacognition and its facets in decision-making contexts (Chapters 3 and 6).
3. Gaining an in-depth understanding of the relationship between age, metacognition, financial decision-making, and risk attitudes (Chapters 3, 4, 5 and 6).
4. Contributing to the understanding of the neural bases of metacognition (Chapter 5).
5. Providing a contribution to the literature on the psychological variables affecting social/strategic interactions (Chapter 6).

Thesis Format

The research aims outlined above will be addressed in the different chapters of this thesis. The thesis presents the following structure:

Chapter 1 presents a literature review on decision-making. The review summarises research relevant to various domains covered in this study, with a focus on the decision-making process. First, a reflection on different perspectives to study decision-making is presented. Then, main contributions made by behavioural economics and psychology to decision-making will be discussed. Finally, the main literature on age differences in the cognitive and emotional processes that underlie decision-making is analysed.

Chapter 2 consists of a literature review that aims at summarising some of the theoretical frameworks on metacognition available in the literature, focusing on the one chosen as a reference for the current thesis. The chapter also provides an overview of the current knowledge and understanding of the development of metacognition and different available methodologies to assess the construct.

Chapter 3 reports the results of a quantitative study aimed at studying changes in metacognitive ability associated with ageing and investigating if higher metacognitive competences can buffer against cognitive decline and low cognitive abilities in the execution of a financial decision-making task.

Chapter 4 uncovers the main findings of a small study investigating the role of metacognition as determinant of risk attitude and analysing whether metacognition can explain the existing variability in the literature on the relationship between risk preferences and ageing.

Chapter 5 presents an EEG study designed to provide direct, quantitative measures of the functioning of key metacognitive components (specifically metacognitive experiences, monitoring and control) and explore how age-related changes in the functioning of the above metacognitive facets interact with financial decision-making.

Chapter 6 discusses a quantitative study exploring how metacognition is involved in the context of social strategic interactions and providing a different explanation to justify the deviations observed in real people from the self-interest behaviour predicted by game theory paradigms.

Chapter 7 provides a general discussion of the main research findings presented in the different chapters. This chapter also elucidates the main limitations of the studies, reflects on practical applications and policy implications, and provides suggestions for future research directions.

Note: This thesis adopts an alternative format (i.e., it includes manuscripts that have been submitted for review). Therefore, and citing the University of Bath's regulations:

"As each academic paper will have self-contained components that may overlap with other sections of the thesis, there may be some duplication of material. The Guidelines for examiners of candidates for degrees by research at the University of Bath alerts the examiners to expect some duplication." (QA7, page 9).

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Chapter 1

An Interdisciplinary Review of Research on Decision-Making with a Special Focus on Age Differences

Chapter Rationale

The narrative literature review discussed in this chapter aims to reflect on economic decision-making from a behavioural and psychological perspective and identify research conducted on age-related changes in the processes that underlie decision-making. The purpose is to contextualise the effects of ageing within the wider, general decision science literature and consider if and how older adults' decision processes are the same or different from those of younger individuals. This answers the research question of what is unique about age changes in the processes that underlie choice behaviour and how they affect decision outcomes.

Therefore, general theories of choice behaviour are reviewed, as they offer a broad framework that informs the understanding of the particularities in decision-making. In addition, this narrative review synthesises existing knowledge with specific reference to the age-related literature.

An Interdisciplinary Review of Research on Decision-Making with a Special Focus on Age Differences

Introduction

Decision-making is concerned with the processes by which individuals choose an option or a course of actions from a set of alternatives on the basis of certain criteria or strategies, with the aim of obtaining outcomes at least as satisfactory as those associated with the other available options (Wang & Ruhe, 2007; Wilson & Keil, 2001). It is possible to identify three interrelated branches in the theory of decision-making: descriptive models, normative models, and prescriptive models. Descriptive models are concerned with how people actually make decisions, without trying to modify, influence, or judge such behaviours (Bell, Raiffa, & Tversky, 1988). They are evaluated by the extent to which they correspond to observed choices and behaviour. Normative theories use logical axioms and rules to provide models of how an idealised, rational decision maker should think and behave, without considering the limited cognitive capacity and the emotional concerns of real people (Bell et al., 1988). Prescriptive theories attempt to bridge the existing gaps between descriptive observations and normative principles, by helping people make better decisions. They aim at identifying thinking and decisions processes that are useful not for an idealised, de-psychologised automaton, but for real individuals (Keller, 1989). The rationale behind this is that good advice should be tailored to the person to whom it is addressed, considering that individuals differ in their thoughts, emotions, needs, and abilities (Bell et al., 1988).

In the attempt of providing mathematically treatable models, standard economic and finance normative theories have simplified human diversity, assuming the rationality of the decision maker. In the last decades, researchers have realised that human behaviour does not fit the strict model of rational behaviour offered by standard economic theory and that the study of decision-making is most effective if conducted in interdisciplinary terms. The recent approaches known as behavioural finance and neuroeconomics attempt to develop a better understanding of economic behaviour by integrating ideas from economics with insights from psychology (Earl, 2005). Specifically, behavioural finance attempts to explain investors' reasoning patterns and the role of the underlying emotional processes (Glaser, Nöth, & Weber, 2004). The related field of neuroeconomics brings together behavioural economics and neuroscience with the aim of discovering the biological mechanisms associated with choice behaviour and specifying more accurate models of decision-making (Glimcher & Rustichini, 2004).

The main feature of this meshing of disciplines is the attempt to avoid the shortcomings that arise from a single perspective by integrating normative, descriptive, and prescriptive models of decision-making. Psychology, neuroscience, economics, and finance can broaden their horizons and obtain more significant results by taking into account the insights of the each other. Economics and finance provide the analytical structure of decision theory, which is based on contributions such as the expected utility theory, insights from microeconomics and game-theoretical models of strategic thinking and interacting (Baddeley, 2013). Psychology and neuroscience contribute with a tradition of empirical research on cognition and emotion, and increasingly precise methods to study human behaviour and its neural mechanisms (Sanfey, Loewenstein, McClure, & Cohen, 2006).

Yet, perhaps the main aspect on which economics, finance, neuroscience, and psychology contribute to each other is the understanding of the nature of the decision-making process, which represents the framework of this thesis. The research project discussed in this thesis enters in this interdisciplinary milieu by investigating particularly how metacognition – i.e., is the ability to monitor, control, and think about our cognitive processes – interacts with cognitive and emotional processes and can help individuals make better decisions. In particular, the project takes into account the age-related differences in decision-making. Research carried out in the field of ageing and decision-making has led to the identification of patterns of age differences in the choice process, but the explanation of these differences may be enhanced by taking into account more factors that may affect decision-making differently across the lifespan, such as metacognition, and investigating their consequences. Studying metacognition in older adults not only is important for improving older adults' lives, but can also deepen the understanding of the decision-making process, of the factors and neural mechanisms that govern it, and their changes over the lifespan.

In what follows, a broad analysis of the evolution of the research on decision-making is provided. The discussion starts with the contribution of standard economic models and the principle of *homo oeconomicus* and proceeds with the contribution of behavioural economics and psychology. It assesses the relevance of cognitive and emotional processes for decision-making, presenting some behavioural finance applications and focusing on the associated age-related changes. Guided by the rationale that ageing has an impact on different aspects of economic preference, including risk attitudes, the chapter also provides a detailed discussion of age-related changes in psychological processes affecting risk preferences and their implications for decision-making. A brief conclusion summarises the main contributions outlined in the chapter and the implication for the PhD work discussed in this thesis.

The Contribution of Economics

Economics offers a useful theoretical framework to understand human behaviour and a general reasoning system applicable to a wide range of problems. The rationale is the idea that behaviour can be interpreted as a decision process where individuals choose between a number of alternatives with the goal of maximising utility (Sanfey et al., 2006). Even if criticised for its assumptions, this perspective has represented for many years the fundamental starting point for the development of economic models, and still represents a reference for research investigating decision-making in many different disciplines.

In the eighteenth and nineteenth centuries, philosophers and economists such as Bentham (1748-1832), Gossen (1810-1858), and Jevons (1835-1882) used the concept of *utility* as a numeric indicator of an individual's happiness and overall well-being. Given this idea, individuals were treated as 'rational actors,' obeying various principles of rational behaviour and making choices so as to maximise their utility; that is, to make themselves as happy as possible. However, these classical economists have never really described how to measure utility (Plous, 1993). Unable to solve conceptual problems aroused by questions such as: how can we quantify the 'amount' of utility associated with different choices? Or, do we have all the same utility?, economists have stopped considering utility as a measure of happiness and reformulated the concept of utility as a way to describe preferences (Varian, 2010).

With regard to choice under uncertainty, probably the most famous theory moving in this direction is the *expected utility theory*, published by John von Neumann and Oskar Morgenstern in their classical work, *Theory of Games and Economic Behaviour*, in 1944. Von Neumann and Morgenstern's expected utility theory is a normative theory of behaviour, intended to describe how people would formulate preferences if they followed certain requirements of rational decision-making. The authors have shown that there exists a utility function, which is consistent with people's expressed preferences and that an 'optimal' decision is the one that *maximises* this expected utility.

Even if the label *expected utility theory* is often used to refer to Von Neumann and Morgenstern's theorisation, it is actually a 'family' of theories that conceptualise the decision maker as *homo oeconomicus*; that is, individuals are assumed to be able to rationally calculate advantages and disadvantages of each alternative, compare them, and choose the course of action that maximises expected utility (Plous, 1993). However, when applying expected utility theory to more important and complex real world choices, it is easy to recognise that decision makers do not operate in this way. Individuals may misunderstand information related to the alternatives and their consequences, avoid making comparisons between options, and have biased perceptions or memories. Moreover, people differ in their attitudes towards risk and even if probabilities remain the same, an optimal decision under risk may change with the circumstances (Neumann & Politser, 1992). Many researchers have criticised expected utility theory because it does not consider many factors that cannot be inferred from principles of rationality but affect decision-making (e.g., culture, ethical and social norms, morality, fairness, or emotions; Kahneman, Knetsch, & Thaler, 1986; Shweder, 1986). In view of these limitations of expected utility theory other researchers have attempted to enrich decision-making models by incorporating psychological factors, giving birth to a new discipline: behavioural economics.

The Contribution of Behavioural Economics

Behavioural economics provides conceptual alternatives to the standard economic models and attempts to explain the foundations of suboptimal behaviour. Whereas classic economic models treat decision-making as a mere cognitive process of calculation, behavioural economics argues that decision-making is more complex and depends on the interactions between noneconomic variables such as: cognition, emotions, mood, personalities, attitudes, preconceptions about the world, etc. (Baddeley, 2013). Two main contributions to the understanding of these deviations from rationality are represented by Kahneman and Tversky's Prospect Theory and their Heuristics and Biases Approach, which are discussed below.

Prospect theory. The very influential prospect theory is a behavioural approach developed by Kahneman and Tversky (1979) to address some of the limitations of the expected utility theory and describe decision-making under risk. Building on experimental evidence revealing behavioural anomalies that are inconsistent with the rationality and the stable preferences assumed by the standard neoclassical approach, Kahneman and Tversky have focused on systematic biases, cataloguing the types of discrepancies between the expected utility theory and descriptive behaviour, and elucidating how the expected utility theory could be modified to better predict actual behaviour.

Some of the key insights of prospect theory include that losses are felt more strongly than gains and that decision makers treat preferences as a function of 'decision weights', which might not correspond to objective probabilities (Kahneman & Tversky, 1979). The authors argue that the first step of the decision process consists in an editing process during which decision makers organise and reformulate the available options as to simplify the choice. Still, Kahneman and Tversky have outlined the framing effect, which refers to the fact that a choice is affected by the order or manner in which the options are presented (Tversky & Kahneman, 1981).

Prospect theory successfully captures experimental results and is promising for understanding deviations from rationality and anomalies in financial decision-making. For example, Thaler, Tversky, Kahneman, and Schwartz (1997) have analysed myopic loss aversion and found that loss aversion combined with the tendency to evaluate outcomes frequently leads to suboptimal decisions.

The main advantage of Prospect Theory is its ability to show with empirical observations that normative models such as the expected utility theory are not always representative of human behaviour. Human beings are not always comparable to the ideal rational man assumed by standard models, but rather, they make systematic mistakes, such as overweighting small probabilities and underweighting large probabilities (Kahneman & Tversky, 1979). However, the theory does not consider the influence of individual differences on decision-making and how individuals can deal with the outlined behavioural biases. Rather than focusing on the outcome of choice behaviour, the research project discussed in this thesis aims at understanding some of the psychological mechanisms that underlie the decision-making process and how individuals can be helped recognise and avoid biased and misleading tendencies.

Despite the great contribution of prospect theory in describing choice behaviour, a further limitation of prospect theory is that it still predicts that decision-making is based on the integration of option attributes, such as probabilities and values. Another view is the *heuristics and biases approach* (Tversky & Kahneman, 1974), which documents many instances of deviations from economic rationality and claims that risky decisions may not rely on an integrative process but can rather be based on a set of comparative processes, such as the use of shortcut heuristics (Gigerenzer & Goldstein, 1996; Kahneman, Slovic, & Tversky, 1982; Tversky & Kahneman, 1974). Evidence suggests that human behaviour is not governed by a unitary mechanism, but rather can be guided by either deliberate or heuristic processes – i.e., ‘rules of thumb’ that simplify the complex decision process by.

The heuristics and biases approach. The *heuristics and biases approach* is still highly influential in the field of decision-making, although it was launched in the 1970. Its main aim is to study the shortcuts known as heuristics that people use in real life when making decisions. Heuristics can be defined as simple procedures or ‘rules of thumb’ that simplify the complexity of the decision process by limiting the comparison of the possible options on a reduced set of attributes (Gilovich & Griffin, 2002).

The heuristics and biases approach is in line with the *bounded rationality* developed by Simon (1987, 1990), who has stated that the complex optimisation problems assumed by the standard economic models are unrealisable in real life due to the limited cognitive processing ability of the human mind and the complexity of the environment. Instead, in many real-world situations, individuals use approximate, heuristic methods for making decisions. According to Simon, decision makers aim to 'satisfy' rather than 'maximise'; that is, seeking something that is 'good enough' and acceptable, although it may not be the optimal solution. More specifically, satisfiers use a shortcut that sets an aspiration level, looks through the possible options in sequence, evaluating them in terms of the degree of satisfaction they would provide, and terminates the search for alternatives as soon as one is found that meets the aspiration level (Simon, 1956, 1990).

The heuristics and biases program has the advantage of contributing to a better understanding of the processes used to make different types of real world judgements. Kahneman and Tversky have identified a set of efficient shortcuts able to outperform the complex computational methods assumed by economic standard models of decision-making. However, since heuristics benefit from a trade-off between effort and accuracy, they can lead to systematic biases (Tversky & Kahneman, 1974). If one of the aim of the heuristics and biases approach is to classify these predictable errors, the research discussed in this thesis attempts to understand how individuals can correct their biased tendencies by using their metacognitive ability. This seems particularly relevant in the field of financial decision-making, where it may be useful for investors being able to acquire further awareness of the way they make decisions and identify possible mistakes caused by the use of overly simplistic heuristics.

One aspects that characterises the heuristic and bias approach and warrants discussion for the aim of this thesis is the dichotomy between deliberate versus automatic behaviours. Since the beginning, the heuristics and biases approach has been guided by the idea that intuitive judgements can be located between the automatic, parallel operations of perception and the controlled, serial operations of reasoning (Kahneman & Frederick, 2002). The so-called *dual-process theories* of reasoning are consistent with the hypothesised existence of these two types of mental processes and can advance the contribution of the heuristics and biases approach by considering how heuristics work in decision-making and can be overridden when misleading.

The Contribution of Psychology

While economic formal models assume that individuals make decisions on the basis of a rational evaluation of the alternatives and their consequences, other research has demonstrated that these models are not descriptive of human behaviour (Tversky & Kahneman, 1974). Rather, reasoning and decision-making are more complex processes and their outcome depends on the interaction between different systems.

Dual-process theory. Psychological evidence suggests that choice behaviour is derived, overall, by the interaction of two qualitatively different types of processes (e.g., Evans, 2008; Shiffrin & Schneider, 1977; Strack & Deutsch, 2004). Metcalfe and Mischel (1999) have differentiated between a hot versus a cool system, where the former comprehends affective processes and the latter includes more cognitive and deliberative processes. As Gladwin and Forward (2015) have pointed out, the terms “hot” and “cold” are widely used, but many other labels have also been suggested, such as: “impulsive” versus “reflective” (Strack & Deutsch, 2004), “reflexive” versus “reflective” (Lengfelder & Gollwitzer, 2001), the “X-“ versus the “C-” system (Lieberman, 2007), “automatic” versus “controlled” (Shiffrin & Schneider, 1977), and “System 1” and “System 2” (Kahneman, 2003; Stanovich & West, 2000).

System 1 is a set of instinctive and innate skills that individuals share with other animals and allow them to perceive the world and orient attention (Evans, 2003; Kahneman, 2012). System 1 is often defined as a set of sub-systems that are relatively quick, automatic, effortless, heuristic-based, affective, and can often be carried out in parallel. On the contrary, System 2 is a set of deliberate and analytic processes that require attention and rely on limited capacity mechanisms (Kahneman, 2012). System 2 has the advantage of being highly flexible and able to support a wide variety of goals (Evans, 2003, 2008). However, it processes information sequentially, on the basis of abstract and logical reasoning, and is thus slower and more effortful.

Across a wide range of tasks, especially when confronted with complex decisions, people rely on System 1 by default. Since individuals usually make decisions on the basis of strategies that worked well in the past, if they have relevant expertise, they will recognise the situation and provide an intuitive solution that is likely to be correct (Kahneman, 2012). When the task is difficult and a skilled solution does not come to mind, individuals can still use a heuristic process to imagine the various possible outcomes and choose the one that 'feels right' (Fletcher & Carruthers, 2012). However, as previously mentioned, System 1 relies on heuristic processes and can result in suboptimal judgements and decisions. In these cases, individuals can switch to a slower, more deliberate form of thinking, governed by System 2. One of the main roles of System 2 is to monitor the quality of the responses provided by System 1 and inhibit its biased judgements if better decision alternatives exist, overriding them with a different response, based on reflective reasoning (Kahneman, 2012).

As Thompson (2009) has pointed out, one of the crucial aspects for dual-process theory is the understanding of the timing and the degree of System 2 interventions. One of the possible frameworks to scrutinise System 2 engagement is based on metacognitive processes (e.g., Evans, 2009; Stanovich, 2009; Thompson, Prowse Turner, & Pennycook, 2011). Metacognition is the ability to think about System 1 and System 2 processes at a higher level of reflection (Thompson, 2009) and represents a cognitive means to monitor and regulate cognitive actions (Nelson & Narens, 1990).

Metacognition can be interpreted as a set of monitoring processes that evaluate the adequacy of System 1 intuitive outputs and determine whether and to what extent an intervention of System 2 is required (Thompson, 2009; Thompson et al., 2011). A control metacognitive process would thus use System 2 to modulate, reinforce or correct the output of System 1 (Fletcher & Carruthers, 2012). Within this integrated framework, decision-making is seen as a continuous cycle where the interactions between non-analytic and analytic processes are supported by metacognitive processes that feed back into System 1 and System 2 processes to either reinforce or correct their output. The outcome is a dynamic flow of information in which decision quality increases, enhancing in turn the expertise of the decision maker and the ability to reason quickly and accurately. According to these premises, it seems plausible to hypothesise that the development of relevant metacognitive competences can counteract the biased tendencies that drive people's behaviour (Colombo, Iannello, & Antonietti, 2010) and assume that better choices would follow from the acquisition of a more adequate use of metacognition, as hypothesised in this research project.

Cognition and Emotions in Decision-Making

Multiple-system theories and the distinction between automatic versus deliberate processes link to the focus of research in psychology and behavioural economics on how cognition and emotions are involved in attitude formation and impact upon individuals' actions. Based on extensive study of the brain and on the experience of brain-damaged patients, Damasio (1994) has argued that we cannot understand human behaviour if we do not recognise that reason and emotion are integral parts of a human being, and that brain and body are interconnected. This interaction reflects the link between decision-making systems.

Emotions can influence cognitive processes and can be involved in the decision-making process at either an intentional or an unintentional level. In the first case, the potential reactions to the decision outcome are taken into consideration when evaluating the possible alternatives (e.g., Bell, 1982; Josephs, Larrick, Steele, & Nisbett, 1992; Ritov, 1996). For example, individuals often choose an alternative with the aim of minimising the possibility of experiencing regret later (Bell, 1982; Mellers, Schwartz, & Ritov, 1999). In the second case, decision makers are subject to the *affect heuristic* (Slovic, Finucane, Peters, & Macgregor, 2002); that is, affective states associated with mental representations of objects are used as a cue in making decisions. Individuals' choices can also be affected by incidental emotions that are not related to the current decision, such as emotions elicited by a prior unrelated situation that persists and affects subsequent behaviour (e.g., Lerner, Small, & Loewenstein, 2004).

Although in some situations emotions can lead to better decisions than a careful and deliberate analysis of all the available options, intense emotions can in some circumstances lead to impulsive, suboptimal, and sometimes self-destructive choices (G. Loewenstein, 1996). Recognising that emotions have a profound impact on behaviour has important implications. In particular, it seems relevant to understand how individuals can recognise the possibly misleading effect of emotions on decision-making and the need to turn to a more effortful and deliberate decision process. As seen in the previous section, metacognition seems to be a good candidate in helping individuals in this process (Thompson et al., 2011) and its interplay with cognition and emotion is further analysed in this research work.

As mentioned in the introduction, most research on decision-making has been conducted in terms of normative theories to assess performance, descriptive models to explain decision-making, and prescriptive solutions to improve choice behaviour. However, very little attention has been spent to acknowledge the dynamic nature of decision-making and study how decision-making skills develop and change during the life cycle (Dhami, Schlottmann, & Waldmann, 2011). Since population is getting older worldwide, it seems particularly relevant to enhance the understanding of the effect that ageing has on the maintenance of independent decision-making. Research conducted in the last decades has demonstrated that the cognitive and emotional process that have been proven to be relevant to decision-making are indeed affected by ageing and can lead to relevant changes in choice behaviour. Keeping a reference to dual-process theories, the following section addresses the specific changes in the deliberative and affective/experiential processes that may be attributable to life-span changes and have relevant implication for decision-making.

Age-Related Changes in Economic Behaviour

Age is a descriptive variable accounting for many of the changes that characterise economic behaviour in late life (Mohr, Li, & Heekeren, 2010). Older adults[1] undergo important changes in different aspects of their life and are required to make important decisions, which might impact the remaining years. A better understanding of the psychological processes that underlie choice behaviour in later adulthood can help identify areas of vulnerability and competence that may in turn be used to support older adults facing the challenges associated with ageing (E. Peters, Hess, Vastfjall, & Auman, 2007).

Since this thesis aims to understand age differences in the role of metacognition in decision-making and its interplay with cognitive and emotional processes, it is important to gain a general picture of the main age-related changes in cognitive and emotional processes and their impact on choice behaviour. Accordingly, the following session reviews research on age-related changes in decision-making, and how they may be explained by age-related changes in deliberative and affective information processing.

[1] Older adults are usually defined as individuals aged 65 years or older (American Psychological Association, 2014), although alternative interpretations are available in the literature (e.g., over 55 years; Fein, McGillivray, & Finn, 2007; Zamarian, Sinz, Bonatti, Gamboz, & Delazer, 2008).

Cognitive system and ageing. Research from different domains (e.g., preferential choice, mathematical skills and memory tasks) has highlighted that people have a repertoire of many different, possible strategies for comparing all of the various pieces of information involved in a choice (Payne, Bettman, & Johnson, 1988; Siegler, Adolph, & Lemaire, 1996). Furthermore, individuals are able to select strategies that fit specific environments and situations; that is, they adapt their strategy use to the structure of the task to enhance performance (Mata, Schooler, & Rieskamp, 2007; Rieskamp & Otto, 2006). However, in everyday life, strategy use varies largely across the population (Mather, 2006).

Fluid intelligence and crystallised intelligence are two components of intellectual functioning that are related to decision-making in general and strategy selection in particular, and follow different trajectories across the lifespan (Horn & Cattell, 1967; Mata et al., 2007). While fluid intelligence tends to decline with age, crystallised intelligence remains stable, or even improves in later adulthood (Mata et al., 2007).

***Fluid intelligence*.** Fluid intelligence is the ability to think logically and solve new problems (Horn & Cattell, 1967), and consists of deliberative processes such as working memory, processing speed, and inhibitory function. Research has documented a decline in the efficiency of these processes with advancing age (Baltes, Staudinger, & Lindenberger, 1999). Older adults tend to be slower at processing and learning new information and in complex choice environments, they have greater difficulties in understanding information concerning the available options (Finucane et al., 2002; Wood, Busemeyer, Koling, Cox, & Davis, 2005). Due to a decline in memory, they tend to rapidly forget options' values and struggle inhibiting the impact of irrelevant information and automatic response sets (e.g., Finucane, Mertz, Slovic, & Schmidt, 2005; Henninger, Madden, & Huettel, 2010; Lemaire, Arnaud, & Lecacheur, 2004;

Queen & Hess, 2010). Age-related cognitive decline may lead older adults to rely on simpler and less cognitively demanding strategies, regardless of environment structure, and select non-adaptive strategies which affect the quality of their decisions (e.g., Mata et al., 2007; E Peters, Finucane, MacGregor, & Slovic, 2000; Sanfey & Hastie, 2000).

According to the literature on information search patterns, when making decisions individuals deliberately select pieces of information using a combination of compensatory and noncompensatory decision strategies (Johnson, 1990; Queen, Hess, Ennis, Dowd, & Grühn, 2012). Whereas compensatory strategies consist in summing, weighing, or averaging information for each alternative, noncompensatory strategies consist in comparing each alternative on the most important dimensions and eliminating those that do not contain desirable values (Queen et al., 2012). Researchers have found that older adults make a more marked use of less cognitively demanding noncompensatory strategies such as satisfying; that is, focusing on the attempt to identify an alternative that is 'good enough' rather than the best one (e.g., Mata et al., 2007; Mata, von Helversen, & Rieskamp, 2010; Queen et al., 2012; Riggle & Johnson, 1996).

From the above review it is clear that previous research on age-related differences in decision-making has focused mainly on the cognitive decline that may degrade decision competence. Moreover, the approach adopted in most studies has considered decisions as purely rational processes aimed at choosing the optimal option after having carried out a deliberate evaluation of all the possible alternatives. However, it should be noted that good expertise and knowledge in the domain of the decision can lead to a faster and less rigorous consideration of the information related to the possible options, without altering the quality of the outcome of the decision process (Mather, 2006). This reflection links to some recent studies stressing that while fluid intelligence tends to decline with age, crystallised intelligence usually increases over the lifespan as a reflection of experience (Mata et al., 2007).

Crystallised intelligence**.** Crystallised intelligence refers to the repertoire of knowledge acquired with experience, education, and culture (Cattell, 1963). Previous studies have found that crystallised intelligence tends to increase with age and remain stable after 60 years of age (e.g., Finucane et al., 2005; Horn & Cattell, 1967). In particular, there is evidence that older adults are better able than younger adults to place problems in context and adjust their strategy according to the specificity of the situation (Blanchard-Fields, Mienaltowski, & Seay, 2007; Watson & Blanchard-Fields, 1998).

Experience and familiarity with the decision context can minimise the impact of complexity, even if it leads to a more limited information search (Queen et al., 2012). Increased experience in older adults may compensate the cognitive decline and lead to a more adaptive decision-making (Baltes et al., 1999). As a reflex of wisdom, older adults are less affected than younger adults by the attraction effect; that is, the phenomenon by which inserting an irrelevant alternative among the possible choice options leads individuals to change their preference and choose a different alternative from the original set (Kim & Hasher, 2005). Still, cognitive losses can be compensated by intrinsic motivational factors that lead individuals to use compensatory strategies in the evaluation of the choice alternatives (Queen et al., 2012).

In summary, fluid and crystallised intelligence provide two possible views on the impact of ageing on decision-making: a 'negative' view, based on the physiological age-related cognitive decline that limits the repertoire of possible strategies and leads older adults to rely on simpler strategies, and a 'positive' view, based on the evidence that older adults have more experience in selecting effective strategies based on the specific tasks and environments (Mata et al., 2007). The research project discussed in this thesis aims at adding to this distinction by understanding how older adults can engage in metacognitive processes which, strengthened by the use crystallised intelligence and past experiences, can compensate the natural physiological decline in fluid intelligence.

Affective system and ageing. As previously discussed, decision-making is also affected by emotional processes, especially when choices are made under conditions of risk and uncertainty (Schwarz, 2000; Tversky & Kahneman, 1974; Weber & Johnson, 2009). The relationship between emotion and decision-making is particularly relevant for ageing research because older adults undergo important emotional changes that may influence decision-making processes and behaviour (Mather, 2006). In particular, research suggests that older adults make a more marked use of heuristic processes (Slovic et al., 2002), exhibit inaccuracies in affective forecasting (Weierich et al., 2011), and are subject to a positivity bias that leads them to maintain positive affect and avoid the experience of negative emotions (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000). Each of these processes is discussed in the following sections.

The use of heuristics during the decision-making process. Previous research has suggested that ageing involves a shift towards a more emotional and heuristic form of decision-making (Slovic et al., 2002; Weierich et al., 2011). Whereas effortful information processing declines with age, intuitive processing is preserved, or even enhanced in elderly (Isaacowitz, Charles, & Carstensen, 2000; Park, Nisbett, & Hedden, 1999). Older adults tend to rely more than younger adults on learned stereotypes (Mather, Johnson, & De Leonardis, 1999), on their past experience (Frey, Mata, & Hertwig, 2015), and on a particular type of heuristic: the affect heuristic – i.e., the tendency to base choices on the emotional impression associated with the decision (Mikels, Shuster, & Thai, 2015). Using an affective impression can be far easier and more efficient than analysing all the attributes of the possible options, especially in complex decision contexts (Slovic et al., 2002). Since due to cognitive decline, older adults tend to process information more slowly than younger adults, they can feel more pressured by time and rely more heavily on the affect heuristic with the aim of making quick decisions (Yates & Patalano, 1999).

The reliance on emotions and heuristics can lead older adults to make suboptimal decisions in some situations and aid decision-making in other circumstances. A greater reliance on affect can be detrimental, for example, when a decision feels familiar but is actually quite different from decisions made in the past, or when facing a delicate health care or financial decision, requiring a careful and systematic analysis of complex information (Carpenter & Yoon, 2011). However, in other circumstances, the use of emotions and heuristic processes can help older adults making better decisions. Studies on framing effects have shown that older adults perform better if the information is presented in a more emotion-focused format, which boosts affective reactions to the available options rather than encouraging individuals to engage in systematic analyses of the attributes of each option (Carpenter & Yoon, 2011; Mikels et al., 2010). For example, in the field of health care decisions, Mikels and colleagues (2010) have investigated whether individuals asked to deliberately analyse the possible alternatives obtain a different decision outcome than individuals asked to focus on the emotions associated with each option. Results indicate that younger adults perform better when they analytically analyse the available options, whereas older adults make choices of higher quality when they take into account the emotional reaction to the options. These findings support the idea that affect heuristic can aid older adults' decision-making.

Another interesting result is that older adults' performance seems to be enhanced by a major focus on emotional stimuli with positive valence (e.g., Charles, Mather, & Carstensen, 2003; Mather et al., 2004). This phenomenon is discussed next.

The positivity effect. Older adults tend to reduce their negative affective experience and focus on information with a positive valence (i.e., the so-called positivity effect; Carstensen et al., 2000; Mather & Carstensen, 2005). According to the Socioemotional Selectivity Theory, with advancing age, individuals begin perceiving time as more limited and, as a consequence, change their goals, focusing less on opportunities and more on limitations, prioritising positive activities and experiences (Carstensen, 2006; Carstensen, Isaacowitz, & Charles, 1999). Despite physical decline and social losses, older adults experience higher levels of emotional well-being, longer durations of positive emotions and shorter durations of negative emotions than younger adults (Carstensen et al., 2000). Only when approaching their 80s, individuals exhibit a decrease in the quality of emotional experience, but the frequency of negative emotional experiences remains lower than in younger adults (Charles, Reynolds, & Gatz, 2001). However, the ability to avoid negative experiences, focusing on the positive, requires good cognitive control (Knight et al., 2007; Mather & Knight, 2005). Under cognitive load, such as when dealing with more than one task at the time, older and younger adults' attentional resources are directed to negative stimuli in a similar manner (Knight et al., 2007).

There is psychological evidence showing that the increased focus on regulating current emotions in older adults affects preferences, attention and memory (Mather & Carstensen, 2005). Evidence shows that emotional stimuli can enhance performance, even in tasks which require the activation of cognitive processes that decline with age, such as attention and memory (e.g., Charles et al., 2003; Denburg, Buchanan, Tranel, & Adolphs, 2003; Mather et al., 2004). Older adults tend to respond faster to and are more likely to remember positive stimuli than neutral or negative information (Fung & Carstensen, 2004; Mather & Carstensen, 2003). They look preferentially towards positive stimuli and away from negative ones (Isaacowitz, Allard, Murphy, &

Schlangel, 2009), and show a decreased reactivity of the amygdala (a region of the brain associated with emotional attention) in response to emotionally negatively- vs positively-valenced pictures, while in younger adults there are similar levels of activation for both (Mather et al., 2004). Furthermore, age-related decline in long-term memory seems to be impaired in the retention of negative or neutral information, while it is preserved for positive information (Kensinger, Garoff-Eaton, & Schacter, 2007; Kensinger, O'Brien, Swanberg, Garoff-Eaton, & Schacter, 2007). Still, older adults exhibit a positivity bias in their autobiographical memories (Kennedy, Mather, & Carstensen, 2004) and show choice-supportive memory; that is, they attribute more positive features to the chosen option and more negative features to the rejected options (Mather & Johnson, 2000; Mather, Shafir, & Johnson, 2000).

To summarise, the predominant focus placed by older adults on positive emotional information seems to improve performance in different domains and can be considered a strategy used by older adults to deal with the cognitive decline and the related limitations in mnemonic and attentive processes. However, in circumstances requiring a reflection on both negative and positive information, older adults' avoidance of negative information could be detrimental. This point is further explained in the following section in the context of affective predictions about the future.

The power of the present on predictions about the future. Human beings possess the ability to simulate the future in their minds by combining incoming information and stored memories into mental representations of the external world (Gilbert & Wilson, 2007). When making a future plan, they use past experiences and acquired general knowledge as an effective guideline to construct ideas about the future (Atance & O'Neill, 2001; Okuda et al., 2003). Mental simulations of the future can elicit emotional reactions in the present, allowing people to anticipate the pleasant or unpleasant character of future events and predict the reactions they are likely to have when the simulated events actually occur (Golub, Gilbert, & Wilson, 2009; Schwarz & Strack, 1999).

Recently, researchers have recognised that this affective forecasting can be inaccurate and started questioning on age differences in the ability to predict future emotional experiences. As Gilbert and Wilson (2007) have pointed out, simulations of future events are biased if built on memories that do not accurately represent the past. Even if these affective forecasting errors are common to all the human beings, due to their biased memory retrieval, older adults can exacerbate this error. Old age is a phase of life characterised by complexity, instability, and uncertainty. As people age, they have difficulties in remembering the past and are less able to project themselves into a future characterised by different features from the present (Weierich et al., 2011). As a consequence, older adults might rely by default on what 'feels right', according to the current emotional state. A decision-making based exclusively on the current emotional state is extremely risky, as it can minimise the reliance on relevant past experience and compromise the ability to objectively evaluate future scenarios.

Another bias in the affective forecasting can result when individuals omit incidental features of future events and mispredict them as more positive or negative (Liberman, Sagristano, & Trope, 2002; Weierich et al., 2011). Considering the findings on the positivity effect, it can be claimed that older adults are likely to make mistakes in their forecasting by mispredicting future events as more positive. Particularly, they tend to perceive retirement as an extended holiday and risk to perceive 'life after retirement through hazy rose coloured glasses' (Weierich et al., 2011, p. 198). When thinking about future events, the propensity to avoid emotional swings and pursue only pleasant experiences prevents older adults from making optimal decisions, based on a careful analysis of the details and on the assessment of both positive and negative aspects (Nielsen, Knutson, & Carstensen, 2008; Weierich et al., 2011). This positivity effect also causes an insensitiveness to anticipated losses in older adults; that is, they are not able to emotionally manage hypothetical negative outcomes and prefer to deal with them only at their actual occurrence (Nielsen et al., 2008; Samanez-Larkin et al., 2007).

Overall, these findings are in line with the claim of Socioemotional Selectivity Theory that, with advancing age, individuals attempt to maintain an overall sensation of positive well-being. This sensation may be enhanced by optimising the emotional experience (Carstensen, 2006) and reducing the experience of unpleasant emotions when anticipating losses or negative events (Samanez-Larkin et al., 2007).

From the evidence reviewed in the above section it results clear that the role played by emotions on older adults' decision-making is twofold. If on the one hand a greater reliance on emotions seems to be a good strategy to help individuals dealing with cognitive decline, on the other hand a misleading use of emotional processes can impair decision-making and lead to suboptimal choices. This reflection makes clear the need for a better understanding of the interaction between cognition and emotion in older adults and strengthens the aim of the research project here discussed to consider how metacognition relates to these two types of processes.

On the basis of the above studies demonstrating age-related changes in cognitive and emotional processes and in line with the finding that cognitive abilities and emotions are involved in risk perception and estimate (Mohr et al., 2010), a further topic that requires attention and is discussed in the following section is the relationship between age, perception of risk, and risk-taking behaviour.

Changes in Decision-Making Under Risk over the Lifespan. An important feature of decision-making is that in most situations, the decision outcome involves a degree of uncertainty. Expected utility theories claim that it is possible to predict risky choices by assuming that individuals base their decision-making on an expectation-based computation that assesses the likelihood of the outcome of each alternative (G. F.

Loewenstein, Weber, Hsee, & Welch, 2001). In doing so, they assume that decision-making is a purely cognitive activity, whereas feelings and emotional aspects associated with the choice are not considered part of the process. However, perceptions of risk are highly subjective and the value people place on alternative actions depends on the consequences associated with them. Similar behaviours can present very different risks for individuals in different circumstances and similar risks can result from very different behaviours (Fischhoff, 1992).

Some researchers have analysed how risk perception and risky behaviour differ between younger and older adults. Probably, the most common stereotype is that older adults are more risk avoidant (Okun, 1976). In line with this stereotype is the reasoning that due to a lack of time and diminishing physical resilience, with advancing age it is more difficult to compensate for decisions of poor quality and make up for eventual mistakes (E. Peters et al., 2007). If a younger adult invests in a stock and the market crashes, they still have plenty of time to remedy and save money for retirement, whereas losing savings in older age can be more problematic (National Research Council (US) Committee on Aging Frontiers in Social Psychology, 2006; Weierich et al., 2011). Accordingly, Dulebohn (2002) has examined university employees and found that older adults are more conservative in hypothetical asset allocations.

In conflict with the stereotype of cautious older adults, another strand of research deals with the *risk-as-feelings hypothesis* and the idea that behaviour in risky situations is mediated by emotional aspects, such as mood, time interval between decision and outcome, and vividness in the mental representation of the outcome (G. F. Loewenstein et al., 2001). Particularly, risk aversion seems to be driven by negative emotions, such as fear, dread, and anxiety. Since emotional processes undergo fundamental changes across the lifespan and negative emotions seem to decrease with age, it can be hypothesised that older adults will have a different perception of risk and increase their risk taking behaviour (Mather, 2006). Brouthers, Brouthers, and Werner (2000) have analysed data about managers of the Dutch bank and insurance companies and found that older managers tend to take more risky decisions than younger managers. A study with faculty and university staff has found that risk tolerance – i.e., the maximum amount of uncertainty that a person is willing to accept when making a financial decision – increases with age (Grable, 2000). However, in a study examining the role of positive and negative emotions in risky decision among younger and older adults, Chen and Ma (2009) have found that older adults' decisions are significantly influenced by positive emotions, whereas younger adults' decisions are influenced by negative emotions, but older adults appear to be less likely to make risky choices in investment scenarios. On the contrary, Chou, Lee, and Ho (2007) have studied the influence of age differences on specific mood for risk taking behaviour and failed to find a main effect of age, as individuals in the positive mood exhibited a greater risk taking tendency than individuals in the negative mood, independently of age.

The above result is in line with other experiments showing that age makes no difference in risk attitude and behaviour (e.g., Dror, Katona, & Mungur, 1998; Huang, Wood, Berger, & Hanoch, 2013; Mayhorn, Fisk, & Whittle, 2002). Several studies using the Iowa Gambling Task (where participants learn the contingencies of the payoffs through trial and error) have found no significant age differences in selecting cards from high-reward decks or from the high-risk decks (e.g., Kovalchik, Camerer, Grether, Plott, & Allman, 2005; MacPherson, Phillips, & Della Sala, 2002; Wood et al., 2005). According with this result are findings using hypothetical choice dilemma. For example, Zwahr, Park, and Shifren (1999) have presented participants with a scenario where women had to choose whether to begin an Estrogen Replacement Therapy to combat menopausal distress and showed that younger and older adults do not differ in their estimates of the risk of therapy.

In summary, many of the studies analysing changes in risky behaviour and risk perception across the lifespan have observed a similar behaviour in younger and older adults, contrary to the popular conception of cautious older adults and to the hypothesis that older adults are less risk averse because of the changes in their emotional processes. However, some studies have obtained opposite results. As Mather (2006) has pointed out, conflicting results may be due to factors confounded with age, such as income, time horizon of the investment, and cognitive abilities. To obtain a better understanding of how risky behaviour changes with age, further research should include in the analysis other variables that might affect risky behaviour and its relationship with age. Among the possible underlying variables, the research discussed in the current thesis takes into account the role of cognitive and metacognitive abilities in shaping individuals' risk attitudes and explaining individual differences.

Conclusion

In this chapter, some of the key ideas from the literature on psychology, neuroeconomics, behavioural economics and finance were introduced to form a basic foundation for the exploration of the variables that affect choice behaviour and age-related changes in decision-making. The limitations of the standard economic models were addressed and alternative approaches showing that human decision-making is limited by a bounded rationality were explored. As explained above, the need to make efficient and quick decisions leads to the implementation of heuristic processes, which can cause systematic biases in behaviour and choice. The contribution of both psychology and behavioural economics in explaining how individuals differ from the rational *homo oeconomicus* assumed by the standard economic models were analysed through the discussion of Prospect Theory, the heuristics and biases approach, dual-system theories, and multiple-system hypotheses. Furthermore, it was shown that financial decision-making depends on the interaction between cognitive and emotional processes.

Focusing on insights relevant to the research discussed in the current thesis, the chapter proceeded considering age-related changes in decision-making. To date, only a few studies have analysed age-related changes in the role of psychological factors in decision-making, obtaining divergent results. Some researchers have shown that sometimes these changes lead to the same decisions across the lifespan (Johnson, 1990; Meyer, Russo, & Talbot, 1995; Walker, Fain, Fisk, & McGuire, 1997), whereas in other occasions they result only in subtle differences in the decisions made (Finucane et al., 2002; Mather, 2006). Still, in some other cases, the quality of the decisions made by older adults exceeds the quality of younger adults' choices (e.g., Tentori, Osherson, Hasher, and May, 2001).

Much of the research analysing age-related changes in decision-making has focused on cognitive and emotional processes. As shown in the review, cognitive processes undergo a physiological decline with age, leading to a possible change in the way people make decisions. One of the age-related changes that recurs in many studies is the reliance on less cognitively demanding strategies and noncompensatory rules in older adults. Research has also revealed that older adults may be subject to a memory bias, which can lead to suboptimal decisions. It is easy to realise that most of the available research has focused on the ways in which cognitive decline impairs decision processes, leading to discouraging results about older adults' performance. However, other studies have suggested that older adults benefit from an improvement in their intuitive and emotional processes, which can dominate cognition and improve in turn decision-making. At the same time, a misleading use of emotions and heuristic processes can lead older adults to rely by default to what 'feels right', minimising the consideration on relevant past experience and compromising the ability of making objective judgements of possible future scenarios. As seen in the chapter, this risk can be exacerbated by the propensity to pursue pleasant experiences and avoid unpleasant ones. Another theme that emerges from the literature on ageing and decision-making is a divergent set of results on the relationship between age and risky decisions. The existence of conflicting results may be caused by the influence operated on risk attitude by other variables, such as income, cognitive ability or metacognitive ability, as hypothesised in the research project discussed in the current thesis.

Overall, the literature reviewed in the chapter stresses the existence of significant age-related changes in the decision-making process and the important role played by psychological variables in determining its outcome. Nowadays, individuals of all ages are asked to make more choices and these choices sometimes involve complex decision-making processes. This seems particularly true for financial decisions, which require to structure savings and pension plans. Policies designed to control financial behaviour and improve welfare at both the microeconomic and the macroeconomic levels can benefit from a better understanding of how psychological variables are involved in financial decision-making and affect it (e.g., Baddeley, 2013; Thaler & Benartzi, 2004).

The more important result for the aim of this thesis is that due to cognitive and affective heuristics, to the influence of emotional states, and to the inability to implement the control processes necessary to counteract misleading impulsive or intuitive responses, human behaviour can result in behavioural biased and suboptimal decisions. As Colombo et al. (2010) have pointed out, this tendency is aggravated by a limited awareness of the decision-making process and by little consideration of the possibility that individuals can be led astray by misleading cues and biases. Since individuals are usually confident in their abilities and decisions, but these judgements do not always correspond to actual performance, it seems that better decisions could result from the development of appropriate metacognitive abilities. Focusing particularly on financial decision-making, it seems relevant for investors to be aware of their investment mistakes and of the errors made by their counterparts (Shefrin, 2002).

Guided by the idea that an investigation of the mechanisms that underlie behaviour is more productive than a mere description of behaviour and that psychology can promote the understanding of how to modify them, it seems important to analyse how metacognition can affect decision-making. The separation between cognitive and metacognitive abilities has strong practical effects, as it opens to the possibility that individuals with low cognitive ability can enhance the control ability over their mental processes and consequently compensate their performance with higher levels of metacognition, which can be learned (Veenman, Van Hout-Wolters, & Afflerbach, 2006). To provide a better basis for the understanding of the relationship between metacognition, age, and decision-making, the following chapter traces the development of the construct of metacognition and discusses issues around its functioning and its constituent elements. It provides an analysis of how this ability evolves across the lifespan and what are the available methodologies to assess it.

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Chapter 2

Elucidation of the Construct of Metacognition, its Functioning, Age-Related Changes, and Possible Assessment Methods

Chapter Rationale

After elucidating the state of the knowledge in the decision science literature, it is relevant to shift the attention to the other main process of interest for this thesis; i.e., metacognition. This literature review aims to reflect on the main theoretical models on metacognition available in the literature and present the main features of the enriched model of metacognition proposed by Efklides (2008), which was chosen as a framework for the research project discussed in this thesis. The main purpose of the chapter is to elucidate the functional role of the different metacognitive components and review the main results of the literature on the development of metacognitive competences in later adulthood. Furthermore, the chapter provides an analysis of the assessment instruments that can be used to measure metacognition, in the attempt of providing the rationale for the new methodology developed as part of this thesis.

Elucidation of the Construct of Metacognition, its Functioning, Age-Related Changes, and Possible Assessment Methods

Introduction

According to the findings outlined in the previous chapter and in line with the idea that individuals can be helped improve their monitoring and control processes over decision-making and recognise the biased tendencies that drive behaviour astray, this chapter focuses on the construct of metacognition. Understanding metacognitive processes and strategies used to make choices has a strong impact upon the development of those skills and the improvement of decision-making abilities, which are of particular interest for this PhD project.

Keeping in mind these considerations, the main aim of this chapter is to provide a framework to understand what the different components of metacognition are and what specific functions they exert. In what follows, a historical introduction to the concept of metacognition is provided. Then the chapter discusses some of the theoretical models which have paved the way to the current conceptions and categorisations of metacognition and provides an overview of the different components of metacognition. The issues related to these theories are considered and the relationships between theories are critically analysed. Due to the existence of fragmented theories, the chapter also highlights the need for a unified theory to metacognition, able to clarify the construct and lead to a better understanding of it. The enriched model of metacognition, which was chosen as theoretical framework for the research discussed in this thesis, is discussed. The chapter also analyses how monitoring and control processes are linked to metacognitive experiences and how a malfunctioning in the process can lead to behavioural biases. Previous studies analysing the evolution of metacognition across the lifespan are presented and their limitations are evaluated, highlighting the need of further investigation. The chapter also provides an overview of the possible methodological approaches to assess metacognition and discusses their strengths and weaknesses. A brief conclusion summarises the main contributions outlined in the chapter and the implication for the PhD project discussed in this thesis.

A Historical Introduction

In ancient Greek, the prefix "meta-" (μετά-) was a preposition used to mean "after", "upon", or "beyond". Over the years, many researchers have started using the prefix in an epistemological way, to indicate a notion than represents an abstraction completing or adding to another concept. Accordingly, the term "metacognition" has been coined by John Flavell (1976, 1979) to indicate the knowledge individuals have about one's own cognitive processing, including its active monitoring and regulation, in relation to the goal it serves. The main difficulty with the term is to determine with precision what is cognition and what is metacognition, as the two concepts are related to each other. Most conceptualisations of metacognition define it as a higher-order system overlooking and governing the cognitive system, while simultaneously being part of it (Veenman, Van Hout-Wolters, & Afflerbach, 2006). Langford (1986) has defined cognition as a continuous flow of information and metacognition as awareness of processes and their monitoring and control. Whereas cognition is required to fulfil a task and achieve a particular goal, metacognition is necessary to observe, develop, and evaluate the processes needed to understand task requirements, monitor and regulate performance, and apply such knowledge to new situations (Schraw, 2001). Therefore, metacognition is a basic requirement for cognitive effectiveness (Gourgey, 1998).

In searching for the origins of metacognition, it is possible to go back to the ancient Greece, not only because the prefix meta is derived from the language spoken at that age, but also because philosophers such as Socrates, Plato, and Aristotle expressed concepts related to what today is called metacognition. More than three hundred years before Christ, Socrates stated the importance of reflection and enquiry for a worthy life, Plato expressed the concept of awareness of one's cognition, whereas Aristotle discussed a separate power, a part from seeing and hearing, used by the psyche to become aware of its actions (Spearman, 1923; Tarricone, 2011).

Following their line, many other philosophers have contributed to the conceptualisation of metacognition, although they have not used the term metacognition. In different ways, Descartes, Spinoza, Dewey, Kant, Piaget, and Vygotsky have analysed the reflection process, highlighting aspects that today are considered key features of metacognition. With the sentence "Cogito ergo sum" (English: I think, therefore I am), Descartes (1986) has characterised the processes of reflection, thinking, and reasoning as the essence of self. Spinoza (1930) and Dewey (1933) have discussed the reasoning processes involved in problem solving and explained that reflection is necessary, in a metacognitive manner, to apply processes, strategies, and methods. Without using the term metacognition, Dewey has identified reflective thinking as part of processes such as awareness, monitoring, and regulation of cognition. Dewey has also analysed the possible influence of experience, feelings, and beliefs on reflection and problem solving. Kant (1933) has claimed that reasoning is based on inferences made in the processes of problem solving and decision-making. Such inferences are governed by prior knowledge and understanding, which inform judgements made during problem solving.

Also Piaget's higher-order reasoning is connected to metacognition. He has claimed that reflective thinking is part of the development of abstract thinking in adolescence, which is based on the ability to analyse logically, deal with hypotheses, reflect, and apply hypothetic-deductive reasoning (Inhelder & Piaget, 1958). This form of reasoning involves the creation of new possibilities or hypothetical assertions and the application of reasoning processes to explore their applicability (Piaget, 1970). These processes rely upon reflection and metacognition, stimulate connections between prior knowledge and experiences in similar problem solving situations, and help to investigate new learning and problem solving processes.

Similarly, Vygotsky's conceptions of zone of proximal development and internal verbalisation are integrated in problem solving processes and constitute integral aspects of metacognition (Vygotsky, 1986). During problem solving, verbalisation and internal verbalisation promote the creation of a zone of proximal development, moving from the individual to a social cognitive process. This social cognitive interaction stimulates the development of internalised cognitive processes – i.e., the use of inner speech promotes higher-order reasoning about the relationships between the task, the problem solving process, and the solution. This intrapsychological functioning can be considered metacognitive.

Descartes, Spinoza, Dewey, Kant, Piaget, and Vygotsky are some of the authors that have contributed to the understanding of the role of reflection and metacognition in problem solving. Reasoning relies upon reflection, mental imagery, mnemonic strategies, analysis and abstraction, and is essential for complex problem solving and decision-making. By studying metacognition it is possible to shed light on some fundamental issues concerning the processes used to reflect and regulate mental states, skills, memories, and behaviour (Koriat, 2007).

In recent years there has been an increasing interest in metacognitive processes and a notable amount of research has been conducted, from disparate areas of investigation. The main areas of research include: developmental psychology, with emphasis on the development of theory of mind (e.g., Schneider & Pressley, 1997); social psychology, focusing on the social nature of metacognition and on the relevance of cultural expectations on cognitive performance (e.g., Bless & Forgas, 2000; Jost, Kruglanski, & Nelson, 1998); experimental and cognitive psychology, focusing mainly on metamemory – i.e., knowledge and regulation of memory (e.g., Metcalfe & Shimamura, 1994; Nelson & Narens, 1990); and educational psychology, with emphasis on self-regulated learning (e.g., Hacker, Dunlosky, & Graesser, 1998). More recently, new research has been developed in the fields of judgement and decision-making, analysing how metacognition affects an individual's judgements (e.g., Gilovich, Griffin, & Kahneman, 2002; Schwarz, 2004); neuropsychology, connecting metacognition with executive functions (e.g., Fernandez-Duque, Baird, & Posner, 2000) and prefrontal brain areas (e.g., Fleming, Huijgen, & Dolan, 2012; Shimamura, 2000); forensic psychology, focusing on how people use metacognitive monitoring and control processes when recollecting information from memory (e.g., Goldsmith, Koriat, & Weinberg-Eliezer, 2002; Koriat, Goldsmith, Schneider, & Nakash-Dura, 2001); and clinical psychology, analysing the relationship between metacognition and different psychological conditions (Cooper, Deepak, Grocutt, & Bailey, 2007).

The growing interest in the study of metacognition is due to the fact that we engage in metacognitive activities every day. Activities such as planning how to approach a task, monitoring our comprehension, and evaluating progress towards the achievement of a goal and completion of a task are metacognitive in nature (Livingston, 1997). Metacognition is also involved in those social interactions that require awareness of one's and others' thinking (King, 1998). Nowadays, metacognition is used as an umbrella term encompassing different structures that relate to thinking processes. It has been labelled as 'vague' and 'fuzzy', but also identified as a significant concept in cognitive psychology (Brown, 1987; Efklides, 2008). Its ambiguity is due to the fact that whether metacognition is often described simply as *thinking about thinking*, several other terms are currently used interchangeably in the literature to describe similar and overlapping phenomena (e.g., self-regulation, self-management, meta-learning, executive control), or a specific aspect of those phenomena (e.g., meta-memory, metacognitive beliefs, judgements of learning; Akturk & Sahin, 2011; Livingston, 1997). At the same time, metacognition has been framed in many models, which include similar constructs, but differ in other aspects. The result is the existence of multiple perspectives of metacognition, which provide a fragmentary view of the construct. It is easy to realise that the complexity of metacognition and the existence of different theories limit the depth of understanding of the construct and make the function of metacognition still a matter of hot debate. The next section aims to clarify the construct by identifying two main classes of approaches and considering similarities and differences, strengths and weaknesses.

Models of Metacognition

The models of metacognition available in the literature can be categorised into two main families, namely the self-attributive view and the self-evaluative view (Proust, 2010). The former claims that metacognition presupposes the ability to meta-represent one's own mental states as mental states, and thus involves the ability to read one's own mind, whereas the latter argues that metacognition does not require any form of meta-representation, but rather depends on the ability to control and monitor one's own cognitive processes. To better explicate the differences among the two approaches, the following sections review the main features of Flavell's metacognitive theory, which is representative of the self-attributive view, and Nelson and Narens' model of metamemory and metacognition, which is representative of the self-evaluative view, and then enmesh both these viewpoints to create a more unified and stronger model regarding real-world validity.

John H. Flavell. In line with the self-attributive view, Flavell (1979) has defined metacognition as knowledge that takes as its object and regulates any aspect of a cognitive endeavour. The author has used the label ***metacognitive knowledge*** to define metacognitive beliefs or awareness of the variables that alone or interacting with each other affect the progress and outcome of a cognitive process. He has classified three main categories of these variables: *person*, *task,* and *strategy*.

Person knowledge includes all the beliefs about the self and the others as 'cognitive processors'; that is, how tasks are processed, how good an individual is at them, and which feelings are experienced during the performance. According to Flavell (1979), personal knowledge can be further subcategorised into *intraindividual differences*, *interindividual differences*, and *universals of cognition*. Intraindividual differences are beliefs about oneself as a learner (e.g., the belief that you learn more by listening rather than by reading). Interindividual differences are beliefs about others and their abilities as learners (e.g., the belief that one of your friends is more reflective than another). Universals of cognition relate to beliefs and intuitions, understandings, and impressions regarding general abilities and the way the human mind works (e.g., you can learn that there are various degrees of understanding and sometimes you may not fully understand a concept, even if you do pay attention to its explanation).

Task knowledge concerns the processing demands that a task places upon the individual, the information available during a cognitive task, and its attributes (e.g., it is abundant or insufficient, familiar or unfamiliar, trustworthy or untrustworthy, and so on). It is an understanding of how to use this information in order to achieve the set goals and awareness of what type of goals are pursued when dealing with a specific task or situation.

Strategy knowledge is knowledge about the types of cognitive and metacognitive strategies that are likely to be most effective in achieving a goal. If a cognitive strategy is a tactic designed and used to reach a goal, the purpose of a metacognitive strategy is no longer to reach the goal, but to feel confident that it has been reached. For example, a cognitive strategy to obtain the sum of a list of number would simply consist in adding them up, whereas a metacognitive strategy would be adding the numbers one more time to be sure the answer is correct (Flavell, 1987). In the first case the adding process is used to reach the goal of obtaining the sum, whereas in the second case the strategy is used to verify that the goal has been reached.

Flavell has also noted that these different types of knowledge can interact and combine in groups of two or three. A possible combination involving all three is the situation where a person might believe they (unlike another person) should use Strategy A (rather than Strategy B) in Task X (as contrasted with Task Y).

Summarising, the main assumption made by Flavell, and shared by other theorists of the self-attributive view (e.g., Carruthers, 2009; Dennett, 1991; Leslie, 1987), is that control of one's own cognitive processes requires a meta-representation of one's own mental contents. Metacognition is described in a hierarchical relationship to cognition, as a form of 'metalanguage' that permits individuals to talk about what is happening in their cognitive level (Watts, 1998). The main limitation of Flavell's theory and of the other models of the self-attributive view is that they do not consider the evaluative function of metacognition (Proust, 2010); that is, the practical and normative function that allows individuals to predict whether they are able to solve a specific task in a specific situation and to think how they did in a particular moment through the use of a retrospective evaluation (Proust, 2007, 2010). Two theorists of the self-evaluative view of metacognition are Thomas O. Nelson and Louis Narens, who have explained metacognitive evaluation in terms of monitoring and control function of metacognition.

Thomas O. Nelson and Louis Narens. In modelling metamemory and metacognition[2], Nelson and Narens (1990, 1994) have tried to deal with the limitations of the self-attributive view by claiming that metacognition essentially consists in the ability of evaluate an ongoing cognitive performance. The authors have considered the

[2] The terms metamemory and metacognition are used interchangeably by the authors.

interactive process between monitoring and control and analysed metacognition on the basis of three principles that have been previously used in isolation by other authors. The first principle states that cognitive processes can be split into two specifically interrelated levels: the *meta-level* and the *object-level* (see Figure 2.1). Information flows between the meta-level and the object-level. According to the second principle, the meta-level contains a dynamic model of the object-level. However, the opposite does not occur; that is, the object-level does not have a model of the meta-level. Finally, the third principle asserts that there are two dominance relations, *control* and *monitoring*, which are defined in terms of the direction followed by the flow of information between the meta-level and the object-level (see Figure 2.1). Control takes place when the information flows from the meta-level to the object-level and can affect behaviour at the object-level by starting, continuing, or finishing an action. However, control by itself does not yield any information from the object-level. In order to support the control process and to provide the information necessary to make these control decisions, a monitoring component is needed. Monitoring takes place when the meta-level is informed by the object-level and it changes the state of the meta-level model of the situation (Nelson & Narens, 1990, 1994).

Stated briefly, the *object-level* corresponds to cognition and the *meta-level* corresponds to metacognition. The global system can process information by using all the levels, whereas each level processes different aspects: the meta-level is informed about what is occurring at the lower levels by the object-level through the monitoring function and informs the object level about what to do next (including the option of not applying any change from what the object-level had been doing) through a control process. The feedback relationship between the object-level and the meta-level is evaluative because its function is to represent the distance between actual performance and desired outcome. The overall effectiveness of the regulatory system depends upon the interaction between monitoring and control processes.

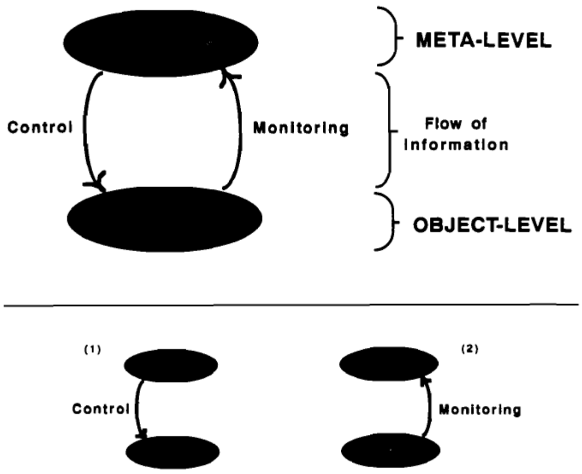

Figure 2.1. Nelson and Narens' model illustrating the flow of information between meta-level and object-level. Reprinted from “Metamemory: a theoretical framework and new findings”, by T.O. Nelson and L. Narens, 1990, The Psychology of Learning and Motivation, 26(4), p.126. Copyright [1990] by Academic Press. Reprinted with permission.

The above description represents an attempt to analyse the features of the main theorisations of metacognition. Not all the models available in the literature are discussed, yet they are sufficient to present the prevailing approaches adopted when dealing with metacognition. Important as such analysis might be, a further description of the metacognitive components can contribute to a more comprehensive representation of the construct. Taking into account both self-attributive and self-evaluative approaches, it is possible to identify two main elements of metacognition, named knowledge of cognition and regulation of cognition.

Knowledge of cognition. As seen in the previous section, the main contribution of the self-attributive view is the definition of knowledge of cognition, or metacognitive knowledge, as knowledge individuals have about their own cognition and cognition in general (Schraw & Moshman, 1995). Many authors have developed Flavell’s argument about knowledge of cognition, claiming that it also involves personal theories, beliefs, and self-awareness (e.g., self-esteem, self-appraisal and self-efficacy), which rely upon self-knowledge and permit to reflect and assess one's own knowledge and abilities (Brown, 1978, 1981, 1987; Jacobs & Paris, 1987; Paris & Winograd, 1990). In the last few decades, researchers have categorised cognitive knowledge in *declarative knowledge* and *procedural knowledge* (Cross & Paris, 1988; Schraw, Crippen, & Hartley, 2006; Schraw & Moshman, 1995). Introduced by Paris, Lipson, and Wixson (1983), an extended categorisation of metacognitive knowledge includes a further component, labelled *conditional knowledge*.

Declarative knowledge can be thought as 'knowing what'. It is the understanding of thinking processes in general and knowledge about strategy applicability and effectiveness, about what type of information is needed to meet task demands, and what factors might affect performance (Cross & Paris, 1988; Kuhn & Dean, 2004; Schraw, 2001; Schraw & Moshman, 1995). It can be thought as a personal reflection about personal knowledge and abilities, answering the question "Do I know it?" (Paris & Winograd, 1990).

Procedural knowledge, also labelled as metastrategic knowing, can be referred to as 'knowing how'. It is understanding, monitoring, and management of one's strategic performance in different types of cognitive tasks (Kuhn & Pearsall, 1998). It allows individuals to use and manage skills and knowledge through the organisation of strategies to facilitate the realisation of cognitive goals for problem solving, and involves awareness and management of cognition (Cross & Paris, 1988; Jacobs & Paris, 1987; Kuhn, 2000a, 2000b; Paris et al., 1983; Schraw & Moshman, 1995). Developed through application and experience, procedural knowledge can become an unconscious, automatic process (Cross & Paris, 1988; Schraw & Moshman, 1995).

Conditional knowledge is similar to Flavell's category of strategy knowledge and involves knowledge of different strategies and the ability to recognise the conditions for their use – i.e. knowledge about when, how, and why to apply a given cognitive strategy, and knowledge about its effectiveness and limitations in different possible problem solving situations (Schraw et al., 2006; Schraw & Moshman, 1995). It can be considered as declarative and procedural knowledge about the utility and effectiveness of certain cognitive actions in various tasks (Jacobs & Paris, 1987). Garner (1990) has emphasised the importance of conditional knowledge, arguing that one reason why individuals do not use relevant strategies is that they often fail to recognise the appropriateness of a strategy in a given setting. Strategy selection is made from the repertoire of strategies of which one has knowledge and needs to be matched with task elements and goals to facilitate successful problem solving.

After recognising the requirements of a task and the possible strategies to solve it, it is fundamental for an individual to implement the monitoring and control process to evaluate their performance. As asserted by the theorists of the self-evaluative approaches, the challenge of an effective metacognitive functioning is its evaluative and regulative aspect.

Regulation of cognition. The second major component of metacognition is *regulation of cognition,* which is the executive component comprising the repertoire of sequential processes used by individuals to control their cognitive activities and to ensure that a cognitive goal has been achieved. It can occur before cognitive activities (planning), during activities (monitoring) or after activities to check their outcome (evaluating; Cross & Paris, 1988; Paris & Winograd, 1990; Schraw et al., 2006; Whitebread et al., 2009). *Planning* involves the identification and selection of appropriate strategies and the allocation of the suitable resources for the task at hand. It can include goal setting, time budgeting, and activating background knowledge (Schraw et al., 2006). *Monitoring* (or regulating) is the self-testing of strategy use and involves being aware and attempting to comprehend and perform a task. Finally, *evaluation* consists in the analysis of performance and strategy effectiveness after the completion of a task.

A useful approach to the understanding of the regulatory function of metacognition is that proposed by Stanovich (2009). The author has posited the need to replace dual-system theories with a tripartite model of mind, which partitions the traditional System 2 into the reflective mind and the algorithmic mind. The algorithmic mind consists of *crystallized rationality*, i.e., the processes by which information is processed and used to build models of the world, such as reasoning and decision-making. The reflective mind is home to metacognitive dispositions such as the tendency to reflect on a problem before responding, collect information before changing idea, look for different perspectives before reaching a conclusion, considering the possible consequences before taking action, and weigh pros and cons of a situation before making a decision. In particular, whereas the algorithmic mind overrides type 1 responses via an inhibitory mechanism, the initiation of the override is initiated at a higher level of control operated by the reflective mind. That is, the reflective mind represents a self-regulation process operating at a higher, metacognitive, level of cognitive control.

Another useful framework to explain regulatory processes is the Hypothetical Thinking Theory (HTT) developed by Evans (2006). According to the model, reasoning and decision-making are facilitated by the formation of mental models that are considered one at a time (singularity principle) and evaluated according to their relevance to the current context (relevance principle). Furthermore, mental models are evaluated by the analytic system with reference to the current goal and accepted if satisfactory (satisficing principle). The mental model (e.g., possible action) considered in the hypothetical thinking is accepted unless it is sensible to replace or modify it. Whereas the fully rational decision-making requires an effortful deliberation of all the possible alternatives before choosing a single model, in real life, individuals tend to regulate behaviour evaluating possibilities one by one, until a satisfying option is found.

The introduction of metacognitive experiences. In the attempt to unify the contributions of self-attributive and self-evaluative approaches, many researchers have considered the relationship between cognitive knowledge and cognitive monitoring. Several empirical studies have demonstrated that cognitive knowledge facilitates cognitive regulation (Schraw, 1994; Swanson, 1990). Schraw and Dennison (1994) have suggested that metacognitive knowledge represents the reflective aspect of decision-making, whereas regulation of cognition is its control aspect. Having declarative metacognitive knowledge available does not guarantee that this knowledge is actually used to regulate cognitive behaviour, as it may be incorrect or incomplete. Individuals may fail to verify the usefulness or applicability of such knowledge for a particular task, or they may lack the skills for doing it (Veenman et al., 2006; Winne, 1996). However, metacognitive knowledge gets continuously enriched and updated by the information coming from the monitoring of cognition through the observation of one's and others' actions and outcomes in a specific tasks, and through interactions and communication with others (Efklides, 2008; Fabricius & Schwanenflugel, 1994; Flavell, 1979).

As explained by theorists of the self-evaluative view, one of the main functions of metacognition is the evaluation of one's own abilities 'in a context-sensitive way' (Proust, 2010, p.995). Some authors have questioned about the means used by individuals to make these judgements and have considered the role of affective states (Hookway, 2003). Flavell (1979) has identified ***metacognitive experiences*** as a set of conscious cognitive or affective experiences used to monitor an ongoing cognitive task. They involve awareness, intuitions, perceptions, feelings and judgements that an individual can experience before, during, or after a cognitive enterprise and inform about the progress made in cognitive performance. Metacognitive experiences are especially likely to occur in situations that require a careful, conscious thinking, such as in novel situations, where every major step must be previously planned and subsequently evaluated; or in risky decisions and actions. Metacognitive experiences can have very important effects on the other components of metacognition: they can affect metacognitive knowledge by adding, deleting, or revising some of its contents; and can activate strategies aimed at either cognitive goals (i.e., to *make* cognitive progress), or metacognitive goals (i.e., to *monitor* cognitive progress), or, in some cases, to achieve both goals.

In order to reach a comprehensive view of what metacognition is and how it functions, the research project discussed in this thesis considers the integration of all these elements as its theoretical framework. Accordingly, the closest definition of metacognition is provided by Hennessey (1999, p. 3), who claims that metacognition is "Awareness of one's own thinking, awareness of the content of one's conceptions, an active monitoring of one's cognitive processes, an attempt to regulate one's cognitive processes in relationship to further learning, and an application of a set of heuristics as an effective device for helping people organise their methods of attack on problems in general."

An Enriched Model of Metacognition

The research reported in this thesis is based on the E*nriched Model of Metacognition* proposed by Efklides (2008), which merges the contributions of self-attributive models (e.g., Flavell's view of metacognition; Flavell, 1987) with those of self-evaluative approaches (e.g., Nelson and Narens' *Metacognitive Model* of consciousness and cognition (Nelson, 1996; Nelson & Narens, 1990, 1994). The result is a coherent framework that attempts to offset the limitations that affect the two approaches when considered separately and to unify in a single model the different facets of metacognition, called metacognitive knowledge (MK), metacognitive skills (MS), and metacognitive experiences (ME), considering the monitoring and control functions of metacognition, and distinguishing three levels of its functioning.

Metacognitive knowledge (MK) is declarative knowledge stored in long-term memory. It involves models of cognitive processes, such as language, memory, and thinking (Fabricius & Schwanenflugel, 1994), knowledge regarding their functioning, and knowledge of the criteria of validity of knowledge, defined *epistemic cognition* (Kitchener, 1983). Metacognitive knowledge is a top down process through which existing knowledge is placed in the context of a particular task. It provides a framework to understand one's own and others' cognition and guides the interpretation of situational data in order to make good decisions to control the ongoing cognitive performance (Efklides, 2006; Jost et al., 1998).

Metacognitive skills (MS) are procedural knowledge intentionally used to control cognition. They include strategies intended to: monitor the comprehension of task requirements, plan the steps to be taken for task processing, monitor the execution of planned action, check and regulate cognitive processing when it fails, and evaluate the outcome of processing (Veenman & Elshout, 1999).

Metacognitive experiences (ME) can be considered the interface between an individual and a task. They are awareness related to the task features, the fluency of cognitive processing (i.e., the ease with which information is processed) and the effort exerted on it, the progress towards the goal set, and the outcome of processing (Efklides, 2002; Efklides, Kourkoulou, Mitsiou, & Ziliaskopoulou, 2006). Metacognitive experiences can take the form of *metacognitive feelings*, *metacognitive judgements/estimates*, and *online task-specific knowledge* (Efklides, 2001, 2006).

Metacognitive feelings include feeling of knowing (FOK), feeling of familiarity (FOF), feeling of confidence (FOC), feeling of satisfaction (FOS), and feeling of difficulty (FOD), and are crucial for effort regulation (Efklides, 2001, 2002; Efklides et al., 2006). They are the result of nonanalytic, unconscious processes that take place especially under conditions that do not allow a full analysis of the situation (e.g., time pressure, lack of access to memory information, or under uncertainty) (Koriat, 2007; Koriat & Levy-Sadot, 1999).

Metacognitive judgements are estimates related to the features of the cognitive processing linked to the task an individual is handling. Judgement of learning (JOL), estimate of effort and time expenditure (EOE), and estimate of solution correctness (EOC) are examples of metacognitive judgements that are strictly connected to feelings of difficulty and confidence (Efklides, 2002). These judgements can result from either analytic or nonanalytic processes, where the former concern the characteristics or demands of a task and the procedures to adopt, whereas the latter are heuristic, inferential, and attributional processes (Efklides, 2006; Kahneman, 2003; Koriat, 2007; Koriat & Levy-Sadot, 1999). In order to make judgements about one's own or others' cognition, an individual may also use social cognition processes, such as judgement formation and judgement correction processes and social comparisons or stereotypic knowledge (Efklides, 2008; Salonen, Vauras, & Efklides, 2005; Yzerbyt, Dardenne, & Leyens, 1998).

Online task-specific knowledge refers to what an individual focuses on when managing a task. It comprises information, ideas, or thoughts about the task and its features (e.g., cognitive procedures we are applying), and task-related metacognitive knowledge retrieved from memory in order to process the task (e.g., analysis of similarities and differences of tasks and procedures used in the past with the current ones; Efklides, 2008). Online task-specific knowledge is indicative of conscious and analytic metacognitive judgements (Efklides, 2001) and differs from other metacognitive experiences in that it deals with the task and its related procedures rather than with the person's affective response to features of cognitive processing (Efklides, 2006).

Metacognitive experiences, especially metacognitive feelings, have a dual character, cognitive and affective, which differentiates them from other facets of metacognition and from affect. According to Frijda (1986), feelings are products of a monitoring process that informs about good cognitive processing and, specifically, about the congruence/incongruity among goal set, current behaviour, and outcome. They can be intended as awareness of subjective responses and states, characterised by an affective component with positive or negative valence (pleasure/displeasure). This implies that feelings do not function at the same level of cognition, namely the object-level, but at a meta-level that include a representation of the object-level (Nelson, 1996; Nelson & Narens, 1990).

The enriched model of metacognition looks at metacognition as monitoring and control processes operating to regulate the ongoing cognitive activity through feedback systems. The utilisation of a strategy is prompted by task characteristics, prior knowledge of strategies (skills), metacognitive knowledge of strategies, metacognitive experiences that inform on task and demands, affect that informs on the valence of strategy use, and motivation, which provides the energy needed to exercise control and perform the task. The facets of metacognition and their relations with the self-regulation process give rise to a multifaceted and multilevel model, represented in Figure 2.2.

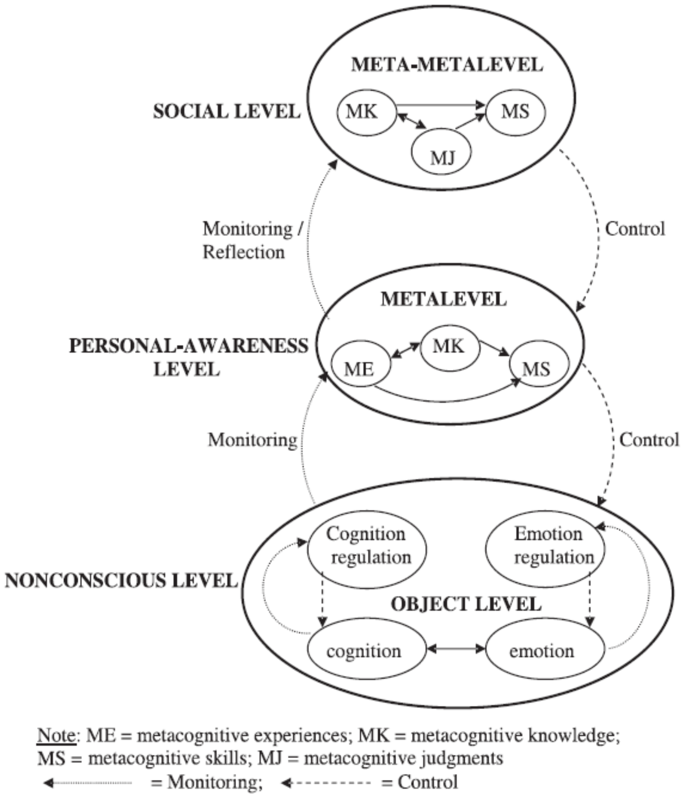

Figure 2.2. The multifaceted and multilevel model of metacognition. Reprinted from "Metacognition. Defining its facets and levels of functioning in relation to self-regulation and co-regulation", by A. Efklides, 2008, European Psychologist, 13(4), p.283. Copyright [2008] by Hogrefe & Huber Publishers.

The model consists of three levels, namely the *object level*, the *metalevel*, and the *meta-metalevel*. The *Object Level* (*Nonconscious level*) comprises processes involved in cognition and in emotions/affect. It functions at a non-conscious level and implicates two separate regulatory systems based on unconscious monitoring and control processes. Monitoring processes are used to detect fluency in cognitive processing, interruption of processing, conflict of response, errors, and expectations about factors that may affect memory or cognition, and anchoring on peer performance (Efklides, 2014; Koriat, 1997; Touroutoglou & Efklides, 2010). Processing fluency is a critical cue for the formation of metacognitive feelings (Efklides, 2002; Koriat, 2007) and emotions (Carver & Scheier, 1998). This can explain why for example, feelings of difficulty are associated with negative affect (Efklides & Petkaki, 2005). On the contrary, control at the object level is used to oversee and regulate eventual increases in effort, time, or attention on the task processing, initiation and termination of processing, changes in the mode of operation, and actions of executive functions (i.e., inhibition of response, updating, shifting of attention, and switching of response; Efklides, 2014; Nelson & Narens, 1994). Since cognitive events and affective states can automatically activate regulatory processes at the object level, control can take place earlier than metacognitive feelings are consciously analysed.

The *Personal-Awareness Level* (*Metalevel*) is constituted by representations of the products of each of the two regulatory systems of the object level and their interactions, that is, thoughts, emotions, ideas, perceptions, and desires. Metacognitive knowledge, skills and experiences are other components of self-awareness at this level, as well as the integration of the individual's explicit representation of the task and its demands with the action executed. At this level, metacognition is not a purely cognitive, *cold* process, as the nature of metacognitive knowledge would suggest. Rather, it is *hot*, since through metacognitive feelings it integrates affect with the monitoring of cognition (Efklides, 2008). At this level, monitoring processes are based on the observation of performance and its outcomes and on the awareness of one's thoughts, metacognitive experiences, task, context, and affective and motivational experiences. The outcome of monitoring reaches conscious awareness in the form of metacognitive or affective feelings (e.g., feeling of familiarity, feeling of knowing, confidence, surprise, curiosity). If cognitive control fails, the individual becomes aware that they needs to switch from an automatic cognitive processing to a consciously controlled one. Metacognitive experiences (such as feelings of familiarity, difficulty, or confidence) provide the input that prompts metacognitive control decisions (e.g., regulation of effort, slowing down or reiteration of processing, etc.) or metacognitive skills, either directly or indirectly through the use of metacognitive knowledge (Efklides, Samara, & Petropoulou, 1999). Metacognitive skills use online task-specific knowledge and metacognitive knowledge, and through the cognitive regulatory loop, they apply strategies to control and regulate cognition, analyse task requirements, and evaluate the response. Metacognitive feelings can also activate the affective regulatory loop, directly through their affective quality, or indirectly through the use of metacognitive knowledge and skills. This latter case implies a cognitive control of emotion. At the same time, the meta-level informs an upper level, namely the meta-meta level, which represents the social level of metacognition (Efklides, 2008).

The *Social Level* (*Meta-metalevel*) comprises only metacognitive judgements about the one and others' metacognitive experiences, knowledge, and skills. There is growing evidence for the existence of a form of socially shared and socially mediated metacognition (e.g., Iiskala, Vauras, & Lehtinen, 2004; Iiskala, Vauras, Lehtinen, & Salonen, 2011; Volet, Summers, & Thurman, 2009). This level of metacognition is depicted as a meta-metalevel, consistently with Nelson and Narens' conceptualisation of metacognition (1990), in which more than one metalevel may exist. The social level of metacognition is informed by self-awareness at the personal level and by information received from the ongoing interactions with others. Through theory of mind, language and reflection, individuals are able to analyse and compare their subjective mental states and knowledge with those of other people and, consequently, to form explicit theories about knowledge and cognition (Efklides, 2008). This process leads to the constitution of a socially shared and socially negotiated representation of self and others in context (King, 1998; Nelson, Kruglanski, & Jost, 1998). Metacognitive knowledge about self and others and metacognitive judgements about other people's current cognitive performance contribute to the co-regulation and other-regulation of cognition and behaviour (Efklides, 2008). Also metacognitive skills can contribute to these processes, through control of one's own cognition following feedback provided by other individuals, or, contrariwise, through the guidance given by the self to another person (other-regulation). Finally, at the social level, monitoring is based on the explicit reflection upon one and others' metacognitive experiences, on the performance in specific tasks and the following outcomes, on social cognition, interaction, and communication with others (Iiskala et al., 2011), and on knowledge of formal theories of cognition, based on analytic processes and applied to selective features of the situation, task, or process (McCabe, 2011). On the other hand, control at this level involves the conscious and analytic implementation of strategies acquired through formal instruction and social interaction processes. It accesses the object level through the personal-awareness level of the interacting individuals. It also comprises the application of metacognitive skills in social interaction or collaborative contexts (Efklides, 2014; Volet et al., 2009).

As mentioned above, the main strength of the enriched model of metacognition is its attempt to unify in a more comprehensive framework previous fragmentary theoretical contributions on metacognition. It suggests that metacognition is constituted by different facets and that it is linked with emotional and cognitive processes via two regulatory loops aimed at monitoring and controlling an individual's cognitive performance. Efklides' model of metacognition is relevant for the project discussed in this thesis also for its conceptualisation of the social level of metacognition. This aspect is important because it reflects the idea that a comprehensive model of metacognition should consider that individuals are part of a society and take into account the interactions with others. Similar arguments are also available in economics; the Ultimatum Game (Guth, Schmittberger, & Schwarze, 1982) and the Beauty Contest game (Keynes, 1936) are examples showing how different situations require a consideration of the mental states of the person we are interacting with. Many economic actions, especially in social strategic interactions, require the use of theory of mind – i.e., a system of inferences and assumptions which allows individuals to attribute mental states (beliefs, feelings, thoughts, intentions, etc.) to themselves and others (Premack & Woodruff, 1978) – and the ability to make predictions about others' behaviour (i.e., mentalising). The use of theory of mind and the ability of mentalising can be explained in terms of metacognition, as they allow individuals to introspectively consider the actions of others (Baddeley, 2013). Little is known about the effect of metacognitive abilities on social economic decision-making and even less about age-related changes in these processes. The absence of a clear understanding of these variables and the consideration that the interpersonal context may be especially important for older adults encourage further investigation of age-related changes in social metacognitive ability and their effect on decision-making, which are subject matter of the PhD project discussed in this thesis.

Monitoring Accuracy of Metacognitive Experiences and their Effect on Control Processing and Behaviour

In the last few decades, a great amount of research on learning and memory has attempted to address the question of how individuals can monitor the presence of information in memory despite their failure to retrieve it. Earlier research has developed a perspective called *direct-access view*, according to which, during learning and remembering, individuals have direct access to memory traces and can base their metacognitive judgements on the detection of the strength of these traces (Hart, 1965; Koriat, 2007). As a consequence, monitoring would involve direct access to the information stored in memory. Later studies have followed an inferential *cue-utilisation view*, which considers metacognitive experiences as based on a variety of cues and heuristics which predict objective performance (Benjamin & Bjork, 1996). Inferential cue-utilisation approaches distinguish between two main categories of metacognitive experiences, namely information-based (or theory-based) metacognitive judgements and experience-based metacognitive judgements (Koriat & Levy-Sadot, 1999; Matvey, Dunlosky, & Guttentag, 2001). The former refer to the use of personal beliefs and knowledge about one's own abilities and the factors that can affect performance, whereas the latter are the result of an inferential process based on the use of non-analytic heuristics (Koriat, 2007). This distinction resembles the differentiation proposed in other domains between two different systems that govern human behaviour (e.g., Kahneman, 2003). Metacognitive experiences may result from a deliberate analysis of beliefs and theories to reach a refined estimate about one's own cognition, or from a heuristic process that produces a purely subjective feeling (Koriat, 2007). In the latter case, the accuracy of metacognitive judgements is not guaranteed and depends on the validity of the cues on which it is based.

Inaccurate metacognitive judgements may affect not only the monitoring process, but also the accuracy of control processes (Efklides, 2008; Nelson, 1996). In turn, inefficient monitoring and control processes can affect the quality of performance (Koriat, 2007). However, with practice, individuals can become more accurate in evaluating their abilities (Efklides, 2014; Hadwin & Webster, 2013). Individuals may learn to base their monitoring on different cues, increasing the awareness of the cues that are indicative of response accuracy, the factors that may affect performance, and the related potential errors. This strengthens the rationale for further investigating the relationship between metacognition and decision-making and verifying whether higher metacognitive competences can offset the decline in cognitive skills and support individuals' choice behaviour.

Some researchers have started investigating how individual differences may affect the monitoring and control processes, and the consequent efficiency of metacognition. Particularly, previous research has suggested that an impaired relationship between monitoring and control may be associated with certain psychotic disorders, such as schizophrenia (Koren et al., 2004) and with age (Pansky, Koriat, Goldsmith, & Pearlman-Avnion, 2002). The relationship between age and metacognition is further discussed in what follows.

Development of Metacognition

Much of the research on metacognition has focused on children, as several researchers have noticed that although they become more sophisticated with formal education, metacognitive knowledge and skills already develop at a very basic level during preschool and early-school years. Several scholars have described the development of metacognition as a very gradual (and not always unidirectional) movement that improves with age (Hennessey, 1999; Kuhn & Dean, 2004; Schneider, 2008; Schraw & Moshman, 1995). Metacognition emerges in its meta-representative form (Kuhn, 2000b) and gradually develops, first in its procedural knowledge component (Schneider & Lockl, 2002), and then in its regulative aspect. However, the development of the ability to monitor and regulate cognition is slower and may remain incomplete in many adults (Lai, 2011).

Of particular interest for the current thesis is the analysis of how metacognition changes with advancing age. As seen in the previous chapter, older adults experience a cognitive decline and relevant changes in their emotional reactions. Understanding how metacognitive abilities change as we age is important, as poor metacognition can lead to negative consequences, such as believing that one is good in a certain activity despite a sequence of failures in it. If the elderly are aware of the alterations in their capabilities, they can slow down their decision-making, reflect on it and implement better strategies. Furthermore, a better understanding of the factors that contribute to different levels of metacognitive competence in healthy older adults can inform the understanding of changes in metacognition in neurologic populations (Cosentino, 2014; Cosentino, Metcalfe, Holmes, Steffener, & Stern, 2011).

Research on metacognitive functioning in older adults has strong implications, as it can shed light on age-related changes in decision-making. However, the literature is characterised by an open debate on whether metacognition changes with age. As Palmer, David, and Fleming (2014) have noted, older adults' life experience should lead to higher levels of metacognitive competence and to more accurate self-knowledge. However, neuropsychological evidence has revealed that the neural bases implicated in the appropriate use of metacognition are prefrontal and parietal cortex (e.g., Fleming & Frith, 2014 and references therein), areas that are also very likely to deteriorate with ageing (e.g., Hedden & Gabrieli, 2004). As a consequence, we might expect metacognitive competence to decline with age. Previous studies analysing age differences in metacognition have used mainly perceptual and memory tasks, and have focused almost exclusively on metacognitive experiences (particularly on feeling of confidence, feeling of knowledge, and judgement of learning), obtaining mixed results.

Several studies have provided initial evidence about whether there are age differences in confidence about decisions, but the literature is somewhat contradictory. Some studies have found that older adults have a preserved or improved accuracy of confidence ratings in tasks involving memory recall (e.g., Lachman, Lachman, & Thronesbery, 1979), questions of general knowledge (e.g., Dodson, Bawa, & Krueger, 2007; Pliske & Mutter, 1996), and problem solving (e.g., Vukman, 2005). On the contrary, other researchers have found significant differences in the accuracy of confidence ratings provided by younger and older adults in different domains such as learning of emotional information, recognition tasks and in the allocation of extra study time according to the perceived difficulty of a learning task (e.g., Bender & Raz, 2012; Froger, Sacher, Gaudouen, Isingrini, & Taconnat, 2011; Tauber & Dunlosky, 2012; Wong, Cramer, & Gallo, 2012). Older adults tend to exhibit a higher overconfidence that younger adults with respect to their performance (Dodson et al., 2007; Hansson, Ronnlund, Juslin, & Nilsson, 2008; Ross, Dodson, Edwards, Ackerman, & Ball, 2012). For example, Devolder (1993) has studied the monitoring process in practical problem solving (i.e., legal and financial problems) and found that older adults are more likely to overestimate their ability to solve problems correctly. On the contrary, younger adults tend to underestimate their performance.

Contradictory results have been found in studies analysing the accuracy of judgements of learning. Some researchers have revealed that younger and older adults have high accuracy of both immediate and delayed judgements of learning in memory recall tasks using paired-associate items (e.g., Connor, Dunlosky, & Hertzog, 1997; Hertzog, Dunlosky, Powell-Moman, & Kidder, 2002; Robinson, Hertzog, & Dunlosky, 2006). In a recent study, Hertzog, Sinclair, and Dunlosky (2010) have evaluated the accuracy of judgements of learning in a cross-sectional sample of adults aged 18-80 and found a linear increase in the accuracy of judgements of learning across the lifespan. However, other experiments (e.g., Daniels, Toth, & Hertzog, 2009) have proved that judgements of learning provided by older adults have lower resolution than the same judgements made by younger adults. Palmer et al. (2014) have studied metacognition in a perception task using a sample of adults between 18 and 84 years old and found that although task performance remains stable, older adults exhibit a decline in the accuracy of their perceptual metacognitive ability. The authors have also combined their results with the finding of Weil et al. (2013) on metacognition in adolescents, revealing a non-linear development of perceptual metacognitive ability with age. Particularly, there seems to be an increase during adolescence, a stabilisation in adulthood, and a decline in older age. The current thesis aims to contribute to the debate on the development of metacognition by testing the accuracy of older adults' judgements in financial decision-making.

Feelings of knowing refer to cue familiarity (Schwartz & Metcalfe, 1992) or information availability in memory (Koriat, 1993). Several experiments have shown similar levels of accuracy in feelings of knowing for general-knowledge information provided by younger and older adults (e.g., Butterfield, Nelson, & Peck, 1988; Souchay, Moulin, Clarys, Taconnat, & Isingrini, 2007). Particularly, Eakin, Hertzog, and Harris (2014) have examined age differences in the accuracy of feeling of knowing for both episodic and semantic memory in a face-name association task. The results show that although there are age differences in the level of episodic memory, feeling of knowing evaluations are equally accurate between older and younger adults. However, other works have provided different results, showing a deficit in the accuracy of older adults' feelings of knowing related to recalling information from episodic memory (e.g., Souchay, Isingrini, & Espagnet, 2000; Souchay et al., 2007).

The mechanisms of these age differences are not entirely understood and some common limitations can be outlined. Many studies have not considered that the inaccuracy of metacognitive judgements and feelings in older adults may reflect age-related deficits in memory or poorer quality of memories rather than a mere metacognitive deficit. As Hertzog and Dunlosky (2011) have pointed out, due to an impairment in memory, older adults may have less access to the contextual details normally used as a cue to evaluate the recollection ability, resulting in overconfident and inaccurate judgements. Furthermore, many of these studies have used extreme age-group designs, based on the comparison between a group of older adults and a group of younger adults, usually students. While the use of extreme groups can accentuate age-related differences, it does not provide an estimate of the developmental function and the trend followed by metacognitive competence across the adult lifespan (Hertzog & Dunlosky, 2011). Still, many studies have not controlled for the influence that task performance can play on measures of metacognitive accuracy (Palmer et al., 2014).

Common measures used to assess the accuracy of metacognitive experiences, such as the Goodman-Kruskal gamma correlation, are affected by task performance (Masson & Rotello, 2009). This aspect is especially relevant in experiments focusing on age differences in the accuracy of metacognition, as it can lead to confound age-related changes in metacognition with age-related differences in performance and cognitive abilities.

On the basis of these limitations, the project reported in this thesis studies metacognition in the context of a financial decision-making task, rather than in recognition tasks based exclusively on memory retrieval, controlling for a decline in cognitive abilities. Furthermore, the project aims to develop a ‘relative’ methodology to assess metacognitive experiences, able to control for the influence of task performance and quantify the extent to which individuals are aware of their performance, given a certain level of cognitive ability.

Assessing Metacognition

Since the modelling of metacognition is strictly related to both the used assessment method and the results obtained from this assessment, the progression in understanding metacognition must be accompanied by the understanding of the best assessments that are suitable to measure and describe metacognition (Pellegrino, Chudowsky, & Glaser, 2002; Saraç & Karakelle, 2012). Many methods for the assessment of metacognition have been proposed in the literature and can be classified as off-line and on-line methods, according to when they are collected. The former are reports based on individual responses provided before or after performing a task, whereas the latter are objective behaviour measurements obtained during task performance (Saraç & Karakelle, 2012).

Off-line measures aim to assess metacognition both in relation to a specific task or in general (i.e., without any explicit reference to a specific task) and can collect self-reports either prior or retrospective to actual task performance. Common off-line techniques are self-report questionnaires and interviews. *Self-report questionnaires* are usually Likert type scales. They can be differentiated in general metacognitive questionnaires, designed to assess metacognition independent of any specific domain (e.g., Sperling, Howard, Miller, & Murphy, 2002), and domain specific self-report questionnaires, aimed to assess metacognition in a single domain such as reading, problem solving, etc. (e.g., Fortunato, Hecht, Tittle, & Alvarez, 1991). On the contrary, *interviews protocols* enable an in-depth investigation of individuals' ideas. Saraç and Karakelle (2012) have identified three main way of assessing metacognition using interview protocols. The simplest way consists in asking subjects to describe a typical behaviour under certain circumstances (e.g., Paris & Jacobs, 1984). Alternatively, subjects can be asked to describe their metacognitive behaviours after completing a task (e.g., Artz & Armour-Thomas, 1992). The more sophisticated protocols depict hypothetical situations and ask subjects to describe what they would do in these particular situations or to generate as many strategies they can think that can be used in such situations (e.g., Zimmerman, 1990).

On-line measures, on the other hand, concern the assessment of domain specific metacognitive strategies during task performance. Typical on-line measures include think-aloud protocols, systematic observations, accuracy ratings and on-line computer-logfile registrations. *Think-aloud protocols* allow researchers to determine individuals' metacognitive ideas 'online' – i.e., participants are instructed to tell verbally how they handle the specific cognitive task they are working on. The session is recorded on audio or video-tape and transcribed, and metacognitive activities are scored according to a coding scheme (e.g., Cromley & Azevedo, 2006). *Systematic observations* are realised by a judge who observes an individual performing a task or watches videotapes of the performance and scores metacognitive behaviours (e.g., Veenman, Kerseboom, &

Imthorn, 2000). They are particularly useful in determining individuals' non-verbal metacognitive behaviour (Akturk & Sahin, 2011). *Accuracy ratings* represent ongoing assessments of performance. The individual performs a criterion task and immediately after makes a judgement regarding confidence, ease of solution, or performance accuracy (e.g., Schraw, 2009). Afterwards, the absolute difference between an individual's rating and her actual performance is calculated (e.g., Hacker, Bol, & Bahbahani, 2008; Nietfeld, Cao, & Osborne, 2005). *On-line computer-logfile registrations* consist in the presentation of the task on a computer, while subjects' activities are automatically recorded and coded in a logfile according to a defined coding scheme (e.g., Veenman, Bavelaar, de Wolf, & van Haaren, 2014). Logfiles contain traces of row cognitive activities that take place during task performance, such as: frequencies of certain key presses, scrolling, object manipulations, and screen selections, together with time indications (Veenman, 2013). A fundamental step to take logfile analysis to a metacognitive level is the selection of potential indicators of metacognitive skills, which should be based on a rational analysis of the task at hand and knowledge of metacognition literature (Veenman, 2013). A second important step in the use of logfiles is their validation against other online assessments of metacognition. High correlations have been found in previous studies between logfile scores and think-aloud measures of metacognition (see Veenman et al., 2014).

All these assessment methods have pros and cons. Off-line methods are favoured by some researchers because they allow to access aspects of thinking that are not directly observable (Schraw & Moshman, 1995). However, since they merely rely on participants' self-reports, these measures are subject to memory failure, distortion, and interpretative reconstruction (Veenman, 2011a, 2011b). On-line measures are not subject to this limitation, as the coding of participants' behaviour is based on criteria that are externally defined by nonpartisan judges and observers (Veenman, 2011b).

Nevertheless, on-line methods are time-consuming and effortful because they need to be individually administered (Veenman et al., 2014). Off-line methods, on the contrary, rely too heavily on verbal ability. In addition, they may not capture implicit cognitive processes – i.e., subjects may not be aware of their cognitive knowledge and monitoring, which suggests that think-aloud measures may underestimate an individual's metacognitive ability (Lai, 2011).

Metacognition is a complex construct, involving multiple types of cognitive knowledge, cognitive regulation, affective and motivational states. Although studies in this area are exponentially increasing, such complexity still involves some issues related to the assessment and measurement of the construct. Results from studies using multiple metacognitive measures are discrediting the measures frequently used in metacognitive research and making researchers scrutinise what they are actually measuring (Saraç & Karakelle, 2012). For instance, Veenman (2005) has highlighted that sometimes researchers take for granted that metacognitive activity can be assessed by means of questionnaires, without realising that the obtained scores may not correspond to actual behavioural measures of the task performance.

Besides the theoretical implications of the multifaceted and multilevel model of metacognition, it is evident that the methodology needs to be enriched. In order to measure metacognition more accurately, researchers should use multiple methods that do not share the same source of error (Garner & Alexander, 1989). It can be hypothesised that a better understanding of the construct of metacognition can be reached by combining the use of on-line and off-line measures and mixing behavioural and physiological measures (Efklides, 2008). Neuropsychological measures can help researchers outline the cerebral architecture that underlies metacognition, and better understand the monitoring and control processes that link functioning at the object-level with the use of metacognition (Fleming & Dolan, 2012; Van Veen & Carter, 2002). As a consequence, in order to obtain more precise results, the research project discussed in this thesis uses a combination of on-line and off-line measures to test the different facets of metacognition. A new methodology to assess the accuracy of metacognitive experiences is created and validated, taking into account the limitations of previous studies outlined in the chapter. Electroencephalography (EEG) is also used with the aim of adding to the finding obtained with the other methodology by directly measuring the functioning of metacognitive monitoring and control processes and better explaining the relationship between metacognition and age.

Conclusion

The goal of this chapter was to provide an explanation of what metacognition is and how it works. The first section described the evolution of the concept of metacognition and highlighted its complexity. The contributions of self-attributive and self-evaluative approaches were considered, showing how they can lead to the development of a multidimensional model. Metacognitive knowledge was defined as knowledge about one's own cognition and about the factors that might impact upon performance (declarative), knowledge about strategies (procedural), and knowledge about when and why to use strategies (conditional). According to the self-evaluative view, the regulative function of metacognition was examined. Metacognitive regulation has been defined as the monitoring of one's cognition, including planning activities, monitoring or awareness of comprehension and task performance, and evaluation of the efficacy of monitoring processes and strategies. Analysing the relationship between knowledge and regulation of cognition, the role of emotions was introduced and a brief description of metacognitive experiences was provided. The chapter proceeded presenting the model of metacognition chosen as reference for the research project discussed in this thesis: the enriched model proposed by Efklides in 2008. One of the main advantages of this model is its ability to integrate previous contribution in a more comprehensive and coherent model, differentiating the facets of metacognition and its levels of functioning. This model seems to constitute a good theoretical framework for the development of research examining the facets and levels of metacognition and their interactions, investigating the brain processes involved in self-awareness, and studying individual and social metacognitive processes involved in knowledge construction (Efklides, 2008). According to the author, existing research on metacognition is limited by having a vague theory behind it. It has considered only some facets of metacognition, such as on how metacognitive experiences are implicated in the learning process (e.g., Nelson & Dunlosky, 1991) or on how monitoring and control processes are used to evaluate the performance in a memory task (e.g., Ratcliff & Starns, 2013). However, no studies have attempted to test Efklides' whole model by applying it to a specific context. Some studies have analysed the accuracy of monitoring and control processes and their influence on cognitive performance. However, many of them have not controlled for the influence that task performance can play on measures of metacognitive accuracy (Palmer et al., 2014), leading to the difficulty to 'purify' age-related changes in metacognition from age-related differences in performance and cognitive abilities.

The chapter reviewed previous studies analysing age differences in metacognitive abilities. Several studies have provided some initial evidence about whether there are age differences in monitoring accuracy, but it is somewhat contradictory. The mechanism of these age differences are not entirely understood and there are some limitations that need to be addressed, such as the lack of control for the influence of task performance on measures of metacognition, which makes difficult to purify metacognitive ability from other age-related changes in cognitive abilities. As previously stated, the current thesis addresses this limitation by implementing a new methodology to assess metacognition able to control for the influence of task performance.

Finally, different available methods to assess metacognition were considered. Two main groups of methods (i.e., on-line and off-line) were analysed, considering advantages and limitations of both. As Lai (2011) has observed, the assessment of metacognition is challenging for many different reasons. Among all, metacognition represents a complex construct involving different types of processes, it is not directly observable, and existing measures tend to focus on specific and decontextualised aspects, without forming a coherent picture of what metacognition is and how it works. Due to the difficulty in assessing metacognition, a single instrument enabling connections among different metacognitive processes and allowing the measurement of all of these processes is not yet available in the literature (Schraw, 2009). It can be hypothesised that a better understanding of the construct of metacognition can be reached by using more than one on-line and one off-line measure, mixing behavioural, neuropsychological, and physiological measures (Efklides, 2008).

The literature presented in the above chapter provides the theoretical background to design a study that examines the relationship between metacognition, age and financial decision-making. Such research can enlighten and extend what is already known about the psychological variables involved in the decision process. Financial decision-making is complex and depends on a number of economic and non-economic variables. Behaviour is also conditioned by whether and the extent to which individuals are actually aware of their own reasoning, of the biases or errors which may affect it, and of the tendencies and attempts to adjust accordingly. An understanding of the implications of metacognition for financial choice behaviour may help improve decisions and provide strategies to develop skills in financial decision-making. From the policymakers' perspective, these insights can be used to structure intervention to improve self-regulation, co-regulation, and other-regulation and, indirectly, improve their outcomes.

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Chapter 3

Age Differences in the Effect of Metacognition on Financial Decision-Making

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Chapter Rationale

The narrative literature review reported in the previous chapters revealed that limited attention has been paid to age differences in the role that metacognition plays in decision-making. Research has shown that there is a strong association between age-related cognitive declines and reduced decision-making capacity (Dixon, Backman, & Nilsson, 2004) and thus older adults are more likely to show decision biases (Kennedy & Mather, 2007). Since behaviour is conditioned by the extent to which individuals are metacognitively aware of their own reasoning and the potential biases that may affect it, understanding how metacognition is involved in choice behaviour may help offset biased tendencies and provide strategies to maintain the ability to make sound decisions with advancing age.

Nevertheless, metacognition is a complex construct and although studies in this area are increasing, such complexity still involves some issues related to the assessment and measurement of the construct. Many of the instruments available in the literature offer a fragmented view of metacognition, as they tend to focus only on one or two metacognitive facets, without providing a global picture of metacognitive abilities. Furthermore, most of them only apply to learning and memory tasks or perceptual decision-making.

Therefore, a behavioural study was undertaken and is presented as Chapter 3 specifically to develop a more comprehensive methodology in line with Efklides' (2008) model of metacognition to assess the different facets of metacognition in the context of decision-making and provide insight into how metacognition interacts with cognitive abilities in predicting financial decision-making behaviour.

Statement of Authorship

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Age Differences in the Effect of Metacognition on Financial Decision-Making

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Abstract

Due to a decline in cognitive abilities, decision-making abilities can be compromised with advancing age. This is a significant issue given the increasing pressure to take control over one's own financial and personal wellbeing in old age. This paper introduces a novel experimental method to investigate metacognition in decision-making tasks and reports the results of an empirical study investigating the age-related effects that metacognition may have on financial choice behaviour. The main findings show that young adults have significantly higher cognitive ability, whereas older individuals provide more accurate metacognitive judgements. Furthermore, there is evidence that metacognition can predict decision-making success. Critically, some metacognitive components buffer individuals against cognitive decline, providing an alternative route to sound financial decisions. Together, these findings emphasise the importance of studying metacognition in the context of financial decision-making. They confirm that cognition and metacognition undergo different changes with ageing and have an impact on financial decision-making.

Keywords: Ageing, Cognitive Ability, Financial Decision-Making, Metacognition

Age Differences in the Effect of Metacognition on Financial Decision-Making

This paper investigates how metacognition is linked to age-related differences in financial decision-making, focusing particularly on the interrelation between cognition and metacognition and exploring whether metacognition can be used by older adults to buffer against cognitive decline and improve the outcome of their decision-making.

It is well established that age-related declines in cognitive ability are associated with reduced decision-making capacity (Dixon et al., 2004) and may lead older adults to make mistakes and suboptimal decisions (Kennedy & Mather, 2007; Peters, Hess, Västfjäll, & Auman, 2007). A major focus of past research has been the identification of domains where older adults make worse decisions that their younger counterparts. However, equally relevant is the study of the processes that can counterbalance cognitive decline and prevent older adults from making bad decisions. Since behaviour is conditioned by the extent to which individuals are metacognitive aware of their own reasoning, of the biases that may affect it, and the attempts to adjust accordingly, an understanding of the implications of metacognition for choice behaviour may help counteract biased tendencies and provide strategies to develop skills in decision-making.

Defined as the ability to think about the ongoing cognitive performance and guide, monitor, and regulate cognitive actions (Flavell, 1979), metacognition has been proposed as an important resource that allows individuals to acquire awareness of their own reasoning and control processes involved in decision-making, enhancing in turn the ability to reason accurately and resulting in better choices (Colombo, Iannello, & Antonietti, 2010). In particular, if the elderly are aware of the alterations in their capabilities, it seems plausible to hypothesise that they can attempt to compensate for cognitive decline by using their metacognition.

Despite the agreement on the relevance of investigating metacognition for a more complete understanding of decision-making, little research has been carried out in the field, leading to a paucity of knowledge pertaining to the age-related changes in metacognition and their effects on decision-making. Furthermore, the existence of multiple perspectives of metacognition, which provide a fragmentary view of the construct, translates into disparate methodologies and the need for a more comprehensive approach to assess metacognition, able to clarify the construct and its components, and lead to a better understanding of its functioning.

Previous studies analysing age differences in metacognition have used mainly perceptual and memory tasks, and have focused almost exclusively on metacognitive experiences (particularly on feeling of confidence, feeling of knowledge, and judgement of learning), obtaining mixed results. As Palmer, David, and Fleming (2014) have noted, older adults' life experience should lead to higher levels of metacognitive competence and more accurate self-knowledge. However, neuropsychological evidence has revealed that the neural bases implicated in the appropriate use of metacognition are prefrontal and parietal cortex (e.g., Fleming & Frith, 2014 and references therein), areas that are also very likely to deteriorate with ageing (e.g., Hedden & Gabrieli, 2004). As a consequence, a decline in metacognitive competence with ageing might be expected.

Several studies have provided initial evidence about whether there are age differences in confidence about decisions, but it is somewhat contradictory. Some studies have found that older adults have a preserved or improved accuracy of confidence ratings in tasks involving memory recall (e.g., Lachman, Lachman, &

Thronesbery, 1979), questions of general knowledge (e.g., Dodson, Bawa, & Krueger, 2007), and problem solving (e.g., Vukman, 2005). On the contrary, other researchers have found significant differences in the accuracy of confidence ratings provided by younger and older adults in different domains such as learning of emotional information and recognition tasks (e.g., Bender & Raz, 2012; Tauber & Dunlosky, 2012). Older adults tend to exhibit a higher overconfidence than younger adults with respect to their performance (Dodson et al., 2007; Hansson, Ronnlund, Juslin, & Nilsson, 2008). Still, other experiments have proved that metacognitive judgements provided by older adults have lower resolution than judgements made by younger adults (e.g., Daniels, Toth, & Hertzog, 2009; Palmer et al., 2014).

The mechanisms of these age differences are not entirely understood and some common limitations can be outlined. Many studies have not considered that the inaccuracy of metacognitive judgements and feelings in older adults may reflect age-related deficits in memory or poorer quality of memories rather than a mere metacognitive deficit (Hertzog & Dunlosky, 2011). Furthermore, many studies have not controlled for the influence that task performance can play on measures of metacognitive accuracy (Palmer et al., 2014). This aspect is especially relevant in experiments focusing on age differences in the accuracy of metacognition, as it can lead to confound age-related changes in metacognition with age-related differences in performance and cognitive abilities.

The existence of many different methodologies to assess metacognitive experiences has led to heterogeneity of approach (Fleming & Lau, 2014). As previously mentioned, numerous metacognitive experiences have been examined; nevertheless, the ability to compare results obtained in different studies is complicated by the different methodological approaches implemented. Some researchers have focused on calibration (or absolute accuracy), which refers to how accurately individuals judge their performance overall relative to their actual response (Fleming & Lau, 2014), whereas other scholars have investigated sensitivity (or relative accuracy), which refers to the ability to judge the performance at the ongoing cognitive task and differentiate between correct and incorrect responses (Efklides, 2014).

Another aspect on which existing research diverges is the moment in time when metacognitive experiences are measured. A basic division is between prospective and retrospective judgements. Prospective judgements are made to predict future events, whereas retrospective judgements refer to events that were previously experienced. Most of the existing research has focused on the link between actual accuracy of task performance and retrospective metacognitive judgements (e.g., Zehetleitner & Rausch, 2013). Other authors have compared the accuracy of prospective and retrospective metacognitive judgements and shown that retrospective ratings tend to be more aligned with the actual response (e.g., Siedlecka, Paulewicz, & Wierzchon, 2016). However, to the best of our knowledge, no studies have provided a combined measure of accuracy of both prospective and retrospective metacognitive experiences.

In light of the limitation highlighted above, the current study investigated metacognition in the context of financial decision-making, rather than in recognition tasks based exclusively on memory retrieval, controlling for a decline in cognitive abilities. The first part of this research aimed at developing a new methodology to assess metacognition in the field of decision-making. The second part of the research examined age differences in the effects of metacognition on financial decision-making, referring to the metalevel of the multifaceted model of metacognition proposed by Efklides (2008), which was chosen for its peculiarity of considering different aspects disregarded by other theoretical approaches and attempting to combine previous models of metacognition into a more comprehensive and precise representation of the different facets of metacognition and its levels of functioning.[3]

The choice of the financial context is motivated by the recognition that due to the increase in life expectancy, older adults are required to make financial decisions and maintain a financial asset longer, but the ability to make appropriate financial decisions with advancing age can be compromised by a physiological decline in cognitive abilities and the increasing complexity of financial instruments. A better comprehension of metacognitive processes and how they interact with cognitive ability could shed further light on the factors that govern decision-making and how they change over the lifespan, identifying in turn areas of vulnerability and understanding how to help older adults make better decisions. The separation between cognitive and metacognitive abilities has strong practical effects, as it opens to the possibility that metacognition (which can be trained to be more effective; Schraw, 2001) can be used by older adults to compensate the physiological cognitive decline and improve their decision-making.

More specifically, the following hypotheses were tested:

Hypothesis 1. Metacognition and cognition follow different patterns across the lifespan and thus we can expect significant differences between younger and older adults.

[3] The current study focuses more specifically on the metalevel, which is constituted by metacognitive knowledge, skills, and experiences. Metacognitive knowledge is a top-down process through which already existing declarative knowledge is placed in the context of a particular task to interpret situational data. Metacognitive skills are strategies that use procedural knowledge to control cognition, regulate performance, and evaluate the outcome. Metacognitive experiences are heuristic, inferential processes that inform about the ongoing cognitive performance on the basis of feelings, judgements, and cues obtained by the task, the context, or cognitive processing (Efklides, 2008). Furthermore, according to the model, the metalevel interacts with the object-level (where cognitive and emotional processes operate) via a bottom-up monitoring process and a top-down control process (Efklides, 2014).

Hypothesis 2. Metacognitive and cognitive abilities can predict performance at the financial decision-making task.

Hypothesis 3. Metacognitive ability moderates the impact that cognition has on financial decision-making.

Study 1: The construction of a new methodology to assess metacognition in the context of decision-making

The main aim of this first study was to develop a new methodology suitable for assessing the different components of metacognition in a decision-making context and providing a more complete measurement of the construct, in line with Efklides' multifaceted model of metacognition. Two existing instruments – i.e., the Metacognitive Awareness Inventory (MAI; Schraw & Dennison, 1994) and the Metacognitive Experiences Questionnaire (MEQ; Efklides, 2002) – were selected from the literature and adapted. The development of the methodology and its validation process are described in what follows.

Method

Participants. A total of 118 participants (age range 20-94, *M* = 42.4 years, *SD* = 19.9; 65 female) were recruited online and in the community with flyers and advertisement on newsletters and forums. The sample size was chosen on the basis of the number of participants used in Schraw and Dennison (1994) to assess the validity of the Metacognitive Awareness Inventory. Participants either volunteered without payment by taking part in the study online or received a compensation of 10 pounds by taking part in the study at the University of Bath. All participants were healthy and free of neurological and psychiatric disease. They gave their consent to participate in the study and the research was approved by the University of Bath Psychology Ethics Committee.

Measures.

Metacognition. Adapted Metacognitive Awareness Questionnaire (MAI; Schraw & Dennison, 1994). The original version of the MAI consists of 52 self-report items aimed at investigating two major components of metacognition (i.e., knowledge about cognition and regulation of cognition) and reliably identifying if individuals are metacognitively aware of how they learn (i.e., if they possess the ability to reflect upon and control their learning). We slightly rephrased some of the items so that participants rated the extent to which they were aware and used their metacognitive strategies when solving a problem or making a decision rather than when learning new information, as in the original version of the instrument. A sample item is item 28, which originally stated "I find myself analysing the usefulness of strategies while I study" and was changed in "I find myself analysing the usefulness of strategies while solving a task". Items 16 and 37 from the original version of the MAI (i.e., "I know what the teacher expects me to learn" and "I draw pictures or diagrams to help me understanding while reading") were excluded because they referred more specifically to learning processes and it was difficult to rephrase them in terms of decision-making. The adapted MAI consists of 50 items tapping into two subscales measuring respectively metacognitive knowledge and metacognitive skills (A full list of all the items can be found in the Supplementary Material available online). Respondents rate each item on a 4-point scale (1 = never; 2 = sometimes; 3 = often; 4 = always).

Adapted Metacognitive Experiences Questionnaire (MEQ; Efklides, 2002). It is a self-report questionnaire measuring task-specific metacognitive experiences and consists of a prospective form to be completed before each trial of the task and a retrospective form to be completed after each trial of the task. The original instrument contains 12 items for the prospective part and 11 items for the retrospective part. Some of the questions measure judgements that are specific to the prospective or retrospective part, whereas some others can be used both prospectively and retrospectively. In this study only five questions were selected among the ones that can be asked both before and after coming across a task (the questions used in this study can be found in the Supplementary Materials). Respondents rate each item on a 4-point scale (1 = not at all; 2 = a little; 3 = enough; 4 = very).

Financial performance. A financial task was built with the software MouseLab Web (Johnson, Payne, Schkade, & Bettman, 1988) and executed on a computer. To test subjects' financial abilities, the task provides participants with nine different scenarios where they have to decide how to invest a certain amount of money among a number of options that change in difficulty and number of possible options (see the Supplementary Material for sample questions). For each question it is checked whether participants can find the optimal option. One point is assigned for each correct answer, whereas a score of zero is assigned for incorrect responses.

Procedure. Participants were provided with an information sheet describing the experiment and asked to agree on the consent form before proceeding. The financial task together with the adapted version of the MEQ were administered first, whereas the MAI was answered at the end of the experiment. Total commitment time was about 45 minutes.

Results

Factor structure of the Adapted–Metacognitive Awareness Inventory (a-MAI). In order to examine the internal structure of the a-MAI, participants' answers were subjected to a restricted factor analysis. Initially, the factorability of the 50 a-

MAI items was examined. Several well-recognised criteria for the factorability of a correlation were used. Firstly, it was observed that 48 of the 50 items correlated at least .30 with at least one other item, suggesting reasonable factorability. Furthermore, there were no items with correlation higher than .80. Secondly, Bartlett's test of sphericity was significant ($\chi^2(1225) = 2614.81$, $p < .001$), indicating that it was appropriate to use the factor analytic model on this set of data. The Kaiser-Meyer-Olkin measure of sampling adequacy indicated that the strength of the relationships among variables was high (*KMO* = .786). Given these overall indicators, factor analysis was deemed to be suitable.

A principal axis analysis with oblique (Oblimin) rotation was performed on the data. In the first step, two factors were extracted, as the main aim was to test the ability of the a-MAI to differentiate two components of metacognition (i.e., metacognitive knowledge and metacognitive skills) and factors were expected to be correlated. In the second step, the iterative procedure was performed to obtain a clear factorial solution, including exclusively the items of interest. This procedure allowed us to drop the items that were not appropriately measuring the two factors. A total of 11 items were eliminated because they did not contribute to a simple factor structure and failed to meet a minimum criterion of having a primary factor loading of above .30, and no cross-loading of .30 or above. Items 1, 3, 4, 24, 30, 40, 46, 49, and 50 were eliminated because they did not load above .30 on any factor. Items 8 and 22 were excluded from the scale because they had factor loadings greater than .30 on both factors.

A final principal axis factor analysis with Oblimin rotation was conducted on the remaining 39 items. The obtained pattern matrix revealed that factor one consists of 21 items, whereas factor two comprises 18 items. The factor loadings of the items of the a-MAI are displayed in Table 3.1.

Table 3.1

Pattern Matrix for the Adapted–Metacognitive Awareness Inventory Items Used in the Current Study

Scale Item	Factor	
	1	2
I ask myself if I have considered all options after I solve a problem.	.81	
I ask myself if I have considered all options when solving a problem.	.66	
I ask myself questions about how well I am doing while I am handling a new task.	.64	
I periodically review to help me understand important relationships between concepts.	.60	
I ask myself how well I accomplished my goals once I'm finished.	.60	
I find myself pausing regularly to check my comprehension.	.58	
I find myself analysing the usefulness of strategies while solving a task.	.57	
I ask myself if I did as much as I could have once I finish a task.	.54	
I ask myself questions about the material before I begin.	.54	
I re-evaluate my assumptions when I get confused.	.51	
I focus on the meaning and significance of new information.	.51	
When solving a task, I ask myself if it is related to what I already know.	.47	
I check what I've done after I finish.	.43	
I ask myself if there was an easier way to do things after I finish a task.	.41	
I try to break performing down into smaller steps.	.41	
I consider several alternatives to a problem before I answer.	.39	
I slow down when I encounter important information.	.38	
I know how well I did once I finish a test.	.37	
I try to translate new information into my own words.	.33	
I change strategies when I fail to understand.	.33	
I have control over how well I perform in a task.	.31	
I am good at organising information.		.63
I use my intellectual strengths to compensate for my weaknesses.		.60
I can motivate myself to work when I need to.		.58
I do best when I know something about the topic.		.55
I consciously focus my attention on important information.		.50
I use different strategies depending on the situation.		.49
I understand my intellectual strengths and weaknesses.		.49
I am a good judge of how well I understand something.		.46
I know what kind of information is most important to analyse when solving a task.		.45

I have a specific purpose for each strategy I use.		.44
I am aware of what strategies I use when I solve a problem.		.42
I am good at remembering information.		.41
I perform better when I am interested in the topic.		.39
I find myself using helpful strategies automatically.		.38
I use the organizational structure of a task to help me solving it.		.37
I organise my time to best accomplish my goals.		.36
I know when each strategy I use will be most effective.		.35
I think about what I really need to do before I begin a task.		.31
Eigenvalue	10.35	2.62
Percentage of variance	26.54	6.71
Cronbach's Alpha	.90	.86

The first factor was robust, with a high eigenvalue of 10.35, and it accounted for 26.5% of the variance in the data. It is clear from Table 3.1 that these items all relate to the ability of monitoring and controlling cognitive performance. This factor loads onto reported levels of ability to plan the execution of a task, select and implement appropriate strategies, monitor the performance, correct eventual mistakes, and evaluate the outcome of cognitive processing. In light of the contents of the items, this factor was labelled “Metacognitive skills”. The second factor, namely metacognitive knowledge, had an eigenvalue of 2.63 and accounted for a further 6.7% of the variance. This factor relates to the ability of using declarative knowledge stored in the long-term memory to understand the task at hand, possible cognitive strategies to solve it, and the conditions under which these strategies are most useful, enhancing in turn the control of the ongoing cognitive performance. In line with the original version of the MAI, this factor was labelled “Metacognitive knowledge”.

Internal consistency for each of the scales was examined using Cronbach’s alpha. Both factors demonstrated a high degree of internal consistency. The α coefficient for metacognitive skills was .90, while the coefficient for metacognitive knowledge was .86. The Cronbach's α for the entire questionnaire was .92. Overall, the factor analysis indicated that two distinct factors were underlying participants' responses to the adapted MAI and that these factors were internally consistent. Nineteen of the fifty items did not load onto a factor and were eliminated. Furthermore, five items loaded in a different factor with respect to the original version of the MAI. Such a difference may be due to the rephrasing of the items operated to make them more suitable for a decision-making scenario. In summary, the two factors found were metacognitive knowledge and metacognitive skills. These two factors were considered subscales of the a-MAI and together with metacognitive experiences formed the three components of metacognition further investigated in the current study.

The adaptation of the Metacognitive Experiences Questionnaire for a more comprehensive assessment of metacognitive experiences. Task-specific metacognitive experiences (ME) are constituted by feelings and judgements; i.e., subjective experiences that result from evaluating and monitoring the features of the cognitive processing linked to the task an individual is handling (Efklides, 2002). In this experiment they were measured through the administration of 5 questions of the Metacognitive Experiences Questionnaire (MEQ) before and after performance at the financial task. The MEQ measures ME by means of rating scales, which are able to capture not only the presence of a feeling or judgement, but also its intensity. Furthermore, the structure of the instrument allows to make comparisons between participants' rating and their actual performance and between prospective and retrospective ratings.

Most of the existing research has focused on single metacognitive judgements at a time, exploring how metacognitive judgements provided before or after solving a task correlate with performance and how such correlation changes as function of task experience (see Koriat, 2007 for a review). On the contrary, the current study wanted to simultaneously include in the same questionnaire different feelings that can be experienced in relation to the task at hand, to get a broader overview of the ongoing monitoring process. Furthermore, we aimed at developing a new methodology taking into account prospective and retrospective ratings together, guided by the rationale that individuals with high metacognitive abilities should not only be able to provide accurate metacognitive judgements (i.e., in line with their performance at the ongoing task), but also be consistent in the judgements they make before and after performing the task. The ability to make optimal decisions depends on the ability to make accurate judgements about one's own abilities and performance, on the ability to transform these judgements in strategies to effectively solve the task at hand, and the ability to evaluate whether the goal is met. As a consequence, it seems relevant to adopt a methodology able to keep into consideration the consistency between prospective and retrospective judgements and compare both of them simultaneously with the accuracy of actual performance.

The following rule was developed to assess metacognitive experiences. We use the label "question" to refer to each trial of the financial task. A correct answer at each question of the financial task is scored 1, while a wrong answer is scored 0 (C = 1, W = 0). As the MEQ is on a 4 points Likert scale (from 1 to 4), the total score for the 5 questions administered before each question of the financial task (x_{pre}) and the total score for the 5 questions administered after each question of the financial task (x_{post}) can vary from a minimum of 5 to a maximum of 20.

Furthermore, for each trial of the financial task, the total scores x_{pre} and x_{post} are changed according to the following rule:

- we attribute 0 if the total score is included in the interval [5,12];
- we attribute 1 if the total score is included in the interval [13;20].

5

x_{pre}

20

$$[5{,}12] \equiv 0; \quad [13{,}20] \equiv 1$$

5

x_{post}

20

$$[5{,}12] \equiv 0; \quad [13{,}20] \equiv 1$$

Based on the above conversion and on the correctness of the answer at every single financial question, for each trial of the financial task we can obtain 8 different cases:[4]

	a	b	c	d	e	f	g	h
x_{pre}	0	0	0	0	1	1	1	1
question	0	1	1	0	0	1	0	1
x_{post}	0	0	1	1	0	0	1	1
ME score	1	3	2	2	1	2	3	3

We can then differentiate the level of metacognitive experiences on the basis of accuracy of the answers at the MEQ, consistency in the prospective and

[4] Note that the dichotomised variables x_{pre} and x_{post} do not constitute per se the score of metacognitive experiences that is used in the regression model of study 2. We obtained a dichotomous variable x_{pre} and a dichotomous variable x_{post} for each question of the financial task, which were then compared with the answer at the corresponding trial financial task. Only the sum of the scores obtained from the comparisons for each question of the financial task was then used as a measure of ME for further analyses.

retrospective forms of the MEQ, and their consistency with performance at the financial task. For each trial of the financial task, we can then give participants a score for their metacognitive experiences, ranging from 1 (low ME) to 3 (high ME).

- Case *a* represents a person giving a wrong answer in the financial task, but stating both before and after the performance at the task the ease of the task and the need to spend a small amount of time and effort to solve it. As their evaluation is not consistent with their performance, a low score of ME is attributed: 1 point.
- Case *b* represents a person giving a correct answer in the financial task, recognising the ease of the task and the need of a small amount of time and effort to solve it. Furthermore, their answers in the prospective and retrospective questions of the MEQ are consistent. As a consequence, the highest score of ME is attributed: 3 points.
- Case *c* represents a person giving a correct answer in the financial task and stating the ease of the task and the need to spend a small amount of time and effort to solve it. However, they adjust their evaluation of difficulty after the performance. As their answers in the prospective and retrospective questions of the MEQ are not consistent, an intermediate score of ME is attributed: 2 points.
- Case *d* represents a person giving a wrong answer in the financial task, but stating the ease of the task and the need to spend a small amount of time and effort to solve it and adjusting their evaluation of difficulty after the performance. However, as their answers in the prospective and retrospective questions of the MEQ are not consistent, an intermediate score of ME is attributed: 2 points.

- Case *e* represents a person giving a wrong answer in the financial task, but recognising the difficulty of the task and the need to spend a lot of time and effort to solve it. However, their answers in the retrospective questions of the MEQ state that the task was easy, and are not consistent with their performance and with their answers in the prospective questions of the MEQ. As a consequence, a low score of ME is attributed: 1 point.
- Case *f* represents a person giving a correct answer in the financial task, but stating before the performance at the task that it is a difficult question, requiring a lot of time and effort and adjusting their evaluation of difficulty after the performance. However, as their answers in the prospective and retrospective questions of the MEQ are not consistent, an intermediate score of ME is attributed: 2 points.
- Case *g* represents a person giving a wrong answer in the financial task, but recognising the difficulty of the task and the need to spend a lot of time and effort to solve it. Furthermore, their answers in the prospective and retrospective questions of the MEQ are consistent with each other and with the performance. As a consequence, the highest score of ME is attributed: 3 points.
- Case *h* represents a person giving a correct answer in the financial task, but stating both before and after the performance at the task that it is a difficult question, requiring a lot of time and effort. They either spent a lot of time to solve the task or had a good intuition and guessed the correct one. In both cases they have been able to find the right answer despite the difficulty of the question. Since they have been consistent in their judgements before and after the performance, the highest score of ME is attributed: 3 points.

Finally, it is possible to calculate a total score of ME by summing the scores obtained for each trial of the financial task.

After observing the above matrix, it could be claimed that case *h* is the most problematic, as it is difficult to disentangle whether the task is solved correctly because the subjects identified the correct answer or because they guessed it and found the correct answer by chance. Furthermore since performance on the financial decision task figures into the scaling of the accuracy measure of ME, it could appear that this generates an artificial correlation. It is worthwhile to consider this here. According to our scoring measure, success and failure are equally potential contributors to a high metacognitive experiences score, so the measure is 'balanced'. Yet, even if the possible cases are eight and we separate them in four (*a*, *d*, *e*, *g* against *b*, *c*, *f*, *h*) it could be argued that the effect is not appropriately balanced because the total sum of the single scores in *b*, *c*, *f*, *h* (i.e., when solving the task correctly) is higher than the total sum of the single scores in *a*, *d*, *e*, *g* (i.e., when making a mistake at the task). To explore this potential issue, we considered the possibility of excluding case *h* from the test to have a more balanced (and actually less 'favourable' to test our hypothesis) measure of ME. We ran the analyses of Study 2 twice, - with and without case h in the measurement of ME - and found exactly the same results. Therefore, the inclusion of *h* is warranted.[5]

Standardised scores of metacognitive abilities. According to Efklides' model, metacognition is constituted by three main components: metacognitive experiences, metacognitive knowledge and metacognitive skills. The methodology described above and the a-MAI can be used to assess the three components of metacognition in the context of a decision-making task.

[5] Raw data from the experiment as well as the experimental results are available from the corresponding author upon request.

A standardised score for each facet can be obtained by dividing an individual's score by the maximum obtainable score. This step is better exemplified in what follows. As in the current study the financial task is constituted by 9 trials and the score of metacognitive experiences for each trial is in the range 1-3, the total score for metacognitive experiences (ME) can vary from a minimum score of 9 to a maximum score of 27.

$$\text{ME} \begin{cases} \nearrow 9 \\ \searrow 27 \end{cases} \qquad \text{ME}_s = \frac{me_s}{27} \in [\tfrac{1}{4}, 1]$$

Metacognitive knowledge (MK) is measured through the administration of 18 items of the Adapted–Metacognitive Awareness Inventory. The minimum score that can be obtained is 18, while the maximum score is 72.

$$\text{MK} \begin{cases} \nearrow 18 \\ \searrow 72 \end{cases} \qquad \text{MK}_s = \frac{mk_s}{72} \in [\tfrac{1}{4}, 1]$$

Metacognitive skills (MS) are measured through the administration of 21 items of the Adapted–Metacognitive Awareness Inventory. The minimum score that can be obtained is 21, while the maximum score is 84.

$$\text{MS} \begin{cases} \nearrow 21 \\ \searrow 84 \end{cases} \qquad \text{MS}_s = \frac{ms_s}{84} \in [\tfrac{1}{4}, 1]$$

Discussion

The main aim of Study 1 was the development of a more comprehensive methodology to assess metacognition, measure the accuracy of metacognitive experiences and capture the different facets of metacognition in the context of decision-making tasks.

Metacognition is a complex construct and although studies in this area are exponentially increasing, such complexity still involves some issues related to the assessment and measurement of the construct. Many of the instruments available in the literature focus only on one or two metacognitive facets, without providing a global picture of metacognitive abilities. Furthermore, most of them only apply to learning and memory tasks or perceptual decision-making (Ackerman & Thompson, 2017). In this study, the Metacognitive Awareness Inventory and the Metacognitive Experiences Questionnaire were selected among the instruments available in the literature and adapted to create a more comprehensive measurement of the different components of metacognition, in line with Efklides' multifaceted model of metacognition. The items of the MAI were adapted to refer to decision-making tasks and the results show that the instrument and its subscales have good internal consistency and a factor structure that is consistent with that of the original scale, able to disentangle metacognitive knowledge and metacognitive skills.

A new methodology to assess the accuracy of metacognitive experiences was developed from the MEQ, taking into account the limitations presented by previous studies conducted to investigate the accuracy of metacognitive judgements. One of the advantages presented by the new assessment is the ability not only to compare prospective and retrospective judgements in terms of accuracy, but also to integrate them in a single measure, according to the idea that it is more accurate a person able to provide accurate judgements before performing a cognitive task and to be consistent in their judgements after the performance. Second, this methodology allows to investigate at the same time different types of metacognitive experiences that can arise when solving a decision-making task. Third, a more sensitive 4-points scale is used instead of binary scales to capture the existence of intermediate states (e.g., when the person is unsure whether their response was correct or incorrect, but still feels more confident than a guess). Finally, individuals are asked to assess their metacognitive experiences for each single trial, whereas some previous studies have obtained a single measure of metacognitive accuracy across all trials (Sherman, Barrett, & Kanai, 2015).

In conclusion, the methodology described above provides a means of assessing a range of metacognitive components that may play an important role in decision-making. The instruments have good psychometric properties, although continuing their evaluation is recommended as the measures are novel.

Study 2: Age-related differences in the influence of metacognition on financial decision-making

The general purpose of the second study was the application of the methodology developed in Study 1 to investigate the effects that metacognition has on financial decision-making and the main differences in these processes between young and older adults.

Method

Participants. A total of 41 young adults (age range 20-33, *M* = 25.83 years, *SD* = 3.2; 18 female) and 40 older adults (age range 55-94, *M* = 67.8 years, *SD* = 8.0; 18 female) were recruited on campus at the University of Bath and in the community with flyers and advertisement on newsletters and forums. Participants were paid £10 for participation and received up to £10 to compensate for travel expenses. Participants were excluded if they reported any past or current neurological events or illnesses. The study was approved by the University of Bath Psychology Ethics Committee and all participants gave written informed consent.

***Measures*.** For the assessment of metacognition and financial knowledge the methodology created and tested in Study 1 was implemented. To get an estimate of cognitive ability, the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 2011) was used. The two-subset form was used to provide a score of cognitive abilities, which was in the range 55-157. The two-subset form of the WASI includes Vocabulary, which requires the respondent to verbally describe the meaning of a list of 31 specified term, and Matrix Reasoning, which requires the participant to decide which alternative of five is most reasonably the missing part from a logical sequence. In order to have comparable data for younger and older adults, unstandardised individual scores were calculated for each subtest by weighting the observed score by the maximum possible score on that subtest.

Since according to Efklides' model the object-level does not include directly metacognition but consists of cognitive and emotional processes and their interrelation, some features of individuals' functioning at this level (e.g., dysfunctional emotional ability) may undermine the validity of the experiment by acting as confounding factors of metacognition. Therefore, some additional tests were included among the materials to control for these features and exclude unsuitable participants. These measures are a facial expression recognition task and the Barratt impulsiveness scale (BIS-11; Patton, Stanford, & Barratt, 1995).

A facial expression recognition task was used to capture any eventual impairment in emotional abilities. It comprised two facial expression pictures for each of the six universal emotions, plus two neutral faces. All pictures were retrieved with permission from the database hosted by the Psychological Image Collection at Stirling (PICS).

The Barratt impulsiveness scale (BIS-11; Patton et al., 1995) was used to measure impulsivity. The 30items self-report questionnaire consists of a total score and three subscales measuring different aspects of impulsivity: non-planning, motor and cognitive impulsivity. Respondents rate each item on a 4-point scale (1 = rarely/never; 2 = occasionally; 3 = often; 4 = almost always/always).

Procedure. The entire testing session lasted approximately 60 minutes. All participants received experimental materials in the same order. The order of completion was as follows: Participants were provided with an information sheet describing the experiment and asked to sign a consent form before proceeding. The WASI and the facial expression recognition task were administered first by the examiner. Participants were then asked to complete the financial task together with the adapted version of the MEQ on a computer. Finally, the remaining questionnaires and some demographic questions were answered. At the end of the study participants were debriefed and paid.

Results

Comparisons between the two samples. Between groups comparisons were used to investigate the existence of significant differences in the levels of cognition and metacognition in younger and older adults. A Mann-Whitney U test was used and the results showed that young adults have higher levels of cognitive abilities than their older counterparts (young: *Mdn* = 1.63, *Range* = 1.38−1.81; older: *Mdn* = 1.56, *Range* = 1.08−1.70; $U(41,40) = 479$, $Z = -3.22$, $p = .001$, $r = -.36$). On the contrary, older adults have significantly higher scores of metacognitive experiences (young: *Mdn* = 0.74, *Range* = 0.48−0.96; older: *Mdn* = 0.81, *Range* = 0.52−1.00; $U(41,40) = 1041$, $Z = 2.10$, $p = .036$, $r = .23$), while there are no significant differences among younger and older adults in the other components of metacognition.

Regression analysis. To test the second hypothesis and check whether metacognition predicts performance at the financial task and whether there exist differences between younger and older adults, a regression was used. Since performance is measured as the proportion of correct answers provided out of 9, a generalised linear model was used, with a binomial distribution and a logit link function.[6] A first regression analysis was applied to explain performance at the financial task in terms of metacognitive and cognitive abilities. The main predictors were the three components of metacognition and cognitive ability, while schooling and age were used as control variables. The main results are shown in Table 3.2.

For older adults the higher the schooling, the better the performance at the task. Most importantly, the accuracy of metacognitive experiences resulted to be a significant predictor for both samples, whereas cognitive abilities were a significant predictor of financial performance only for younger adults. Specifically, when metacognitive experiences increase one unit and the other variables are controlled, the odds that the financial task can be solved correctly increase by a factor of 1.6 times for younger adults and a factor of around 1.3 times for older adults. The result that metacognitive experiences are a significant predictor of performance at the financial task is consistent with Hypothesis 2. Furthermore, for young adults, a one unit increase in cognitive ability increases the odds of succeeding at the financial task of around 1.6 times.

[6] Continuous variables were centred to the mean.

Table 3.2

Predictors of Performance at the Financial Task; Model 1

	Young Adults			Older Adults		
Variable	B	SE	OR	B	SE	OR
Constant	1.46	1.05	4.32	-2.29*	.75	.10
Schooling (Base = Some secondary school)						
Graduated secondary school (GCSE)	-	-	-	1.69**	.42	5.40
6th Form (A-level)	.50	.33	1.66	1.39*	.56	4.03
Some University	.34	.39	1.40	2.20**	.41	9.03
Graduated University	.06	.35	1.06	1.57**	.41	4.79
Post-Graduate University (Masters, PhD, etc.)	.45	.31	1.56	2.07**	.42	7.95
Higher (post docs, MBA, etc.)	1.75**	.31	5.75	1.54*	.56	4.68
Age	-.07	.04	.93	.01	.01	1.01
Metacognitive Experiences (ME)	.47**	.13	1.60	.23*	.07	1.25
Metacognitive Knowledge (MK)	.20	.15	1.22	-.17	.17	.84
Metacognitive Skills (MS)	-.14	.13	.87	.08	.14	1.08
Cognition	.46*	.16	1.58	.06	.11	1.06
Deviance		30.14			24.26	
Pearson Chi-Square		28.61			23.56	
AIC		3.67			3.73	

Note. * $p < 0.05$. ** $p < 0.01$

A second generalised linear model was performed adding to the previous model the product between each metacognitive component and cognitive ability. The main aim was to better characterise the interplay between cognitive and metacognitive abilities in predicting performance at the financial task and test the third hypothesis. We predicted metacognition to moderate the effect that cognitive ability has on performance and counteract the reductive effect of cognitive decline. Accordingly, we expected positive coefficients for cognitive ability and for the interaction between cognitive ability and metacognition. The main results are shown in Table 3.3.

Table 3.3

Predictors of Performance at the Financial Task; Model 2

	Young Adults			Older Adults		
Variable	B	SE	OR	B	SE	OR
Constant	1.56	1.30	4.76	-4.15*	1.53	.01
Schooling (Base = Some secondary school)						
Graduated secondary school (GCSE)	-	-	-	4.20*	1.34	66.77
6th Form (A-level)	.56	.35	1.75	3.95*	1.50	52.20
Some University	.33	.36	1.40	4.69*	1.45	109.78
Graduated University	.05	.35	1.10	4.07*	1.42	58.27
Post-Graduate University (Masters, PhD, etc.)	.55*	.27	1.73	4.59*	1.33	98.58
Higher (post docs, MBA, etc.)	1.01	.89	2.75	4.02*	1.44	55.95
Age	-.08	.05	.92	-.00	.02	1.00
Metacognitive Experiences (ME)	.41*	.13	1.50	-.17	.12	1.19
Metacognitive Knowledge (MK)	.25	.19	1.28	-.10	.14	.90
Metacognitive Skills (MS)	-.10	.21	.91	.08	.12	1.09
Cognition	.50*	.16	1.66	.12	.11	1.13
Interaction ME * Cognition	.18	.15	1.20	-.17	.12	.84
Interaction MK * Cognition	-.18	.20	.84	-.39	.27	.68
Interaction MS * Cognition	-.14	.26	.87	.57*	.27	1.77
Deviance		26.01			19.27	
Pearson Chi-Square		24.36			18.63	
AIC		3.72			3.76	

Note. * $p < 0.05$. ** $p < 0.01$

Different results were obtained for younger and older adults, partially supporting the main hypothesis. For younger adults, metacognitive experiences and cognitive abilities remained the significant predictors of performance at the financial task, whereas none of the interaction terms were significant. For the elderly, metacognitive skills were the metacognitive component that had a positive, significant impact on the relationship between cognitive ability and performance at the financial task.

However, the information that can be garnered from the table above can be improved upon as it does not reveal whether the effect of metacognition on task performance changes for different levels of cognitive ability. To elucidate on these factors, the marginal effect of each component of metacognition for different levels of cognitive ability was computed and graphically displayed (Figure 3.1). This allows us to know whether an increment of metacognition can significantly improve or hinder task performance for different levels of cognitive ability. In each graph, the blue line represents the point estimate and indicates how the marginal effect of the different components of metacognition change with the level of cognitive ability. The blue area surrounding the line is delimited by 95% confidence intervals and allows us to determine the conditions under which metacognition has a statistically significant effect on task perform for different levels of cognitive ability. Significance is depicted as the values when the confidence bands are entirely above or below zero.

The analyses reported in Figure 3.1a suggest that an increase in the accuracy of metacognitive experiences is beneficial for those older adults whose cognitive ability is below the 50^{th} percentile. However, such effect of metacognitive experiences on task performance loses significance for individuals with higher cognitive abilities. On the contrary and counterintuitively at first glance, an increment of older adults' metacognitive knowledge seems to have a significant, negative effect on task performance for individuals with high cognitive abilities (above the 75^{th} percentile; see Figure 3.1b).

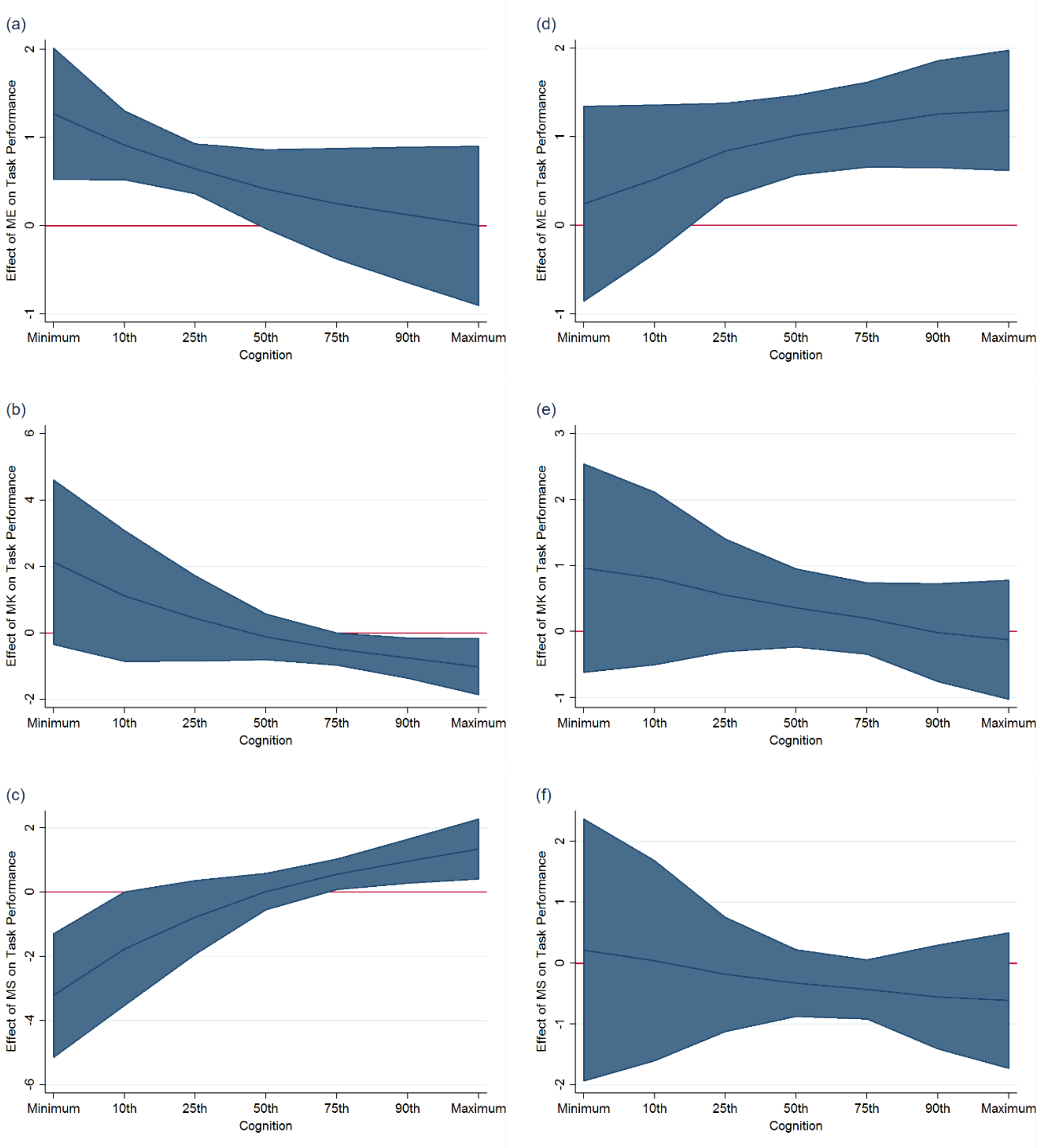

Figure 3.1. The conditional effects of metacognitive experiences (a. and d.), metacognitive knowledge (b. and e.), metacognitive skills (c. and f.) on task performance as a function of cognitive ability. The figures on the left refer to older adults (Cognitive abilities: Minimum = -3.76; Maximum = 1.00) whereas the figures on the right refer to younger adults (Cognitive abilities: Minimum = -1.5; Maximum = 1.8).

Although the marginal effect of metacognitive knowledge on task performance is not significant for older adults with lower cognitive ability, the figure seems to suggest a positive effect for an increment of MK. An increase in older adults' metacognitive skills has a detrimental effect on performance at the financial task for individuals with cognitive abilities below the 10th percentile and positive for older adults with cognitive abilities above the 75th percentile (see Figure 3.1c). Different results have been obtained for the sample of younger adults. Whereas an increase in metacognitive knowledge or skills seems to have no significant effects on task performance (see Figures 3.1e and 3.1f), an increment in metacognitive experiences seems to have a positive influence on task performance for all those younger adults who are approximately above the 20th percentile in terms of cognitive ability (see Figure 3.1d).

Discussion

This study investigated the relationship between metacognition, age, and financial decision-making, with the aim of enlighten and extend what is already known about the psychological variables involved in the decision-making process. The first analysis explored age-differences in cognitive and metacognitive abilities. Consistent with the hypothesis that cognitive and metacognitive abilities differ between younger and older adults, it was found that younger adults have much higher cognitive abilities than older adults, whereas older adults provide much more accurate metacognitive judgements related to the questions of the financial task and their ability to solve them. The first result is in line with the existing literature stressing the cognitive decline that characterises old age (see Salthouse, 2010 for a review). The second result falls within the ongoing debate on the development of metacognitive experiences and supports previous studies finding that ageing does not affect the accuracy of metacognitive judgements used to monitor the ongoing cognitive processing (e.g., Hertzog & Dunlosky, 2011). Our study allowed us to examine metacognitive experiences in decision-making rather than in a memory task and the findings support those scholars who posit that the inaccuracy of metacognitive judgements and feelings in older adults may reflect age-related deficits in memory or poorer quality of memories rather than a mere metacognitive deficit (Hertzog & Dunlosky, 2011). Highly accurate metacognitive experiences are important for older adults as they represent a spared monitoring process that can be uses to improve performance.

With the aim of further investigating the influence of metacognition on financial decision-making a regression analysis was then implemented. Partially in line with the hypothesis that metacognitive and cognitive abilities can predict performance at the financial decision-making task, the first model showed that higher accuracy of metacognitive experience leads to more successful decision-making for both younger and older adults, while cognitive ability is associated with a higher level of decision-making functioning only for young adults. The second model, taking into account also the interaction between cognition and metacognition, showed that the interaction between metacognitive skills and cognitive ability positively influences older adults' decision-making. In line with the hypothesis that a high level of metacognitive ability can balance the natural decline in cognitive abilities, this result suggests that an increase in metacognition can strengthen the effect of cognitive ability on task performance towards more effective decision-making.

Despite the relevance of these results, a more detailed overview of how cognitive and metacognitive abilities interact and predict performance at the financial task was provided by the marginal effects shown in Figure 3.1. The analysis showed that an increase in the accuracy of metacognitive experiences is beneficial for older adults with low cognitive ability. According to Efklides (2014), metacognitive experiences can help individuals by providing them with information regarding their competences and the amount of effort and time required to solve the task, and directing them towards the right solution of the task. On the contrary, the loss of significance with high cognitive abilities could be explained by the lifetime experiences that characterises older adults. That is, throughout their life individuals with high cognitive abilities may develop the ability to efficiently solve different tasks, without the need of questioning consciously and intensively on their competences and their feelings on the ongoing cognitive performance.

The negative effect that an increment of metacognitive knowledge has on task performance for older adults with high cognitive abilities might be due to the inflexibility of the information-processing system. Metacognitive knowledge is a top-down process through which existing knowledge is placed in the context of a particular task and provides a framework to interpret situational data. As a result of experience and expertise, older adults might have organised their knowledge in a very structured system and partially lost the flexibility that allows them to change mode of thinking as a function of different task demands (Lemaire, Arnaud, & Lecacheur, 2004). Due to the decline in older adults' working memory and its limited capacity, an increase in metacognitive knowledge may cause a cognitive overload (Paas, Renkl, & Sweller, 2003; Sweller, 1994). More specifically, individuals with higher cognitive abilities are overwhelmed by the amount of information that needs to be processed simultaneously, they enter a loop of thoughts and are not able to find the solution of the task they are handling.[7] Highly skilled individuals may over-think and doubt their own knowledge and capabilities, ending up being more critical than unskilled individuals on what they have to do or which is the best way to solve a task.

[7] This is reminiscent of an observation made by Bertrand Russell in his essay The Triumph of Stupidity: "*The whole problem with the world is that fools and fanatics are always so certain of themselves, but wiser people so full of doubts*".

The effect that an increase in metacognitive skills has on performance at the financial task differs depending on the level of cognitive ability, being detrimental for older adults with very low cognitive abilities and positive for older adults with higher cognitive abilities. It seems plausible to hypothesise that for those individuals who do not possess sufficient cognitive skills to execute cognitive tasks, an increase in metacognitive skills creates a sort of bottleneck effect. That is, the mere awareness of the steps needed to solve a task and the ability to monitor progress towards the set goals is detrimental if not supported by an increase in the analytic skills necessary to solve the problem. An increment of metacognitive skilfulness can overwhelm individuals with low cognitive abilities, making them unable to operate an accurate control over the ongoing cognitive performance. On the contrary, the results suggest that individuals with high cognitive abilities can benefit from an increase in metacognitive skills, which allows them to monitor more accurately the ongoing cognitive performance and ensure that the goal set is reached.

Unlike older adults, the only significant interaction for younger adults is that between metacognitive experiences and cognition, although it is not significant for very low levels of cognitive abilities. There is evidence showing that in many domains poor performers lack the skills to assess their own performance (e.g., Ehrlinger, Johnson, Banner, Dunning, & Kruger, 2008; Kruger & Dunning, 1999). Dunning, Johnson, Ehrlinger, and Kruger (2003) have suggested that this lack of awareness occurs because in many domains the skills needed to perform correctly correspond to the expertise necessary to evaluate the accuracy of one’s own responses. The lack of a significant effect for individuals with very low cognitive abilities seems to be in line with these findings. On the contrary, as Ehrlinger et al. (2008) have pointed out, if a lack of skills leads to the inability to evaluate the quality of one's performances, one means of improving metacognitive ability is to improve one's level of skill. That is, the accuracy of metacognitive experiences is developed together with the accumulation of experience and relates to intelligence. In light of this consideration, the significant effect that metacognitive experiences have on task performance for high levels of cognitive ability might be due to the improvement in knowledge and skills and the experience with a variety of tasks, which provide individuals with extensive feedback and allow them to garner information about their abilities and improve in turn their performance.

The lack of significant effects of metacognitive knowledge and skills on task performance for younger adults leads back to the debate on the relationship between metacognitive and cognitive abilities (see Veenman & Spaans, 2005 for a more extensive explanation). Whereas the lack of significance in the results for younger adults seems to support those scholars who posit that metacognition and cognition represent two independent processes (e.g., Allon, Gutkin, & Bruning, 1994), the results of the same analysis conducted on older adults suggest that with ageing metacognitive and cognitive processes interact more strongly with one another during the resolution of decision-making tasks. These findings are in line with previous studies showing that metacognition is only partially independent of intelligence (e.g., Stankov, 2000; Veenman, Kok, & Blöte, 2005).

Taking into consideration the existence of significant differences in metacognitive strategy usage between novices and advanced subjects (e.g., Veenman & Elshout, 1999), it seems plausible to hypothesise that in the early stages of adulthood metacognitive and cognitive processes work mainly independently because young adults are still in the process of acquiring a repertoire of metacognitive abilities. This is in line with the theoretical framework proposed by

Veenman et al. (2005), according to which metacognition initially makes a task manageable, while intellectual skills come in afterwards to operate more effectively upon the gathered data. Research on learning has shown that metacognition, rather than intelligence, initiates learning (Veenman & Elshout, 1999; Veenman, Prins, & Elshout, 2002), as there is, in fact, no material available for the cognitive toolbox to operate upon. Metacognitive processing, such as carefully doing things step-by-step, helps organise a complex task, thus reducing the burden on working memory. However, it also seems that metacognitive and cognitive processes do integrate each other with the accumulation of life experience and the interplay between the two gets a larger degree of automatisation, enabling individuals, and particularly older adults, to adapt task strategies to the different task environments they encounter.

General discussion

The study reported here allowed the development of an experimental method to measure metacognition in decision-making tasks and the main findings provided novel evidence for the role of metacognition in financial decision-making and the existence of significant differences between young and older adults. Most research on decision-making and ageing has studied how the physiological cognitive decline impairs choice behaviour (e.g., Boyle et al., 2012) and the more central role played in older adults' decision-making by the spared or even enhanced emotional and heuristics processes (e.g., Carstensen & Mikels, 2005). However, there is still a gap in understanding how the higher level of cognition – i.e., metacognition – is related to financial decision-making. Furthermore, although previous studies have revealed that individuals with a deeper metacognitive awareness have better performance in problem solving tasks (see Davidson & Sternberg, 1998), neither of these studies tested age-related differences, nor did they verify the role of metacognition, as moderator, in the effect that cognitive abilities have on financial decision-making. We extended the findings to show that metacognition plays an important role in the decision-making process and its effect varies according to age and level of cognitive ability.

An understanding of the implications of metacognition for financial choice behaviour is relevant for policies designed to control financial behaviour and improve welfare, as it may help improve decisions and provide strategies to develop skills in financial decision-making. The merger of the above results with those of previous studies showing that metacognition is a teachable skill (e.g., Bailey, Dunlosky, & Hertzog, 2010; Schraw, 2001) strengthens the implications that the development of high metacognitive capabilities has for decision-making. This seems to be particularly relevant for older adults. In line with previous studies demonstrating the beneficial effect of metacognitive trainings for older adults (e.g., Dunlosky, Kubat-Silman, & Hertzog, 2003), it seems relevant to conduct further research to investigate more in depth the interplay between metacognitive processes and different cognitive aspects and understand how to structure interventions on metacognition, with the aim of verifying whether enabling individuals' self-awareness and regulatory processes can compensate the physiological cognitive decline and benefit older adults' decision-making.

The current study referred to metacognition in terms of the three components suggested by Efklides (2008) as the subprocesses operating at the metalevel; that is, metacognitive experiences, metacognitive knowledge, and metacognitive skills. According to the model, however, metacognition is a broader construct, including also social metacognitive processes. Further studies could investigate the role of social metacognitive processes in decision-making and focus on the interplay between cognition and the processes operating at the meta-metalevel of Efklides' model of metacognition (2008). This could ascertain whether also social metacognition can be used by older adults to compensate for cognitive decline and improve their performance.

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Chapter 4

The influence of cognitive and metacognitive abilities on risk aversion. A comparison between young and older adults

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Chapter Rationale

As noted in the literature review, one of the key components of economic decision-making is risk. At the same time, the literature has presented contradictory results in terms of the age-related differences in risk attitude and risk behaviour. Furthermore, limited evidence-based research is available regarding possible psychological variables affecting risk attitude and explaining the age-differences identified by previous studies and the variability in the main findings. Chapter 4 presents the results of an empirical investigation of the role of metacognition in explaining age-differences in risk aversion.

Statement of Authorship

<table>
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<tr><td colspan="10">The influence of cognitive and metacognitive abilities on risk aversion. A comparison between young and older adults</td></tr>
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<tr><th>Candidate’s contribution to the paper (detailed, and also given as a percentage).</th><td colspan="9">Chiara Scarampi made considerable contributions to the conception of the study (95%), as well as the methodological design (95%).The experimental work, including data collection, data analysis and interpretation was predominantly conducted by Chiara (95%). Chiara was responsible for establishing an international collaboration with A. Palermo. Chiara has also executed the presentation of the data in journal format (95%), as well as presented its content at national and international academic conferences.</td></tr>
<tr><th>Statement from Candidate</th><td colspan="9">This paper reports on original research I conducted during the period of my Higher Degree by Research candidature.</td></tr>
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The Influence of Cognitive and Metacognitive Abilities on Risk Aversion. A Comparison between Young and Older Adults

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Abstract

Research on financial decision-making has revealed mixed findings about age differences in risk preferences. Conflicting results may be due to factors confounded with age. To obtain a better understanding of how risky behaviour changes with age, this paper reports the results of an empirical study investigating the role of cognition and metacognition as explanatory variables of risk attitude. The main results show that younger and older adults do not differ in risk taking. However, in both samples lower cognitive ability is associated with greater risk aversion, whereas high metacognition has an opposite effect for the two samples, being associated with risk taking in younger adults and risk aversion in older adults. Our findings provide new insight into the variability in decision preferences expressed by older adults, indicating that rather than depending on ageing, differences in risk attitude between young and older adults can be justified taking into account cognitive and metacognitive abilities.

Keywords: Ageing, Cognitive Ability, Metacognition, Risk Attitude

The influence of cognitive and metacognitive abilities on risk aversion. A comparison between young and older adults

This paper investigates how metacognition is linked to age-related differences in risk preferences, focusing particularly on the possibility that, together with cognitive ability, metacognition can explain the acknowledged relationship between age and risk attitudes.

Several individuals' decisions, including investment and savings decisions, voting behaviour, healthcare decisions, and health behaviour, are characterised by uncertainty and are affected by risk preferences. Recognition of the influence of risk preferences on human behaviour has generated considerable interest in understanding and predicting individual inclinations towards risk and their determinants.

At the same time, a growing empirical literature has investigated the relationship between risk attitudes and age, stressing the importance of considering the implication of this relationship on the macroeconomic fundamentals of markets as well as on socio-political outcomes (Bonsang & Dohmen, 2015). Nevertheless, most of the experiments on risky decision-making that include older adults are controversial. Probably, the most common view is that older adults are more risk avoidant (Okun, 1976). In line with this view is the reasoning that due to a lack of time and diminishing physical resilience, with advancing age it is more difficult to compensate for decisions of poor quality and make up for eventual negative outcomes (Peters et al., 2000; Peters, Hess, Vastfjall, & Auman, 2007). For instance, if a younger adult invests in stocks and the market crashes, they still have plenty of time to remedy and save money for the retirement, whereas losing savings in the older age can be more problematic (National Research Council (US) Committee on Aging Frontiers in Social Psychology, 2006). Accordingly, some studies have found that individuals become more risk averse as they grow older (e.g., Albert & Duffy, 2012; Dohmen, Falk, Golsteyn, Huffman, & Sunde, 2017; Dohmen et al., 2011; Roalf, Mitchell, Harbaugh, & Janowsky, 2012). On the contrary, others empirical works have reported no age differences in risk behaviour (e.g., Dror, Katona, & Mungur, 1998; Kovalchik, Camerer, Grether, Plott, & Allman, 2005).

Yet, in conflict with the stereotype of cautious older adults, another strand of research deals with the *risk-as-feelings hypothesis* and the idea that individuals' behaviour in risky situations is mediated by emotional aspects, time interval between decision and outcome, and vividness in the mental representation of the outcome (Loewenstein, Weber, Hsee, & Welch, 2001). Particularly, risk aversion seems to be driven by negative emotions, such as fear, dread, and anxiety. Since emotional processes undergo fundamental changes across the lifespan and negative emotions seem to decrease with age (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000), it can be hypothesised that older adults will have a different attitude towards risk and increase their risk-taking behaviour (Mather, 2006). Accordingly, there is evidence that older adults actively make investment decisions that involve a high degree of risk (Brown, 2002) and that risk tolerance – i.e., the maximum amount of uncertainty that a person is willing to accept when making a financial decision – increases with age (Grable, 2000).

Due to the contradictory nature of the results, it seems debatable whether or not the relationship under question is necessarily linked to a chronological (calendar) age effect or depends on some other factors that change with ageing. In this last case, where only the (biological) ageing processes affect risk preferences, the consequences of an older population appear to have less intensive effects on a macro level (Bonsang & Dohmen, 2015). Conflicting results may be due to factors confounded with age (Bonsang & Dohmen, 2015; Mather, 2006). To obtain a better understanding of how risky behaviour changes with age, researchers have started investigating other sociodemographic characteristics and psychological variables that might affect risky behaviour and its relationship with age.

Although few, many of these studies have considered the role of cognitive ability and found that risk aversion varies systematically with cognitive ability (e.g., Benjamin, Brown, & Shapiro, 2013; Boyle, Yu, Buchman, Laibson, & Bennett, 2011; Burks, Carpenter, Goette, & Rustichini, 2009; Dohmen, Falk, Huffman, & Sunde, 2010). In particular, Dohmen et al. (2010) have shown that individuals with higher cognitive ability are significantly more willing to take risks, independently of age, gender, education, income, and liquidity constraints.

Since cognitive ability is affected by biological ageing and not necessarily by chronological age, it seems appropriate to look at the effect that ageing – in its chronological sense – has on the relationship between cognitive ability and risk preferences. Building upon previous evidence showing that cognition is related to risk preferences, some recent studies have investigated whether older adults' cognitive decline leads to a decrease in the willingness to take risk (Bonsang & Dohmen, 2015; Boyle et al., 2011). Bonsang and Dohmen (2015) have shown that age differences in risk attitudes are associated with cognitive ageing and about the 85% of the association between risk preferences and ageing can actually be attributed to cognitive ability. Henninger, Madden, and Huettel (2010) have found that age effects upon decision quality are mediated by individual differences in cognitive processes (i.e., when processing speed and memory are included in the regression model, age is no longer a significant predictor of decision quality). Similarly, Koscielniak, Rydzewska, and Sedek (2016) have shown that processing speed mediates age differences in the Balloon Analog Risk Task, a strong predictor of real-life risk-taking behaviour. Altogether, these results suggest that cognitive decline correlates with changes in risk attitudes over the lifespan.

Another relevant question that has not been addresses yet is whether also metacognition – i.e., the ability to think about the ongoing cognitive performance and guide, monitor, and regulate cognitive actions (Flavell, 1979) – plays a role in shaping individuals' risk attitudes and can explain individual differences. While there is some literature analysing the link between cognitive abilities and risk attitude, little is known about the predictive role of metacognition on risk preferences.

Jaccard, Dodge, and Guilamo-Ramos (2005) have investigated the role of perceived intelligence and perceived knowledge, two key variables in metacognition, in adolescents' health risk behaviour. Perceived intelligence is a judgement on one's own mental ability and knowledge at the abstract level, whereas perceived knowledge refers to judgements on one's own knowledge in specific domains. The authors have found a significant relationship between higher levels of perceived intelligence and lower probabilities of adverse risk outcomes. On the contrary, higher levels of perceived knowledge about the strategies that can be implemented to prevent the negative consequences that derive from risk behaviour are associated with an increased performance of risk behaviours.

As the authors have suggested, it is possible that the acquisition of a broader knowledge of the possible strategies to avoid negative outcomes diminishes the threat of the negative outcomes of risk behaviour. This interpretation is in line with the risk compensation theory (Adams & Hillman, 2001), which suggests that providing individuals with a protective device (e.g., bicycle helmets, automobile seat belts, etc.) can result in a higher rate of risk behaviour. That is, the sense of increased protection derived from the protective device may result in a lower benefit from the use of the device than expected. Overall, it seems that perceived intelligence at the abstract level exerts a protective function against risk behaviour and the associated negative outcomes. In contrast, higher knowledge about strategies to avoid the adverse outcomes associated with risk behaviour increases the exposure to risk, raising in turn the likelihood of experiencing a negative outcome.

Given the extrinsic link between cognition and metacognition, the investigation of the impact of metacognition on risk behaviour is highly warranted. Understanding metacognitive characteristics and strategies used to make choices has a strong impact upon the development of those skills and the improvement of decision-making abilities. The analysis of the relationship between metacognition and risk attitudes and the differences in the functioning of its monitoring and control processes within younger and older adults can shad further light on the underlying mechanisms of risky behaviour and the psychological variables that determine our attitudes and preferences.

In this study, we referred to the model of metacognition proposed by Efklides (2008), according to which metacognition consists of three facets: metacognitive knowledge, skills, and experiences. Metacognitive knowledge is a top down process through which already existing declarative knowledge is placed in the context of a particular task to interpret situational data. Metacognitive skills are strategies that use procedural knowledge to control cognition, regulate performance, and evaluate the outcome. Metacognitive experiences are heuristic processes that inform the individual about the ongoing cognitive performance on the basis of feelings, judgements, and cues obtained by the task, the context, or cognitive processing.

In this article, we contribute to the literature by providing some new evidence regarding the relationship between metacognition and risk attitude and analyse whether the ‘thinking about thinking’ ability implies a lower willingness to engage in risk behaviour. Based on Gneezy and Potters (1997)’ work, we used a gamble (see the Method section below) to elicit individuals’ preferences for gambling, measuring their degrees of risk aversion. Then, a regression analysis was performed to disentangle the effect of the main explanatory variables (cognition, metacognition, and age differences) on risk attitude.

Method

Participants. A total of 41 young adults (age range 20–33, *M* = 25.83 years, *SD* = 3.2; 18 female) and 40 older adults (age range 55–94, *M* = 67.8 years, *SD* = 8.0; 18 female) were recruited on campus at the University of Bath and in the community with flyers and advertisement on newsletters and forums for a study on financial decision-making (see Scarampi, Fairchild, Palermo, & Hinvest, 2018). At the end of the study, participants received up to £10 to compensate for the expenses involved in travelling to and from the university. More importantly, they were compensated with £10, which they had the opportunity to raise by partaking in a hypothetical investment task.

Participants were screened for and excluded if reporting any past or current neurological events or illnesses. This study was approved by the University of Bath Ethics Committee. All participants gave written informed consent.

Measures.

Metacognition. The adapted version of the Metacognitive Awareness Questionnaire (MAI; Schraw & Dennison, 1994) was used to measure metacognitive knowledge and metacognitive skills. The questionnaire consists of 50 items tapping into two subscales measuring respectively the two constructs. Whereas the original version of the instrument is aimed at measuring the extent to which individuals are aware and use their metacognitive strategies when learning new information, the a-MAI is a measure of MK and MS in the context of decision-making. Respondents rate each item on a 4-point scale (1 = never; 2 = sometimes; 3 = often; 4 = always). Five questions of the Metacognitive Experiences Questionnaire (MEQ; Efklides, 2002) were used to measure metacognitive experiences in the context of a financial decision-making task (see Scarampi et al., 2018). The questionnaire consists of a perspective form to be completed before each trial of the task and a retrospective form to be completed after each trial of the task. Respondents rate each item on a 4-point scale (1 = not at all; 2 = a little; 3 = enough; 4 = very). The scores obtained on both questionnaires were rescaled and summed up to form the score of metacognition used for the analyses in the current study.

Cognition. The two-subset form of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 2011) was used to provide a score of cognitive abilities. The subtests are Vocabulary, which requires the respondent to verbally describe the meaning of a list of 31 specified terms, and Matrix Reasoning, which requires the respondent to decide which alternative out of five is most reasonably the missing part from a logical sequence. The raw scores obtained at each subtest of the WASI are generally transformed in age-corrected T scores, which allow 'peer' comparisons but not cross-age contrasts. In order to be able to compare cognitive abilities in our two samples, we computed unstandardised individual scores, which are not affected by age. Unstandardised scores for each subtest were calculated by weighting the observed score by the maximum possible score on that subtest (i.e., correct proportion on each subtest ranging from 0 to 1).

Risk attitude. A gamble based on Gneezy and Potters (1997) was used to elicit individuals' risk attitude. After their participation, subjects received £10 and took part in an investment task, where they had to decide which part (X) of this endowment they wanted to devote to a risky investment ($0 \leq X \leq 10$). The remainder $£10 - £X$ represented the safe investment, which was kept regardless of the outcome of the investment. The lottery consisted of equal probabilities of winning three times the amount bet or losing it. The outcome of the risky investment was decided by rolling a 6 sided die. If rolling an even number, the investment was successful and the amount X was multiplied by 3; if rolling an odd number, the investment was unsuccessful and the amount X was lost. Thus, if the die rolling was successful, participants ended up with $£10 + £3X$; otherwise $£10 - £X$. Subjects were informed about the characteristics (probabilities and size of gains/losses). The amount invested X was then used as the measure of financial risk-taking.[8]

Procedure. Participants were provided with an information sheet describing the experiment and asked to agree on the consent form before proceeding. The WASI was administered by the experimenter. Participants took then part in a financial decision-making task and filled out all the metacognitive questionnaires. They were also asked to provide some demographic information (gender, age, schooling, and income). At the end of the study they were informed about the gained amount of money and asked if they wanted to take part in the investment task and how much money they wanted to bet. They were then asked to roll a six sided die to determine the outcome of the investment. Participants were finally debriefed and paid according to the outcome of the investment task.

Results

Descriptive statistics. Table 4.1 provides the descriptive statistics for risk preferences, metacognition and cognitive ability for young and older adults.

Table 4.1.

Summary Statistics for the Variables Used in the Analyses

Variable	Young Adults *n*=41	Older Adults *n*=40
Metacognition	*M*=2.21 *SD*=.19	*M*=2.22 *SD*=.25
Cognition	*M*=1.62 *SD*=.11	*M*=1.52 *SD*=.13
Risk Preferences	*M*=3.54 *SD*=3.04	*M*=3.75 *SD*=4.00

[8] As in Gneezy and Potters (1997), the test used in this paper implies that both risk neutral and risk lover participants would invest all the available money. However, since risk aversion is a more common characteristic in the population, the test represents a sensitive measure of the attitude towards risk.

Figures 4.1 and 4.2 illustrate respectively the schooling and the income in the two samples.

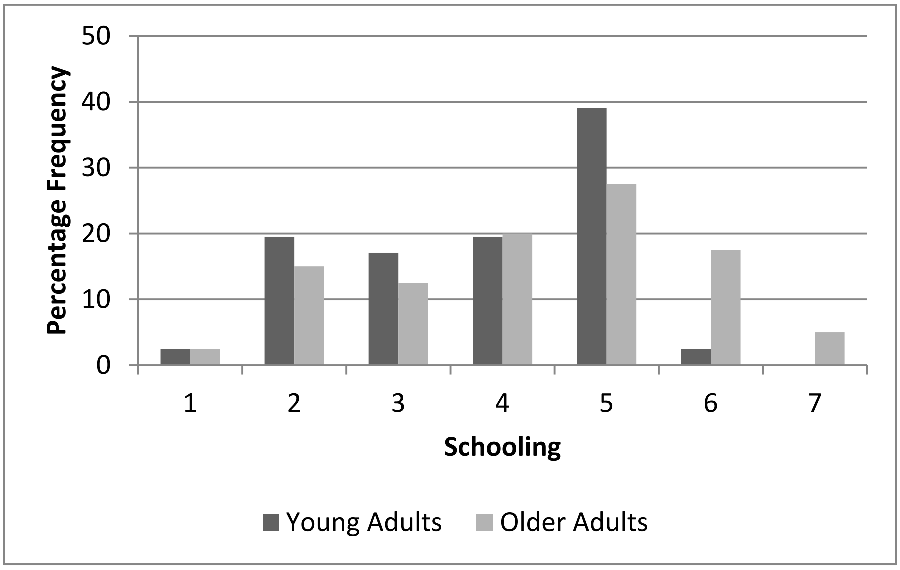

Figure 4.1. Histogram of young and older adults' schooling level. 1 = Some secondary school; 2 = Graduated secondary school (GCSE); 3 = 6th Form (A-level); 4 = Some University; 5 = Graduated University; 6 = Post-Graduate University (Masters, PhD, etc.); 7 = Higher (post docs, MBA, etc.).

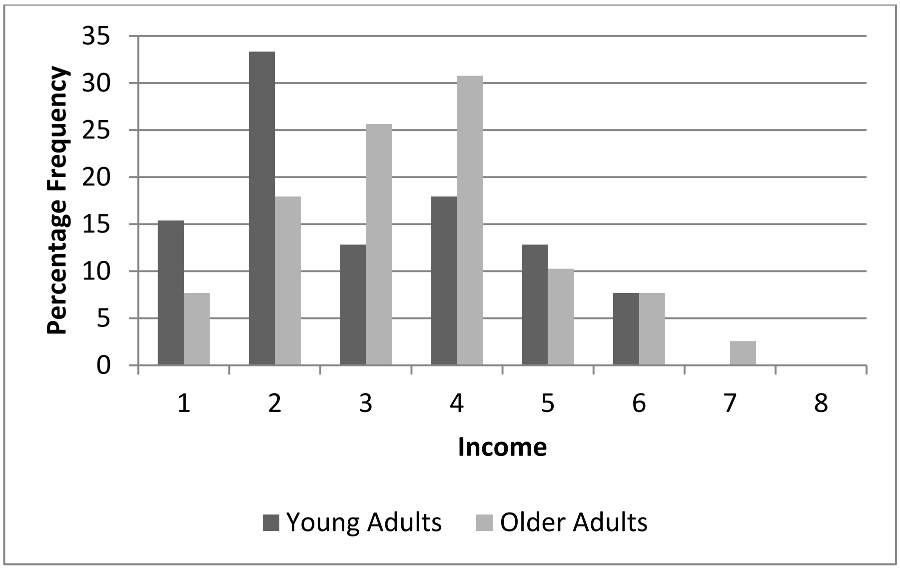

Figure 4.2. Histogram of young and older adults' income. 1 = Up to 9,999 pounds; 2 = Between 10k and 19,999 pounds; 3 = Between 20k and 29,999 pounds; 4 = Between 30k and 39,999 pounds; 5 = Between 40k and 49,999 pounds; 6 = Between 50k and 74,999 pounds; 7 = Between 75k and 99,999 pounds; 8 = 100k+ pounds.

Figure 4.3 shows differences in risk preferences for the two age groups. Both samples tended to invest either a few pounds or all the money they had at their disposal.

However, older adults were more extreme than young adults in their choices and more older adults decided not to invest in the gamble.

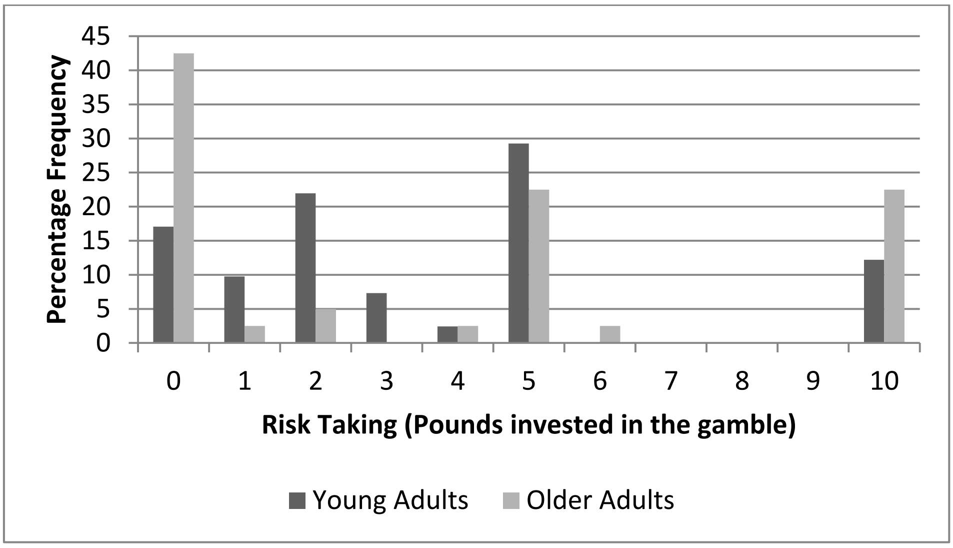

Figure 4.3. Histogram of young and older adults' attitudes to financial risk.

Correlations and comparisons between the two samples. A first analysis tested the existence of significant relationships between the variables, differentiating the two samples. As most of the data were not normally distributed, Spearman's correlation coefficients were computed. For the older sample there was a significant correlation between risk taking tendency and cognitive ability, both in its total score (r_s = .34, p = 032) and in the Matrix Reasoning component (r_s = .33, p = .041). The same correlations were not significant for the sample of younger adults.

Further analyses investigated the existence of significant differences between younger and older adults in risk tendency. As the data were not normally distributed, a Mann-Whitney U test was used to compare the two samples. The results failed to identify significant differences in risk preferences between young and older adults (U(41, 40) = 775.50, Z = -.43, p = .66, r = -.05). In line with previous research, we found that females are more risk averse than males (U(45,36) = 1069.50, Z = 2.53, p = .01, r = .28).

Regression analysis. An ordered probit regression model was used to test the second hypothesis and check whether metacognition predicts risk attitude and whether it does it in a different way in younger and older adults. The main predictors were metacognitive and cognitive abilities, whereas gender, schooling, and income were used as control variables. Two observations were dropped because they were singletons; i.e., the only observations representing a specific category of the dummy variables Schooling and Income respectively. Leaving them in the sample would produce mistaken standard errors. The problem with singletons is that they set some residuals to zero, creating problems when computing the covariance matrix estimator. Neither the presence nor absence of these observations would change the main finding and interpretation of the regression. The main results are shown in Table 4.2.

Because of the nonlinear nature of the ordered probit model, the estimated parameters of the explanatory variables (Table 4.2) do not directly show the magnitude of the effect on risk behaviour. Marginal effects were thus computed to understand the impact of contributing factors on risk preferences. They were evaluated at the joint mean of the covariates. The marginal effects of each factor on the risk level probabilities are shown in Table 4.3 for younger adults and in Table 4.4 for the older sample.[9]

[9] Since the main focus of this paper is on the marginal impact of cognition and metacognition, marginal effects of the other control variables are not reported. A complete set of results is available from the authors upon request.

Table 4.2

Predictors of Risk Taking Behaviour

	Young Adults		Older Adults	
Variable	Coefficients	SE	Coefficients	SE
Metacognition	2.97**	1.12	-2.55*	1.25
Cognition	3.26	1.92	7.82**	2.51
Gender (Base = Female)	1.35**	.41	.72	.47
Schooling (Base = Graduated secondary school (GCSE))				
6th Form (A-level)	.58	1.18	-.84	.98
Some University	-1.14	1.20	-.33	.79
Graduated University	.30	1.16	-.17	.73
Post-Graduate University (Masters, PhD, etc.)	-.51	1.14	.74	.97
Higher (post docs, MBA, etc.)	2.01	1.78	1.78	1.24
Income (Base = up to 9,999 pounds)				
Between 10k and 19,999 pounds	-.24	.57	.75	1.29
Between 20k and 29,999 pounds	-.11	.73	.07	.94
Between 30k and 39,999 pounds	-.87	.68	-.75	.90
Between 40k and 49,999 pounds	1.07	.77	-.51	1.01
Between 50k and 74,999 pounds	1.50	.90	1.84	1.06
$\mu1$	10.81	4.51	6.27	4.84
$\mu2$	11.25	4.53	6.38	4.84
$\mu3$	12.17	4.56	6.58	4.84
$\mu4$	12.45	4.56	6.70	4.84
$\mu5$	12.54	4.56	7.98	4.91
$\mu6$	14.06	4.65	8.14	4.92
Log likelihood	-57.06		-41.22	
LR statistic	30.19		29.69	
Pseudo R^2	0.21		0.26	

Note. * $p < 0.05$. ** $p < 0.01$

Table 4.3

Marginal Effect for the Different Levels of Risk Preferences in the Sample of Younger Adults

	Marginal effects Risk = 0	Marginal effects Risk = 1	Marginal effects Risk = 2	Marginal effects Risk = 3	Marginal effects Risk = 4	Marginal effects Risk = 5	Marginal effects Risk = 10
Metacognition	-.41 (.21)	-.30 (.18)	-.47 (.27)	.02 (.07)	.02 (.03)	.90 (.40)	.23 (.16)
Cognition	-.45 (.31)	-.32 (.25)	-.52 (.38)	.02 (.08)	.03 (.04)	.99 (.63)	.26 (.22)

Note. Standard errors in parenthesis * $p < 0.05$. ** $p < 0.01$

Table 4.4

Marginal Effect for the Different Levels of Risk Preferences in the Sample of Older Adults

	Marginal effects Risk = 0	Marginal effects Risk = 1	Marginal effects Risk = 2	Marginal effects Risk = 4	Marginal effects Risk = 5	Marginal effects Risk = 6	Marginal effects Risk = 10
Metacognition	.95* (.48)	.03 (.04)	.03 (.06)	.00 (.03)	-.60 (.40)	-.08 (.09)	-.34 (.20)
Cognition	-2.90** (.97)	-.10 (.13)	-.10 (.17)	-.00 (.09)	1.83 (.98)	.26 (.27)	1.03* (.52)

Note. Standard errors in parenthesis * $p < 0.05$. ** $p < 0.01$

The main results show that in both samples increased cognitive ability is associated with a decreased probability of not investing in the gamble and an increased probability of investing £10. At the same time, an increase in metacognition is associated with a decrease in the probability of investing £10 in the older sample and an increase in the probability of investing £10 in the sample of younger individuals.

Discussion

This study investigated the relationship between metacognition, ageing, and risk attitude. Using a small but representative sample of young and older adults drawn from community settings, our results provide new insight into the variability in decision preferences expressed by older adults, indicating that rather than depending on ageing, differences in risk attitude between young and older adults can be justified taking into account cognitive and metacognitive abilities. In line with previous research showing that risk aversion varies systematically with cognitive ability (e.g., Benjamin et al., 2013; Boyle et al., 2011; Burks et al., 2009; Dohmen et al., 2010) and age effects upon decision quality are mediated by individual differences in cognitive processes (Henninger et al., 2010; Koscielniak et al., 2016), our results indicate that cognitive ability is positively associated with risk-taking behaviour. This is true controlling for gender, educational attainment, and income.

More interestingly, we found that metacognition is a significant predictor of risk attitudes, but the directionality of its effect changes with age, as high metacognitive abilities are associated with risk-taking behaviour in young individuals and with risk aversion in older adults. The positive relationship between higher metacognition and risk aversion found for older adults is in line with previous evidence showing that perceived intelligence – i.e., the metacognitive ability to judge one's own mental ability and knowledge at the abstract level – is associated with lower probabilities of adverse risk outcomes (Jaccard et al., 2005).

By definition metacognition consists in the ability to evaluate one's own cognitive performance and the effort exerted to solve a task. Since risk preferences were measured with an investment task after participation in a decision-making study, we argue that individuals with high metacognitive capabilities were better able to evaluate the effort exerted during the decision-making task and weight the monetary gain (net of cost of effort) that resulted from their participation in the experiment. Also, in line with prospect theory (Kahneman & Tversky, 1979), we hypothesise that individuals are more likely to exhibit loss aversion when they associate a possible low or even negative net monetary gain with the need of exerting a more demanding cognitive effort. Putting things together, we argue that higher cognitive abilities are associated with a lower cost of effort for performing the task and individuals with higher metacognitive abilities are better able to assess the cost of effort. Knowing that cognitive abilities are higher in young than older adults, we explain with the *risk-as-feeling hypothesis* (Loewenstein et al., 2001) why metacognition makes young individuals more prone to take risks than their older counterparts. More clearly, intending metacognition as a tool to better realise the effort spent in the experiment and the net gain, we postulate that young (and more cognitive) individuals in our experiment were more likely to experience positive feelings, which according to the *risk-as-feeling hypothesis* can be associated with higher risky behaviour (Grable & Roszkowski, 2008; Loewenstein et al., 2001). The opposite applies to older adults with a high level of metacognition, for whom the higher cost of effort experienced in the decision-making task might have accentuated the experience of a negative anticipatory emotion and led to an opposite proclivity towards risk.

The present analysis has some limitations that must be borne in mind. Although the two age groups were matched on gender, schooling and income, we relied on a modest sample. Further studies with a larger sample size can better explicate the differences we have reported. The research also relied on self-report measures of metacognition, which also represent a cause of caution because such reports may contain mistaken evaluations of one's own abilities.

Despite these caveats, the results are suggestive and set the stage for future research on metacognition and risk behaviour. In fact, future research could improve or build upon the results suggested in this paper. For instance, it could be analysed how cognition and metacognition impact upon risk attitudes in social interactions from both a micro and a macro prospective. From a micro point of view, economic policies could take into account the effect of risk attitude, cognition and social metacognition when economics agents' decisions are interrelated. Yet, if an older adults' decision-making has a deeper impact upon aggregate savings, it would be interesting to study how a chronologically older population with a higher metacognitive awareness can affect aggregate variables.

Given the several complex decisions that older adults need to make at a time when cognitive abilities may have started deteriorating, it is important to understand factors influencing decision-making in later life. Our findings support previous research that does not reveal age differences in risk preferences (e.g., Dror et al., 1998; Kovalchik et al., 2005) and reveal that other variables such as cognitive and metacognitive abilities seem to be robust determinants of risk preferences, even in advanced age and among individuals with a broad spectrum of cognitive capabilities. The study informs on two main psychological mechanisms that determine individuals' behaviour in risk and uncertainty conditions. In particular, the association between metacognitive and cognitive abilities with risk preferences has relevant implications for improving older adults' decision-making in several different contexts, ranging from financial investments to voting and health behaviours.

Furthermore, new questions can be raised about the effects of possible interventions aimed at improving cognitive and metacognitive abilities. If a higher cognition leads to a lower degree of risk aversion, then a – chronologically – older population characterised by a slower decline in mental capabilities also implies a higher aggregate risk taking behaviour. This would have as a consequence a different approach that economists should consider in defining polices. Alternatively, this aggregate effect on risk attitude, as from the conclusions of this paper, could be muted by taking into account also metacognition which, as said before, is a teachable skill. We believe that further research in this direction would be of advantage. A better understanding of the mutual roles of cognitive, metacognitive, and affective mechanisms and their relationship with risk attitudes may allow older adults to develop greater awareness of the influence that these processes have on risk preferences and decision-making in general, and inform on how to design new training programs that can affect attitudes towards risk and sustain decision-making in late adulthood.

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Chapter 5

Age Differences in the Neural Markers of Metacognition: Evidence from a Financial Decision-Making Task

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Chapter Rationale

From the study outlined in Chapter 3, significant differences between younger and older adults emerge in terms of metacognition and its effect of financial decision-making. At the same time, very little is known about the neural bases of metacognition. Therefore, an EEG study was undertaken and is presented in Chapter 5 to provide an overview of the age-related differences in the neural components associated with metacognitive monitoring and control processes in the context of a financial decision-making task.

Statement of Authorship

This declaration concerns the article entitled:
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Candidate's contribution to the paper (detailed, and also given as a percentage).	Chiara Scarampi made considerable contributions to the conception of the study (95%), as well as the methodological design (95%).The experimental work, including data collection, data analysis and interpretation was predominantly conducted by Chiara (95%). Chiara has also executed the presentation of the data in journal format (95%), as well as presented its content at national and international academic conferences.
Statement from Candidate	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature.

Signed	Chiara Scarampi	**Date**	05/04/2018

Age Differences in the Neural Markers of Metacognition: Evidence from a Financial Decision-Making Task

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Abstract

In the last years there has been a growing interest in the neural correlates of metacognition, supported by the recognition that it plays an essential role in behaviour regulation and contributes to optimal decision-making. The current study uses EEG to investigate how age-related changes in metacognition modulate four psychophysiological indices that in previous studies have been specifically associated with conflict and error processing: the error-related negativity (Ne/ERN), the error positivity (Pe), the P3, and the N2.

The results show that whereas older adults are slower than their younger counterparts, metacognitive monitoring and control processes are not impaired by ageing. Furthermore, the findings show an association between metacognitive experiences and the N2 and Pe waveforms, suggesting that the amplitude of these components constitutes a robust neural measure of metacognitive experiences, which can be used in future research to assess how individuals monitor and control their performance, without requiring them to provide explicit, subjective ratings of their own abilities.

Keywords: Ageing, EEG, Decision-Making, Metacognition

Age differences in the neural markers of metacognition: Evidence from a financial decision-making task

Empirical evidence indicates that individuals' cognitive actions are accompanied by metacognitive processes. In particular, individuals are capable of accurately evaluating the ongoing cognitive processes and performance by means of metacognitive experiences. These metacognitive evaluations are crucial in determining the outcome of behaviour regulation (Fernandez-Duque, Baird, & Posner, 2000; Scarampi, Fairchild, Palermo, & Hinvest, 2018) and have been proven to support social decision-making (Bahrami et al., 2010). Metacognitive experiences have a fundamental role in the monitoring and control processes operated on cognitive processing. More precisely, they are responsible of initiating the monitoring process that prepares the cognitive system to adaptively respond to environmental stimuli and informing the processes aimed at controlling cognitive performance and ensuring that the set goal is achieved (Efklides, 2002).

The ability to monitor and control behaviour is evident in those situations that require compensatory adjustments in cognitive performance, such as when several competing response options are activated simultaneously (i.e., in presence of a conflict) or when an error has been committed and requires to be detected (Clayson & Larson, 2011). Recently, there has been a growing interest in the neural bases of these metacognitive experiences (Fleming & Dolan, 2012). Previous studies have identified four psychophysiological indices that relate with conflict and error processing and contribute to the explanation of the functional characteristics of metacognitive monitoring and control processes. These event-related brain potentials (ERPs) are the error-related negativity (ERN/Ne; Falkenstein, Hoormann, Christ, & Hohnsbein, 2000; Gehring, Goss, Coles, Meyer, & Donchin, 1993), the error positivity (Pe; Overbeek, Nieuwenhuis, & Ridderinkhof, 2005; Ridderinkhof, Ramautar, & Wijnen, 2009), the P3 (Clayson & Larson, 2011; Coles, Gratton, Bashore, Eriksen, & Donchin, 1985), and the N2 (Carter et al., 1998).

The error-related negativity (ERN) is a negative deflection in the event-related potential associated with monitoring (Yeung, Botvinick, & Cohen, 2004). In particular, previous research has shown a relationship between accuracy judgements and ERP amplitude. Scheffers and Coles (2000) have asked participants to perform the Eriksen flankers task and provide, after each trial, a confidence judgement evaluating whether they responded correctly or incorrectly and how confident they were in the correctness of their judgement on a 5-point scale. The authors found an association between ERN amplitude and perceived accuracy/inaccuracy of their judgements, regardless of whether the actual response made was correct or incorrect. This result suggests that the ERN reflects a monitoring process that evaluates the accuracy of performance and signals an error if a mismatch between the response produced and the correct, or intended, response is detected (Yeung et al., 2004).

Other investigations have compared the functional role of the ERN with that of the Pe – a slow positive wave that tends to follow the ERN – to verify whether these two components reflect two different metacognitive control processes (Hughes & Yeung, 2011; Nieuwenhuis, Ridderinkhof, Blom, Band, & Kok, 2001). Hughes and Yeung (2011) have shown that the Pe varies as a function of individuals' awareness of having made a mistake. The authors have found a correlation between ERN and Pe amplitude in both correct and error trials, suggesting that these two ERPs reflect a broader performance monitoring processes that is not limited to simple error detection mechanisms (Hughes & Yeung, 2011). In line with this hypothesis, Boldt and Yeung (2015) have found that the amplitude of the Pe varies in a graded way with participants' subjective ratings of decision confidence, as expressed on a 6-point scale after each trial. More precisely, higher confidence judgements are associated with reduced Pe amplitudes, independently of objective accuracy. This result seems to confirm that error detection and decision confidence are underlying metacognitive mechanisms (Yeung & Summerfield, 2012).

The P3 is another stimulus evoked ERP related to cognitive control. Although its functional role is still a matter of debate, researchers have recently associated it with metacognitive awareness (Desender, Van Opstal, Hughes, & Van den Bussche, 2016). Previous evidence has shown that the P3 reflects cognitive control (Clayson & Larson, 2011), conscious access (Del Cul, Baillet, & Dehaene, 2007), stimulus evaluation processes (Coles et al., 1985), and experience of agency (Kühn et al., 2011). In another experiment, Desender et al. (2016) have induced feeling of difficulty by subliminally priming correct or incorrect responses and found that the amplitude of the P3 on single trials was predictive of metacognitive estimates of difficulty. As stressed by the authors, this result seems to suggest that the modulation in the P3 reflects attention resources that enable metacognition.

A large literature has also suggested an association between the N2 and cognitive control, defined as a monitoring process that is informative for strategy regulation and performance control (Folstein & Van Petten, 2008). Previous research has suggested that the N2 is generated in the caudal anterior cingulate cortex (ACC) (Van Veen & Carter, 2002), an area related to both cognitive control and subjective experiences (Spunt, Lieberman, Cohen, & Eisenberger, 2012). As a consequence, it seems possible to hypothesise an association between metacognitive evaluations and activity in the ACC, reflected by the N2 component (Desender et al., 2016).

Desender et al. (2016) have investigated the role of the N2 in metacognitive feelings of difficulty but failed to find support for such association. A possible explanation for this result could be that the N2 component is related to a prospective form of metacognitive experiences (i.e., judgements created prior to the response) rather than to judgements of difficulty provided after performance.

Age-related Changes

Several studies have examined developmental changes in the monitoring and control processes associated with metacognition (e.g., Kramer, Humphrey, Larish, Logan, & Strayer, 1994; Mudar et al., 2015). Nevertheless, the current state of the art is characterised by mixed results regarding whether the ability to detect conflict or errors and adjust performance is impaired by ageing.

Lucci, Berchicci, Spinelli, Taddei, and Di Russo (2013) have examined conflict adaptation with a go/no-go task and found that older adults are slower than younger adults, whereas the two groups do not differ in accuracy. This result is in line with the speed-accuracy trade-off theory of ageing and the idea that older adults tend to place more emphasis on accuracy rather than on execution speed (Falkenstein, Hoormann, & Hohnsbein, 2001). However, as noted by Niessen, Fink, Hoffmann, Weiss, and Stahl (2017), this explanation might be too simplistic as a series of recent studies has suggested that older adults tend to allocate more resources than younger adults to performance monitoring (Turner & Spreng, 2012), which may in turn explain the reduction in the error rate. Lucci and colleagues (2013) have also found that the on no-go trials – i.e., the trials eliciting higher response conflict – the N2 peak for older adults shifts from frontal to parietal regions and goes together with a positive activity in the prefrontal regions, which is not observed in younger adults. This results seem to confirm that older adults allocate extra resources in prefrontal regions. Nevertheless, as suggested by Schreiber, Pietschmann, Kathmann, and Endrass (2011), this compensatory process might leave too few recourses available for the execution of sub-functions of the monitoring process such as error processing and error awareness.

Other studies have found different results from these age-related declines in conflict adaptation. For example, West and Moore (2005) have failed to find significant behavioural differences between younger and older adults in a Stroop task. Nevertheless, the results show an attenuation in older adults' P3 and a sustained modulation in the anterior frontal region for younger adults, which reflects greater negativity for incongruent trials than congruent trials. Further support comes from Wild-Wall, Falkenstein, and Hohnsbein (2008), who have confirmed a larger frontal N2 in younger adults for incongruent stimuli compared with congruent stimuli, which is not exhibited by older adults. Nevertheless, contrary to West and Moore (2005), they have found that older adults perform better than younger adults, making fewer errors in a flanker task. Yet, in a further study investigating cognitive control with a go/no-go paradigm, Mudar et al. (2015) have found comparable amplitudes in the N2 and P3 on go trials for younger and older adults, but reduced amplitudes in older adults' nogo-N2 and nogo-P3. This finding suggests a reduction in older adults' neural processes associated with response inhibition, or conflict monitoring in general.

Further research in the age-related literature has focused also on the neural mechanisms associated with error detection. Whereas some researchers agree that ageing is associated with a decline in performance monitoring, which is reflected in a decreased ERN amplitude (e.g., Endrass, Schreiber, & Kathmann, 2012), other studies have reported no significant differences between the two samples in ERN amplitudes (e.g., Schreiber, Endrass, Weigand, & Kathmann, 2012) or even a larger ERN in older adults compared to younger adults (Staub, Doignon-Camus, Bacon, & Bonnefond, 2014). Few studies have investigated age differences in Pe amplitudes. Nevertheless, existing evidence suggests a reduction in the amplitude of the Pe for error detection in older adults, compared to their younger counterparts (Mathewson, Dywan, & Segalowitz, 2005; Niessen et al., 2017). Furthermore, Staub et al. (2014) have suggested that age differences in the amplitude of the Pe depend on the awareness of having made a mistake. This links back to the relevance of metacognition for error detection and the association between the Pe and metacognitive monitoring and control processes.

Overview of Hypotheses

Summarising, there is a recent interest in the neural bases of metacognition. Most studies in the neurocognitive literature have examined confidence judgements and feeling of difficulty in relation to perceptual decision tasks and identified the ERN, Pe, P3, and N2 as ERPs components related to metacognitive monitoring and control processes. Nevertheless, further research is needed to better explain how metacognition develops in time. Whereas previous studies have focused on retrospective metacognitive judgements, in this study, we use EEG to dissociate task-related activity from both earlier and later metacognitive processes. In particular, noting that activity in the ACC is related to the formation of subjective experiences (Spunt et al., 2012) and that the N2 component has been linked to conflict occurring prior to the response rather than after it (Van Veen & Carter, 2002), we hypothesise that the N2 may be modulated by prospective metacognitive experiences. Second, following research on error processing revealing a graded variation of the error positivity according to subject ratings of confidence (Boldt &

Yeung, 2015), we hypothesise that the Pe reflects an interplay between response-related activation and retrospective metacognitive experiences. Furthermore, since the ERN and the Pe are considered to be the error-related homolog of the N2 and the P3 respectively (Ridderinkhof et al., 2009; Yeung et al., 2004), we investigate the relationship between subjective ratings of metacognitive experiences and these event-related potentials and whether metacognitive experiences differ in terms of N2, P3, ERN and Pe amplitudes.

Moreover, although a number of studies has examined developmental changes in these components, little is known about how different levels of metacognition interact with neural activity associated with monitoring and control processes in older adults. As a consequence, another aim of this study is to investigate age-related changes in these components and their association with metacognitive experiences.

Materials and methods

Participants. A total of 20 young adults (age range 20-33, *M* = 24.40 years, *SD* = 3.67; 11 female) and 20 older adults (age range 57–82, *M* = 67.50 years, *SD* = 7.14; 10 female) were recruited on campus at the University of Bath and in the community with flyers and advertisement on newsletters and forums. Participants were paid £10 for participation. Participants did not report any past or current neurological events or illnesses. All procedures were approved by the University of Bath Ethics Committee and all participants gave written informed consent. Two elderly subjects had to be excluded from the analysis because of technical problems with the EEG recording.

Task and procedure. Participants were seated in a dimly lit, electrically shielded room for the duration of the experimental session. The experiment comprised a series of trials on which participants performed a financial decision-making task and were asked to rate metacognitive experiences associated with their cognitive processing and performance (see Figure 5.1 for a summary of task procedure). Metacognitive experiences were asked and rated according to the Metacognitive Experiences Questionnaire adapted by Scarampi et al. (2018), which consists of five questions asked before and after each trial of a decision-making task. This measure has the potential of evaluating the consistency of metacognitive experiences estimated both prospectively and retrospectively, and their accuracy when compared with task performance.

The decision-making task required participants to identify the best investment among the available options. There was a 10 s deadline for the decision and participants were instructed to respond as fast as possible pressing the key corresponding to the number of the preferred option. After responding to the task, the screen cleared for 1000 ms, then the same metacognitive questions previously answered were now asked retrospectively (e.g., "How difficult do you think (or feel) the problem was?") and presented on five separate screens. Participants were asked to rate their metacognitive experiences on a 4-point scale from "Not at all" to "Very" by pressing the key corresponding to the number of the preferred response. There was no time limit to answer these questions. The inter-trial interval was 1 s. Each participant started with 2 practice trials and completed 30 decision-making trials.

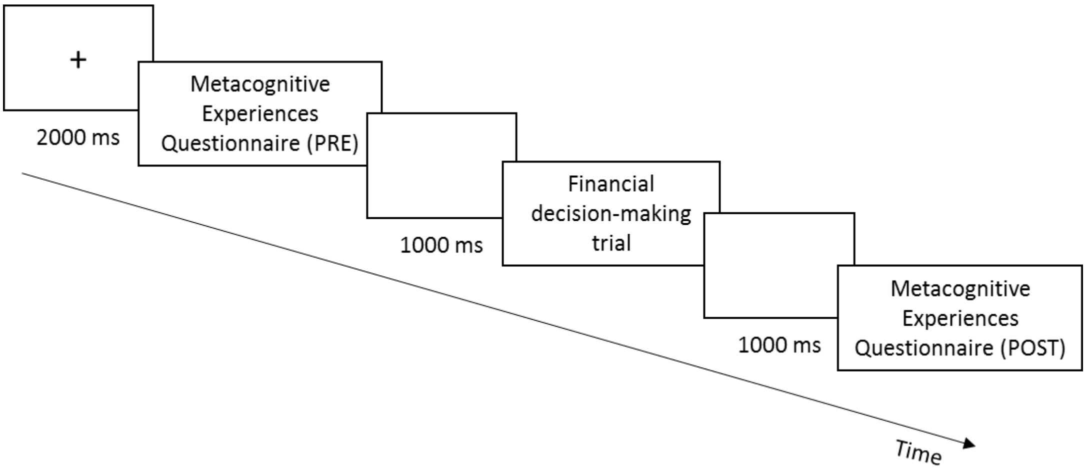

Figure 5.1. Summary of task procedure. First, participants were given the financial question and asked to rate their prospective metacognitive experiences on a 4-point scale. Then, they were asked to choose the preferred option and rate again retrospectively their metacognitive experiences.

EEG recording and data pre-processing. EEG data were recorded from 64 scalp electrode sites using a HydroCel Geodesic Sensor Net (EGI; Eugene, Oregon) and a NetAmps 400 amplifier with a sample rate of 1000 Hz. Electrical impedances were kept below 5 kΩ. Data were preprocessed using BESA software (version 6.1, BESA GmbH). Artifacts including blinks and eye movements were corrected using BESA automatic artifact correction (Berg & Scherg, 1994) and bad (i.e., noisy) channels were replaced by an interpolated weighted average from surrounding electrodes. Any remaining epochs containing artifacts > ± 100 μV were rejected. Epochs of −100 to 1000 ms were defined around stimulus onset and participants' decisions. Epochs were baseline corrected using the pre-stimulus interval (−100 to 0 ms). A 0.01 Hz high pass was applied during artifact correction and a 40 Hz low-pass filter and a 50 Hz notch filter were applied for visualisation purposes only.

ERP analysis. Our main analysis focused on the N2 and the P3, which are successive deflections in the stimulus-locked ERP waveforms, and on the ERP and the Pe, which are deflection in the response-locked ERP waveforms. For the N2, peak latency values were measured as the time points at which the waveform reached the maximum negative amplitudes between 270 and 380 ms after stimulus presentation. N2 amplitudes were then calculated as average voltage of 15 ms pre-peak and 15 ms post-peak (see Clayson, Clawson, & Larson, 2011). The P3 was quantified as the average amplitude value between 350 and 500 ms post-stimulus onset (see Boldt & Yeung, 2015). For the ERN, peak latency values were measured as the time points at which the waveform reached the maximum negative amplitudes in the first 100 ms after response. ERN amplitudes were then calculated as average voltage of 15 ms before and after the latency of the maximum negative peak (see Clayson et al., 2011). The Pe was computed as the difference between error and correct-trial waveforms in an interval of 350 to 500 ms post-response (Boldt & Yeung, 2015).

Results

Behavioural results. Overall, participants made financial decisions with a mean reaction time of 4473 ms (*SE* = 67 ms) and a mean accuracy of 77.48% (*SE* = 1.20%). Comparing older and younger adults, the former were significantly slower than younger adults (older adults: *M* = 5088 ms, *SE* = 319 ms; younger adults: *M* = 3993 ms, *SE* = 372 ms; $t(38) = -2.23$, $p = .031$), whereas the two samples did not differ in the mean error rate (older adults: *M* = 0.76, *SE* = 0.02; younger adults: *M* = 0.79, *SE* = 0.02).

The two samples did not differ in the accuracy of metacognitive experiences, as provided by the total score obtained at the MEQ (Scarampi et al., 2018), which compares the consistency of judgements provided before and after solving the task and their accuracy in evaluating task performance (young adults: *M* = 2.59, *SE* = .06; older adults: *M* = 2.55, *SE* = .04). When comparing the single metacognitive experiences, we did not find significant differences between the two samples. Nevertheless, older adults provided, both prospectively and retrospectively, slightly lower scores for feeling of difficulty and higher ratings of confidence than their younger counterparts, but also higher ratings of effort, time, and thinking processes (only retrospectively) needed to solve the task (see Table 5.1).

Table 5.1

Mean Comparisons of Metacognitive Experiences between Younger and Older Adults

	Younger Adults	Older Adults
Pre 1 (Difficulty)	*M* = 1.87, *SD* = .93	*M* = 1.81, *SD* = .90
Pre 2 (Effort)	*M* = 1.92, *SD* =.87	*M* = 2.10, *SD* =.81
Pre 3 (Time)	*M* = 2.03, *SD* =.89	*M* = 2.27, *SD* =.80
Pre 4 (Confidence)	*M* = 3.01, *SD* = 1.5	*M* = 3.32, *SD* =.97
Pre 5 (Thinking)	*M* = 3.00, *SD* =.97	*M* = 2.37, *SD* =.89
Post 1 (Difficulty)	*M* = 1.79, *SD* =.85	*M* = 1.72, *SD* =.82
Post 2 (Effort)	*M* = 1.90, *SD* =.80	*M* = 2.00, *SD* =.80
Post 3 (Time)	*M* = 1.91, *SD* =.82	*M* = 2.18, *SD* =.84
Post 4 (Confidence)	*M* = 3.19, *SD* = 1.00	*M* = 3.40, *SD* = 1.00
Post 5 (Thinking)	*M* = 2.06, *SD* = .86	*M* = 2.40, *SD* =.90

Electrophisiological results.

Stimulus locked ERPs. Mean comparisons of the amplitude of the N2 in younger and older adults failed to reveal a significant difference between the samples (Older adults: *M* = -.66, *SD* = 1.99; Younger adults: *M* = -.33, *SD* = 1.60). Figure 5.2 represents the grand average stimulus-locked ERP data for the N2 in younger and older adults respectively. A more negative deflection for older adults can be seen in the N2 time window.

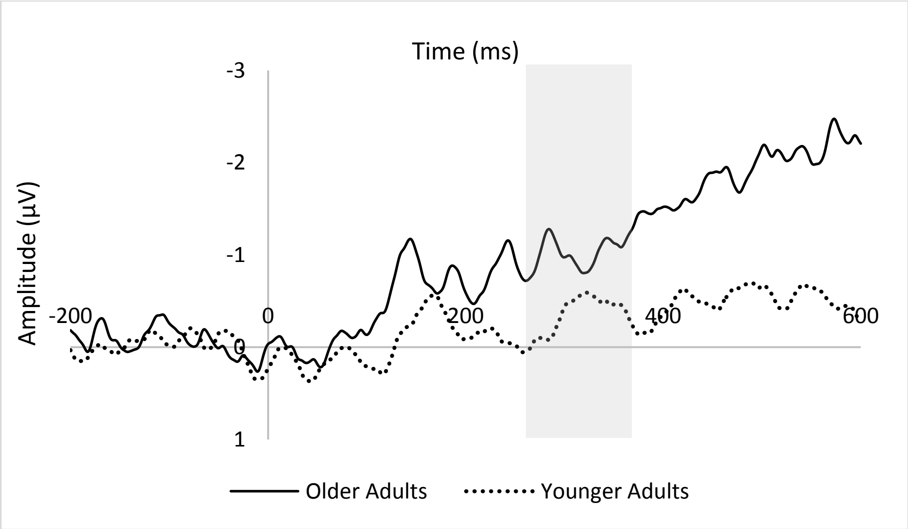

Figure 5.2. Grand average of stimulus-locked ERPs at electrode Cz for younger and older adults. The grey bar reflects the N2 time window.

In order to investigate the relationship between metacognitive experiences and the N2, a repeated measures ANOVA was computed with factors the total score obtained at the MEQ and age on the average voltage in the N2 window. Mauchly's test indicated that the assumption of sphericity was violated, $\chi^2(2) = 9.98$. $p = .007$, therefore the Greenhouse-Geisser corrected tests are reported ($\varepsilon = .78$). The results showed a significant main effect of the score of metacognitive experiences, $F(1.55, 46.47) = 3.72$, $p = .042$, with a significant linear within-subject constrast, $F(1,30) = 5.43$, $p = .027$ (see Figure 5.3). Nevertheless, the analysis failed to find a significant difference of age on waveform amplitude.

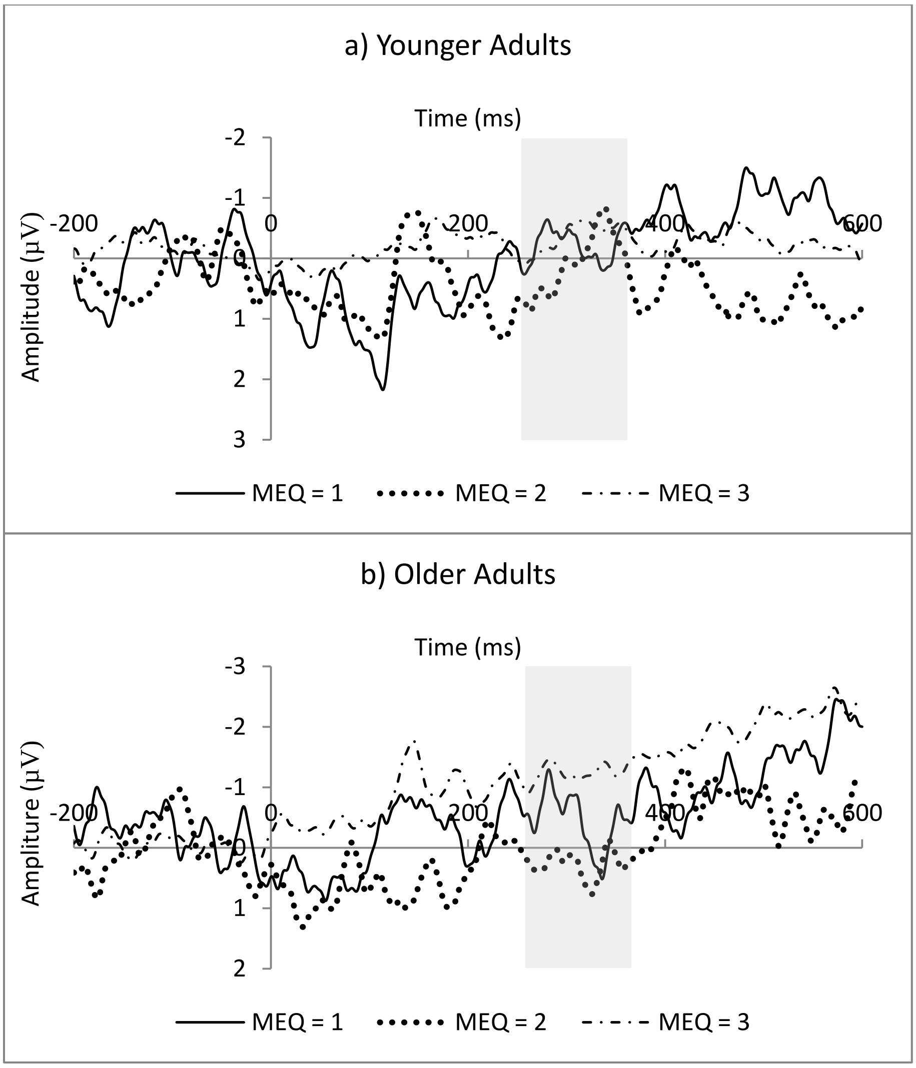

Figure 5.3. Grand average of stimulus-locked N2 at electrode Cz for younger and older adults conditioned on the scores obtained at the MEQ. The grey bar reflects the N2 time window.

Mean comparisons of the amplitude of the P3 in younger and older adults failed to reveal a significant difference between the samples (Older adults: *M* = -.66, *SD* = 1.99; Younger adults: *M* = -.33, *SD* = 1.60). Figure 5.4 shows the grand average stimulus-locked ERP data for the P3 in younger and older adults respectively. Whether a slow positive inflection is visible for younger adults, a clear P3 cannot be detected for older adults.

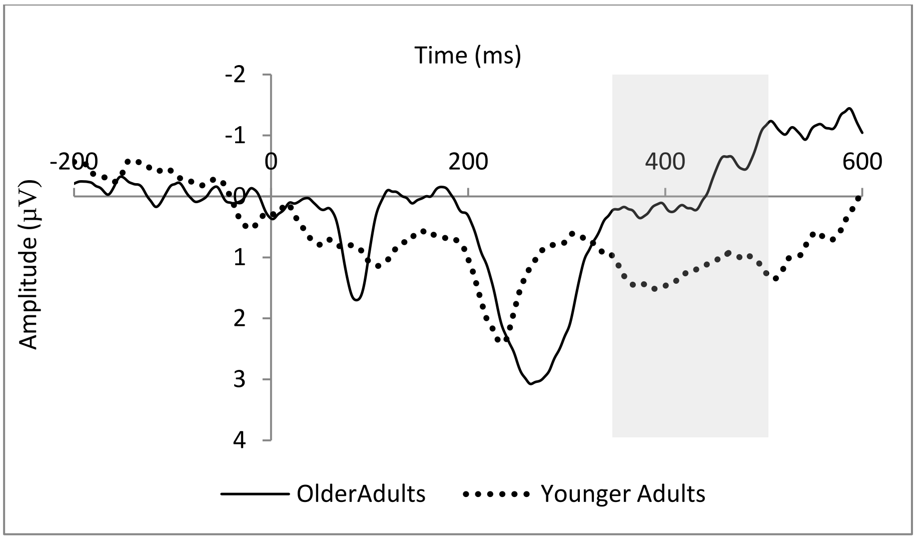

Figure 5.4. Grand average of stimulus-locked ERPs at electrode Pz for younger and older adults. The grey bar reflects the P3 time window.

A repeated measure ANOVA was computed to investigate whether the amplitude of the P3 was modulated by subjective ratings of metacognitive experiences and age group, but failed to reveal a significant effect of metacognitive experiences and age group on the amplitude of the ERP.

Response locked ERPs. A t-test was computed to compare mean ERN amplitudes between younger and older adults. The main results showed that older adults have a more negative inflection than younger adults (older adults: M = -.23, SD = 1.23; younger adults: M =.63, SD = 1.42) and the difference between the two samples is approaching significance; $t(36) = 2.00$, $p = .054$. On the contrary, mean comparisons of the amplitude of the Pe revealed the existence of significant differences between younger and older adults on central electrode sites (electrode Cz – older adults: M = -1.34, SD = 3.78; younger adults: M = 1.87; SD = 3.16; $t(36) = 2.85$, $p = .007$), whereas the amplitude of the component did not differ between the two samples in more parietal electrode sites. Figures 5.5 and 5.6 show the grand average response-locked ERP data for the ERN and the P3 respectively, comparing younger and older adults.

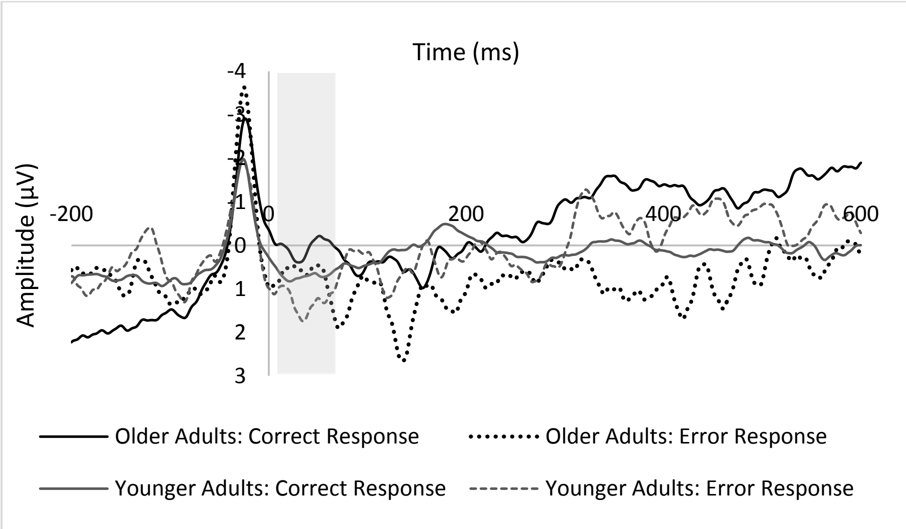

Figure 5.5. Grand average of response-locked ERPs at electrode Cz for younger and older adults. The grey bar reflects the ERN time window.

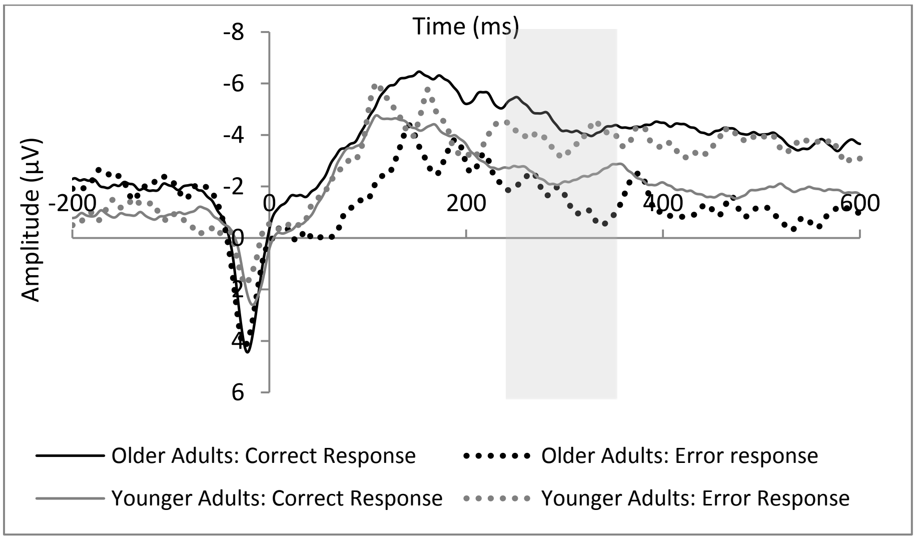

Figure 5.6. Grand average of response-locked ERPs at electrode Pz for younger and older adults. The grey bar reflects the Pe time window.

The ERN amplitude was submitted to a 2 X 2 ANOVA (age group X response correctness). As observed, the average ERN amplitude was significantly affected by the type of response $F(1,36) = 4.4$, $p = .042$, being more negative for error response than for correct trials, independently of age. Another repeated measure ANOVA was computed to investigate whether the amplitude of the ERN was modulated by subjective ratings of metacognitive experiences and age group, but failed to reveal significant effects on the amplitude of the ERP. Conversely, a repeated measures ANOVA with factors judgement of confidence (JoC) and age on the average voltage during the Pe window revealed an almost significant main effect of JoC; $F(3,30) = 2.89$, $p = .052$, with a significant linear within-subject constrast, $F(1,10) = 12.13$, $p = .006$ (see Figure 5.7). On the contrary, the effect of age was not significant.

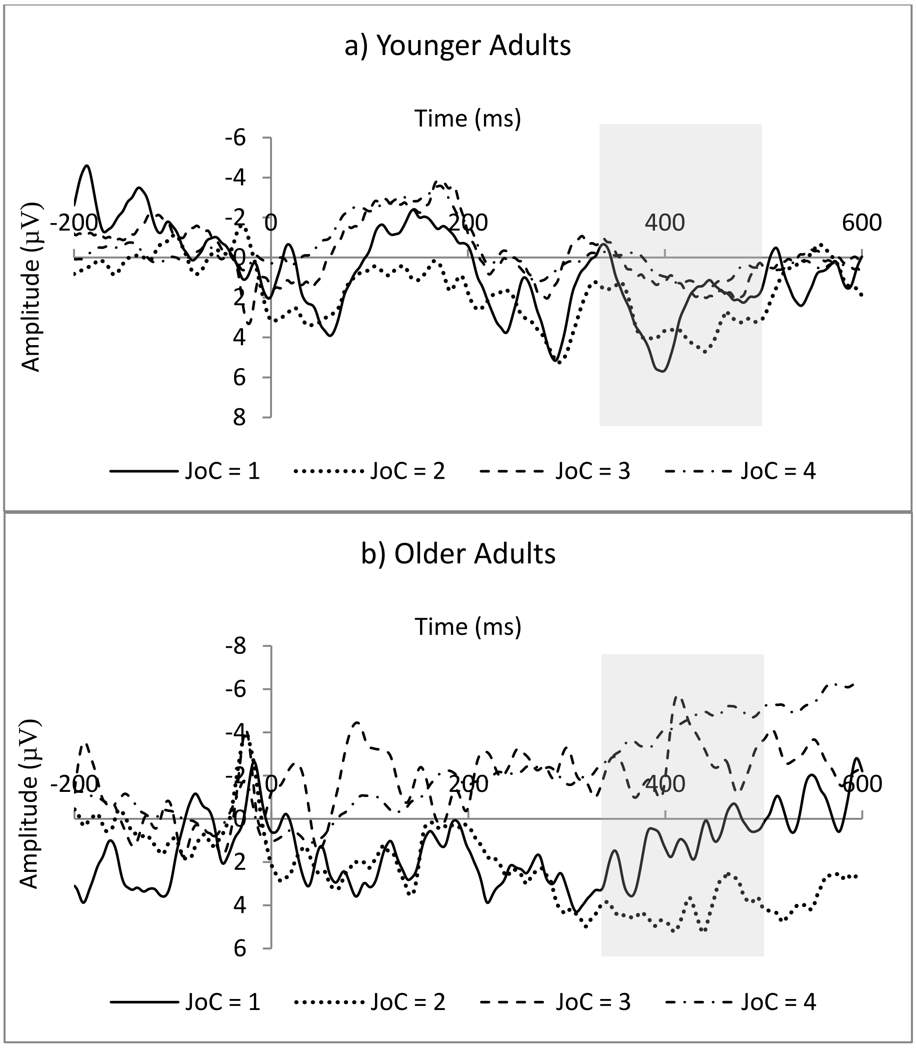

Figure 5.7. Grand average of stimulus-locked Pe at electrode P1 for younger and older adults conditioned on confidence judgements, from 1 = "not at all" to 4 = "very". The grey bar reflects the Pe time window.

Non-significant results emerged from another repeated measures ANOVA computed with factors MEQ score and age on the average voltage during the Pe window across electrodes, $F(2,56) = 2.02$, $p > .1$ (see Figure 5.8).

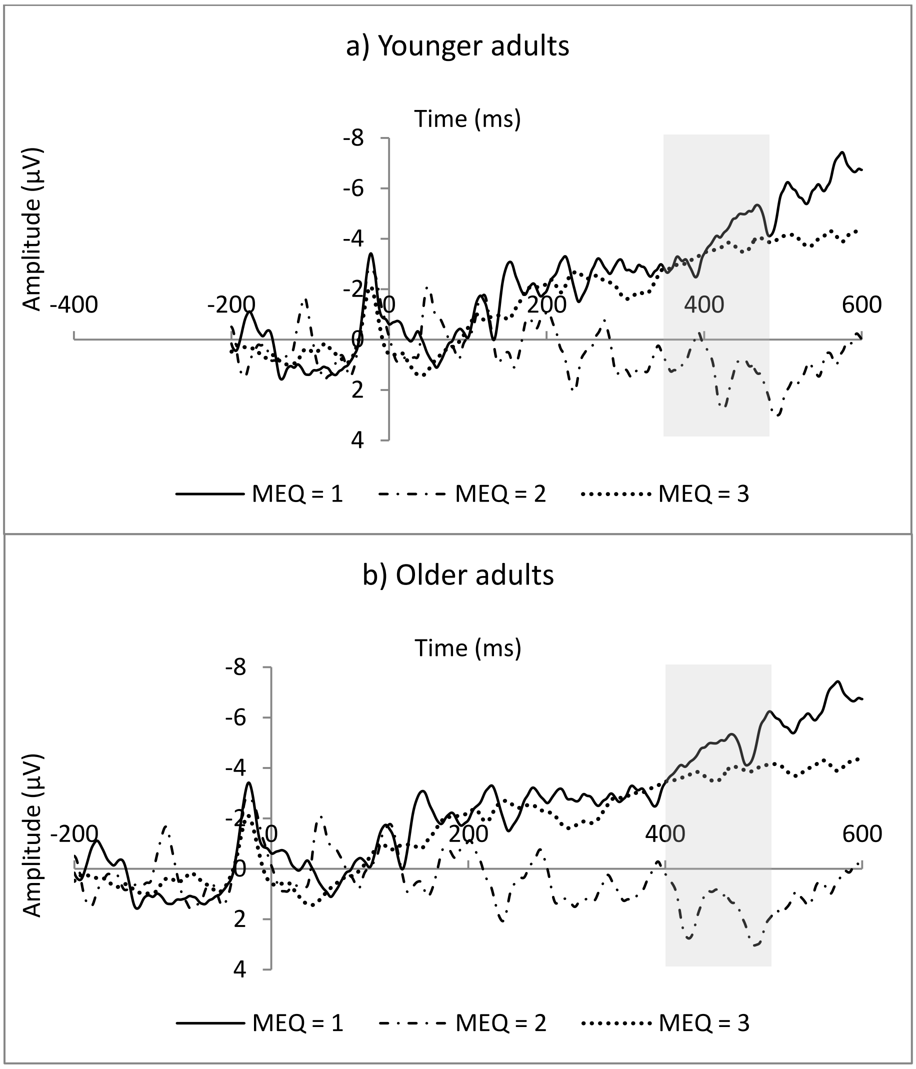

Figure 5.8. Grand average of stimulus-locked Pe at electrode P1 for younger and older adults conditioned on the scores obtained at the MEQ. The grey bar reflects the Pe time window.

Discussion

The present study provides new insight into the temporal dynamics of metacognition, the underlying neural mechanisms, and the associated age-related changes. In the context of a financial decision-making task, we asked participants to rate their metacognitive experiences associated with the ongoing cognitive processing and measured four psychophysiological indices that in previous studies have been associated with metacognitive monitoring and control processes.

Behavioural results from this experiment partially confirmed the speed-accuracy trade-off theory of ageing (Lucci et al., 2013). Older adults were slower than younger adults, but they also made slightly more mistakes in the financial task. Nevertheless, errors committed by older adults might have been due to cognitive declines associated with ageing. A reduction in working memory and information processing skills together with slower analytical processes could explain the higher rate of errors committed by older adults. This is also supported by older adults' metacognitive experiences, which estimated the need of longer execution times and more effortful thinking processes for performing the task.

Further analyses investigated age differences in the morphology of four ERPs associated with metacognitive control processes. Comparisons between the two samples revealed no differences in the amplitude of the N2, a waveform associated with stimulus evaluation and preparation of response (Clayson & Larson, 2011). Nevertheless. the slightly more negative deflection in older adults' N2 and the shift of N2 peak in more parietal sites found in this study align with the results from Lucci et al. (2013). The results also support the suggestion made by Turner and Spreng (2012) that older adults tend to allocate more resources to monitoring their performance. However, in line with West and Moore (2005), the P3 was attenuated in older adults relative to younger adults. The same pattern was identified for the error-related components; that is, older adults had a (almost significant) larger negative deflection in the ERN time window and a significantly smaller positive Pe than younger adults. This seems to support the claim made by Schreiber et al. (2012)

and the idea that the compensatory activity associated with a slightly larger N2 in older adults leads to a smaller availability of resources for sub-functions of the monitoring system, such as error processing.

The findings also contribute to the literature on the neural correlates of metacognition and partially support previous research suggesting a systematic variation in the amplitude of specific ERP components such as the P3 (Desender et al., 2016) and the ERN and Pe (Boldt & Yeung, 2015; Charles, Van Opstal, Marti, & Dehaene, 2013; Scheffers & Coles, 2000). In particular, whereas previous studies did not find support for a role of the N2 in retrospective metacognitive experiences (Desender et al., 2016), we hypothesised that this component might reflect the metacognitive evaluation of the stimulus and of the cognitive processes needed to solve a task before starting its execution. Neither the N2 not the P3 were modulated by prospective metacognitive judgements, but the results showed a relationship between the amplitude of the N2 and the scores obtained at the Metacognitive Experiences Questionnaire. Whereas Desender et al. (2016) argued that the N2 component reflects only task-related activation, our results suggest that this component reflects an interplay between task-related activation and metacognitive experiences. More precisely, not only is the N2 associated with metacognitive evaluations of the stimulus, but also the amplitude of this component reflects whether individuals' metacognitive experiences align with task performance. This finding relates to the existing evidence on the role of ACC activation in metacognitive report tasks (Fleming, Huijgen, & Dolan, 2012). If the N2 is generated in the ACC (Van Veen & Carter, 2002), our findings support previous research linking the ACC with both cognitive control and subjective experiences (Spunt et al., 2012). This seems to suggest that the involvement of the ACC is associated not only with task-related processes, but also with earlier and later metacognitive experiences.

On the contrary, we failed to provide evidence in support of a role of the P3 in metacognition. This might be due to the design of the study. The P3 has been associated with cognitive function in decision-making processes and orientation of response. The financial decision-making task here implemented was slightly more complex than the usual perceptual and memory tasks used to study the functional role of this ERP in decision-making. As a consequence, it is possible that the time required to engage attentional processes on internal information that enables metacognition, as expected for the P3, required more time in this task.

The findings also contribute to the literature on the neural correlates of error processing and partially support previous research suggesting a systematic variation in the amplitude of the Pe (Boldt & Yeung, 2015; Charles et al., 2013; Scheffers & Coles, 2000). In line with Boldt and Yeung (2015), we found that the Pe varies with judgements of confidence on both correct and incorrect trials. These results contribute to the ongoing debate on the functional role of ERN and Pe and over whether error detection is a all-or-none (Wessel, 2012) or a graded process (Boldt & Yeung, 2015; Scheffers & Coles, 2000). In particular, researchers have suggested that ERN and Pe reflect a two-stages monitoring process. At a very early stage, an error detection process reflected by the ERN identifies incorrect motor commands. Whereas this process does not depend on conscious error perception and is not directly involved in remedial actions, a later monitoring process, reflected by the Pe, is related to actual awareness of response (Nieuwenhuis et al., 2001). In our study, ERN amplitude was not modulated by metacognitive experiences, but a significantly more negative deflection was visible for both younger and older adults in the ERN time window for error trials. This is in line with previous studies suggesting that the ERN is an all-or-none signal (Charles et al., 2013). On the contrary, the Pe varied systematically with confidence ratings, suggesting that whereas the ERN is involved in an early evaluation of goal achievement by discriminating between errors and correct responses, the Pe is involved in a deeper evaluation of performance and cognitive processing. Whereas these two ERPs have been associated with error detection processes, we found that the Pe reflects rather subtle shifts in confidence judgements related to the evaluation of the response given at the financial task, on both correct and error trials.

One of the main implications of the findings of this study is a methodological contribution to the assessment of metacognition. Previous studies on error and conflict awareness asked participants to press a button to indicate recognition of an error or manipulated task difficulty inducing specific metacognitive experiences and investigated only retrospective metacognitive experiences. As stressed by Desender et al. (2016), these methodologies might not be able to discern subtle differences in error and conflict awareness because they are not sensitive enough. Conversely, in the current study, we tried to overcome this limitation by asking participants to rate their metacognitive experience on each trial. Furthermore, whereas the methodological approaches used in previous work typically used perceptual tasks such as the Erikson Flankers task, the colour Stroop task, and the go/no-go task, in the current study, we used a more complex and realistic decision task, where metacognitive experiences were given both prospectively and retrospectively. This allows better study of the temporal dynamics of metacognition and differentiate task-related activity from both earlier and later metacognitive processes.

The finding that specific ERPs are modulated by metacognitive experiences points to the possibility of using EEG data as a non-invasive instrument to assess metacognitive experiences. This is particularly relevant in the field of reasoning and decision-making, as metacognitive experiences are the trigger of the monitoring and control processes that orchestrate the cognitive performance. Nevertheless, their assessment can be difficult, as requiring participants to provide repeated ratings of metacognition is effortful and time consuming (Boldt & Yeung, 2015). Furthermore, explicitly asking participants to evaluate their metacognitive experiences may lead to an increased control and alter the nature of metacognitive evaluations (Grützmann, Endrass, Klawohn, & Kathmann, 2014). An objective measure of metacognition, such as that provided by ERP components, is a possible solution to avoid these problems and assess subjective judgements without requiring participants to make explicit subjective, and possibly biased, judgements.

As stressed by Luck (2014), EEG has an important advantage over behavioural measures, which is its ability to provide an online, covert measure of processing when a behavioural response is impossible or problematic. For example, it can be used with individuals who are unable to provide behavioural responses due to a neurological impairment (Fischer, Luaute, Adeleine, & Morlet, 2004) and shed light on the failures of metacognition that occur following brain damage and psychiatric disorders (Fleming & Dolan, 2012). Further research in this direction is highly valuable, as it may allow researchers to better capture the neural mechanisms that relate with specific metacognitive processes and components, enabling, in turn, a better understanding of the mechanisms that underlie and guide decision-making.

This may be supported by research conducted with other neuroscientific methods, which could strengthen the value of the temporal resolution provided by

ERP analyses in cognitive neuroscience and support the existence of a separation in brain regions associated with distinct metacognitive processes aimed at monitoring and controlling cognitive performance (Van Veen & Carter, 2002).

In conclusion, the present study used EEG to examine age-related differences in the neural correlates of metacognition in financial decision-making and dissociate task-related activity from earlier and later metacognitive processes. Overall, the findings add to the debate on the role of metacognitive awareness in conflict and error detection and suggest a strong link between awareness about one's own cognitive processing and metacognitive experiences, which is reflected in the modulation of the N2 and the Pe. Furthermore, we investigated age-difference in these processes and showed that the monitoring system is slower in older adults, but not accompanied by a reduced accuracy. These results have relevant implications also in the age-related literature. In particular, the lack of a main effect of age on the modulation of the amplitude of the studied ERP components suggests that metacognitive experiences are not impaired in older adults and may support decision-making (Scarampi et al., 2018).

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Chapter 6

Social Metacognition: A Correlational Device for Cooperation

Manuscript submitted for publication in *Games and Economic Behavior*.

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Chapter Rationale

As discussed in the literature review, metacognition is not limited to individual processes, but can be extended to social environments. In many situations, the outcome of the decision process does not depend exclusively on the individual's choices, but also upon the choices made by others. A key psychological variable in these scenarios is social metacognition; i.e., the ability to take into account and reflect upon the mental states of others, with the aim of foreseeing their intentions and choose the best behavioural response. Despite its relevance, very few studies have investigated how the social component of metacognition is involved in economic decision-making in the context of strategic interactions. Even fewer studies have looked at the effects of age on the relationship between metacognition and social decision-making.

Whereas the other empirical studies conducted as part of this thesis focused on the role of metacognition in individual decision-making processes, the study discussed in this chapter turned to game theory, a tool to prescribe and analyse strategic interactions between subjects. Particularly, the main aim of game theory is to predict the outcome of strategic interactions; namely, equilibria concepts that can justify and forecast the results of such interactions.

The most used equilibrium concept is the Nash equilibrium (Von Neumann & Morgenstern, 1944), which treats the strategic choices made by interacting individuals as independent and defines the outcome of a game as a situation where none of the involved individuals has an incentive to deviate from such result. The alternative is the correlated equilibrium (Aumann, 1974), which departs from the Nash equilibrium in assuming that individuals' strategies can possibly be correlated with each other rather than independent. Therefore, whereas in the framework of Nash equilibrium each player has to choose its own moves, the correlated equilibrium requires the presence of a trusted, impartial third party (i.e., a mediator) which assists players in choosing their actions, directing and facilitating the coordination of their strategies. More clearly, the correlated equilibrium could ensure players results (equilibria) that are payoff-enhancing with respect to the Nash equilibria and where any deviation is still unprofitable (as for the Nash equilibrium).

In this chapter, we report the results of a study analysing the relationship between social metacognition and the correlated equilibrium. The main aim was to investigate whether the monitoring and control processes that operate at the social level of metacognition can substitute the external device theorised as the fundamental of correlated equilibria and guide individuals in strategic interactions, allowing them to coordinate their behaviour in a class of non-cooperative games. Furthermore, the study investigated age-differences in the effect of social metacognition in decision-making.

Whereas the results indicated the existence of age-differences in some aspects of social metacognition, the study failed to reveal significant differences in the play of younger and older adults. However, some relevant results were found on the more general role of social metacognition in guiding individuals towards interrelated strategies that are utility-enhancing. As a consequence, the chapter consists of a first part written in the format of a journal article which discusses the more general role of social metacognition in strategic interactions. The article is then followed by a commentary discussing the relationship between social metacognition, decision-making, and ageing.

Due to the relevance of the results from an economic perspective, the paper presented in this chapter was sent to a predominantly economic journal. As a consequence, the paper is characterised by a different writing style, which aligns to that of economic articles and is directed to an economic audience for which the paper and the chosen journal are targeted. The commentary after the paper addresses the available literature on the effects of ageing on social decision-making and age differences in the effect that different aspects of social metacognition have on behaviour in strategic interactions. The main results of the study on the age effect of social metacognition on the correlated equilibrium are then presented and discussed.

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Statement of Authorship

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<tr><td>Candidate's contribution to the paper (detailed, and also given as a percentage).</td><td colspan="9">Chiara Scarampi made considerable contributions to the conception of the study (95%), as well as the methodological design (95%).The experimental work, including data collection, data analysis and interpretation was predominantly conducted by Chiara (95%). Chiara was responsible for establishing an international collaboration with A. Palermo. Chiara has also executed the presentation of the data in journal format (95%), as well as presented its content at national and international academic conferences.</td></tr>
<tr><td>Statement from Candidate</td><td colspan="9">This paper reports on original research I conducted during the period of my Higher Degree by Research candidature.</td></tr>
<tr><td>Signed</td><td colspan="5">Chiara Scarampi</td><td colspan="2">Date</td><td colspan="2">04/05/2018</td></tr>
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Social Metacognition: A Correlational Device for Cooperation

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Abstract

This study reports a laboratory experiment wherein we tried to implement a correlated equilibrium, a generalisation of the Nash equilibrium. More specifically, we investigated whether there is a relationship between social metacognition – i.e., the ability to monitor and control one's own and others' mental states – and decision-making behaviour in a Chicken game. We found that a correlated equilibrium is more likely to be reached whenever subjects play in a session with a high level of social metacognition. In addition, we found some evidence that correlated equilibria can be reached without the presence of a third party/mechanism; that is, in certain circumstances social metacognition can act 'as if' it is the correlated mechanism.

Keywords: Age Differences, Correlated Equilibrium, Experimental Economics, Game Theory, Social Metacognition

Social Metacognition: A Correlational Device for Cooperation

> Human behaviour is most fruitfully modelled as the interaction of rational agents with a social epistemology, in the context of social norms that act as correlating devices that *choreograph* social interaction. (Gintis, 2009, p. xiii)

The most used equilibrium concept in non-cooperative game theory is the Nash equilibrium. The alternative equilibrium concept is that of correlated equilibrium (Aumann, 1974), which represents a generalisation of the Nash equilibrium. The correlated equilibrium departs from the Nash equilibrium in assuming the presence of a third party or mechanism, which can correlate the strategies of the players by providing a known probability distribution over outcomes and a signal that assigns a given strategy to each player.

Aumann (1974) has shown that in the set of possible correlated equilibria there could be some that are payoff-enhancing with respect to the Nash equilibrium in mixed strategies. However, despite this appealing result, often the reason for avoiding the correlated equilibrium as a solution concept resides in the difficulty of justifying when and in which manner such external signals become common knowledge among players. This is the case whenever it appears 'unnatural' to admit the presence of a third party or the possibility that players define a correlation device. In this paper, we address this question and in particular we hypothesise that social metacognition – i.e., the ability to reflect upon, monitor and control one's own and others' knowledge, emotions and actions - can guide individuals and allow them to coordinate their behaviour in strategic interactions. We refer as Gintis (2009) to the third party/mechanism/device as *choreographer* and study social metacognition and its role as choreographer of social interactions.

Social metacognition: an overview

As stressed by Gintis (2009), human beings are characterised by the ability to form knowledge and understanding, in particular the understanding and sharing of mental states, which in psychology is often referred to as social metacognition (Frith, 2012; Jost, Kruglanski, & Nelson, 1998). Defined as the ability to reflect upon, monitor and control the self and other's knowledge, emotions and actions (Jost et al., 1998), social metacognition is a fundamental skill. The ability to create an accurate representation of the mental states of others allows individuals to predict others' intentions and determine the most appropriate behaviour for the specific situation.

Whereas several studies have focused on the role of metacognition at the individual level, our study is in line with the framework proposed by Efklides (2008), who has stressed that metacognition is a *sine-qua-non* constituent of social interaction and incorporated a social level in the conceptualisation of metacognition. Hence, we focus on the dynamic accumulation of knowledge and understanding that results from social interactions. According to Efklides' theorisation, social metacognition comprises three components: metacognitive judgements (MJ), metacognitive knowledge (MK) and metacognitive skills (MS). MJ are estimates about one's own and others' metacognitive experiences, knowledge and skills.[10]

[10] Efklides (2008)'s model of metacognition proposes three facets of metacognition at the individual level (Personal-Awareness Level): metacognitive experiences, metacognitive knowledge, and metacognitive skills. Metacognitive experiences are feelings and judgements related to the ongoing cognitive processing. They result from heuristic processes based on familiarity feelings and the use of cues obtained by the task, the context, or cognitive processing. Metacognitive knowledge is declarative knowledge stored in the long-term memory, which is placed in the context of a particular task and guides us in understanding the requirement of the task and deciding how to proceed.

They are informed by self-awareness at the personal level, as well as by information received from the ongoing interaction, such as reflection and observation of thoughts or actions of others.

MK refers to information active in working memory, such as social scripts, relations and phenomena, and relates with social interaction and the need to communicate our thoughts to others or to understand and judge others' thinking. Through communication and reflection, individuals are able to compare their thoughts, emotions and intentions with those of other people, leading to the creation of explicit and socially built models of cognition and representations of each other as cognitive beings (Efklides, 2008; Nelson, Kruglanski, & Jost, 1998).

Yet, whereas self-regulation is defined as the set of cognitive and metacognitive regulatory processes that people use to set goals, plan courses of action and monitor outcomes (Brown, 1987), MS are procedural knowledge (i.e., rules, skills and strategies) that enable people to select responses or actions in social environments. They reflect social regulatory processes through which individuals can reach an – occasionally shared – understanding of each other and regulate accordingly their cognitive and metacognitive processes (Volet, Vauras, & Pekka, 2009). This definition of MS emphasises the ability of social adaptation of our behaviour, which dynamically and relationally adjusts to the behaviour of others and the underlying environment.

Social metacognition is based on monitoring and control processes. Monitoring involves the ability to take into account the mental states of others and is based on awareness of our ME, knowledge of strategies and scripts, observation of

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Metacognitive skills are procedural knowledge used to monitor the comprehension of task requirements, plan the steps to solve it, monitor the execution of planned action, regulate cognitive processing when it fails, and evaluate the outcome of processing.

mental states and actions of others, reflection on one's own and other's behaviour and the related outcome, and on social interaction and communication with others (Efklides, 2014).

Control processes, on the other hand, involve the use of information about the mental states of others, acquired with monitoring processes, to make attributions about the relations between inner states, observable behaviour and action outcome, and thus predict behaviour and regulate cognitive performance. As Volet, Summers, and Thurman (2009) have pointed out, control consists in the application of metacognitive skills and strategies learned through instruction and previous social interactions to the ongoing interactive or collaborative context. It informs on the strategies to use and contributes to meaning making and regulation of one's own cognitive performance in social contexts.

Social metacognition and economic decision-making

In the past years, researchers have started investigating how different aspects of social metacognition are involved in non-cooperative games. Most researchers have focused on mentalising, or theory of mind, a key element of social monitoring and control metacognitive processes. Mentalising can be defined as the metacognitive ability to conceive the self and others as intentional beings, attribute mental states such as feelings, needs, desires, goals, and attitudes (monitoring), and make attributions about the relationships between such inner states and observable behaviour and action outcomes (control; Frith, 2012; Frith & Frith, 1999). Making predictions on the moves of the opponent requires metacognitive and mentalising abilities in that a player should understand the opponent's intentions in order to anticipate their behaviour (Camerer, Loewenstein, & Prelec, 2005). As stated by Powell, Grossi, Corcoran, Gobet, and Garcia-Finana (2017), mentalising and strategic interactions seem to require similar metacognitive processes, as they both rely on an iterative reasoning about the mental states of another person. Nevertheless, strategic interactions require the application of metacognitive skills in a setting where the potential moves are based on a specific set of predictable rules, whereas mentalising refers to inferring others' mental states in a social environment characterised by ambiguity and influenced by cultural and contextual factors.

Existing evidence using behavioural games to explore strategic interactions (e.g., the Prisoners Dilemma, Beauty Contest Game and Ultimatum games) has suggested that the metacognitive ability to infer the mental states of the opponents is beneficial to optimal decision-making (e.g., Behrens, Hunt, & Rushworth, 2009; Fehr & Huck, 2016). With the aim of understanding how social metacognition affects behaviour in experimental games, Fehr and Huck (2016) have elicited measures of cognitive ability and beliefs about others' cognitive abilities in the Beauty Contest Game. One of the requirements to understand how to play the game is what the authors call *strategic awareness* – i.e., the metacognitive ability to form beliefs about others' behaviour. The main findings have shown that choices made by participants with low cognitive abilities are randomly distributed over the whole interval and do not correlate with their beliefs' about others' cognitive abilities. On the contrary, participants with high cognitive abilities avoid numbers above 50 and their choices correlate with their beliefs about others' cognitive abilities. This result suggests that individuals with higher social metacognitive abilities can form more accurate beliefs about others' intentions and action, and act in a more rational way, maximising gains and minimising losses, as predicted by formal economic theory.

To explore the underlying mechanisms of social metacognition, researchers have used a game theory approach in neurocognitive studies (see e.g., Behrens et al., 2009; Camerer, 2009; Gallagher, Jack, Roepstorff, & Frith, 2002). In their fMRI study, Rilling, Sanfey, Aronson, Nystrom, and Cohen (2004) have scanned participants while playing the Ultimatum Game and the Prisoner's Dilemma Game against human and computer partners. They have found activations in two areas associated with mentalising: the anterior paracingulate cortex and the posterior superior temporal sulcus. Activation in these areas was elicited by both human and computer partners, but stronger responses were found in both games to human partners. These results suggest that strategic interactions are not based merely on computational analyses, but require also the use of social metacognitive processes, such as the recognition that the opponent has different mental states from one's own. In a further study using the Ultimatum Game to investigate the neural correlates of decision-making, Polezzi et al. (2008) have found that mid-value offers require a more complex decision process than offers which are clearly fair or unfair. Mid-value offers are also associated with longer reaction times and with an enhanced activity in the superior temporal gyrus, area involved in mentalising processes (Fletcher et al., 1995). The enhanced activity in this area for the responder might mirror the use of social metacognition and mentalising processes in the attempt of understanding the proposer's strategy.

One of the foundations of game theory is that the interaction is strategic and characterised by 'common knowledge'; i.e., individuals reflect on the intentions and actions of the others involved in the interaction and know that they are doing the same (Aumann, 1976). As stated by Kirman and Teschl (2010), understanding the process that people use to infer others' mental states will help understand the knowledge that can be acquired about others' beliefs, intentions and behaviour. Also, the ability to accurately predict other peoples' intentions and actions based on the use of social metacognitive processes can lead to better decisions. Only recently, studies in behavioural economics and psychology have started paying more attention to the existence of individual differences in thinking processes in general and in the attribution to mental states of others in particular, rather than assuming homogeneous players. Closely related to our aim, a series of papers have tried to disentangle the effects of individual differences on the results of strategic behaviour. De Neys, Novitskiy, Geeraerts, Ramautar, and Wagemans (2011) have explored the role of metacognitive control abilities on the tendency to accept unfair offers. Participants were asked to play the Ultimatum Game in the role of responder. A group comprising responders most and least closely following economics rational behaviour (i.e., participants who most and least accepted unfair offers) also participated in a follow-up EEG study with a go/no-go task. The authors have found that the acceptance of unequal splits is mediated by metacognitive control abilities. That is, individuals with higher cognitive control abilities are more likely to act in line with the standard economic predictions and accept unequal splits. This is again in line with what suggested by Kirman and Teschl (2010) and the idea that higher metacognitive skills can lead individuals to behave in line with the hypothesised *homo oeconomicus* and make rationally optimal decisions.

To the best of our knowledge, no previous studies have investigated how social metacognition and the ability to take into account mental states of others relate to the correlated equilibrium. In a theoretical set-up, Hart and Mas-Colell (2000) have shown that in a N-person game there exists a simple adaptive procedure which generates convergence to the set of correlated equilibria (see Hart & Mas-Colell, 2000 and references therein for alternative procedures converging to the set of correlated equilibria). Most of the empirical literature on the correlated equilibrium has focused on whether participants tend to follow or ignore recommendations given by a third party. Closely related to our study are Cason and Sharma (2007) and Duffy and Feltovich (2010), from which we depart adding an analysis to disentangle the role of social metacognition in coordination games.

Cason and Sharma (2007) have attempted to implement a correlated equilibrium with payoffs outside the convex hull of Nash equilibrium payoffs[11] by privately recommending strategies in a Chicken Game. Their results suggest that individuals do not follow recommendations inducing correlated equilibria. However, more experienced participants in the experiment tended to follow recommendations more frequently in the second half of trials, suggesting therefore that after a learning process subjects could start following recommendations. Speculating on the reason why subjects do not follow recommendations from the start – and in line with our theoretical explanation based on social metacognition – the authors have hypothesised that individuals may form beliefs about their opponents' mistakes and update them in subsequent periods. As a possible further research avenue, the authors have stressed the relevance of providing a theoretical argument able to explain what conditions would lead individuals to build more and more accurate beliefs about the probability assigned to opponents following recommendations.

Conversely, Duffy and Feltovich (2010) have used a Chicken Game to explore the empirical validity of the correlated equilibrium with third-party recommendations drawn from different publicly announced distributions. They have found that individuals do not blindly follow recommendations and the likelihood of following a recommendation depends on the underlying distribution of outcomes and

[11] The smallest convex set that contains and connects the points corresponding to the Nash equilibrium payoff pairs.

that a correlated equilibrium that is payoff-enhancing relative to the available Nash equilibria is a necessary condition for recommendations to have any substantial effect on behaviour.

In this paper, we want to observe how social metacognition – as ability to interconnect people's thinking and deriving actions – can help people coordinate their decisions and allow them to obtain better results out of their interactions. The main aim of this paper is to observe whether social metacognition works 'as if' it is *choreographing* people. We therefore hypothesise that individuals with higher social metacognitive abilities will be better able to coordinate their behaviour and their play will converge towards a correlated equilibrium.

Method

Participants. A total of 98 individuals (age range 21-79, *M* = 43.67 years, *SD* = 19.76; 55 female) participated in the study. Participants were recruited online and in the community with advertisement in newspapers, forums, newsletters and social media. Participants received a £5 show-up fee plus up to £9 depending on their performance. All participants were healthy and free of neurological and psychiatric disease. They gave their consent to participate in the study and the research was approved by the University of Bath Psychology Ethics Committee.

Measures. Metacognitive Judgements (MJ), Metacognitive Knowledge (MK), and Metacognitive Skills (MS) were measured through the administration of a new questionnaire: the Social Metacognition Scale (SMS). We adapted and included items from different measures related to social metacognition and invented some extra statements to cover aspects of the construct that we wanted to measure. We obtained a set of 73 items (see the Supplementary Materials for a detailed list of the items). SMS items were first piloted with psychology doctoral students and lecturers who rated the clarity and readability of the items and their appropriateness to measure social metacognition.[12] The scale was then revised by the first author, who discarded the thirteen items that were judged as most problematic (i.e., poorly phrased, vague, or not clearly measuring the construct of social metacognition).

Respondents were asked to rate each item of the questionnaire on a 7-point Likert scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *slightly disagree*, 4 = *neither disagree nor agree*, 5 = *slightly agree*, 6 = *agree*, 7 = *strongly agree*).

As Fonagy et al. (2016) have pointed out, researchers designing self-report measures of mentalising have to deal with the problem of respondents having to rely on their mentalising ability to fill in the questionnaire. Mentalising can be affected by cognitive biases and result in misattributing mental states to others. A relevant class is that of egocentric biases (Ross & Sicoly, 1979). One of the biases in this category is known as *knowledge bias* and refers to the failure in subtracting one's own unique knowledge about the situation when attributing mental states to others. According to the simulation view, in order to understand what another person is thinking or feeling in a particular moment, individuals tend to imagine what they would think or feel in the same situation (Carruthers & Smith, 1996; Davies & Stone, 1995a, 1995b; Gordon, 1986; Heal, 1986). As posited by Nickerson (1999), self-beliefs are used as an anchor point for understanding others. According to the author, adjustments are subsequently made in the right direction, but often by a very small extent. The model predicts that one's estimates of what another person knows are likely to be mistaken in the direction of what one knows, or thinks one knows.

In an attempt to get around the problem, a set of items were scored with polar-scoring, whereas other items were scored with a median-scoring method. In the

[12] The Social Metacognition Scale was administered to a group of PhD students and lecturers in cognitive psychology, with knowledge on the construct of metacognition. They were instructed to rate the clarity of the items and comment on potential issues of the scale.

polar-scoring method, the strongest agreement is associated with the highest score of social metacognition (or the lowest score for reverse-coded items). Sample statements are "*I'm often curious about the meaning behind others' actions*" and "*If I'm sure about something, I don't waste time listening to other people's arguments*" respectively. In line with the suggestions made by Fonagy et al. (2016), responses in the median-scoring method should reflect an awareness of the opaqueness of mental states. A sample items is "*I can tell how someone is feeling by looking at their eyes*". Items in this set were thus rescored so that the median score (i.e., 4) corresponded to the highest score of social metacognition and the extreme score to the lowest scores.

A total score of social metacognition was obtained by summing the scores obtained by participants at all of the items retained from the Exploratory Factor Analysis described in the Results section below.[13]

The game. As in Duffy and Feltovich (2010), we designed and conducted an experiment in which individuals played the Chicken Game shown in Figure 6.1, which generates correlated equilibria with payoffs that lie outside the convex hull of Nash equilibrium payoff pairs.

	D	*C*
D	*0,0*	*9,3*
C	*3,9*	*7,7*

Figure 6.1. The basic Chicken Game

This game has two Nash equilibria in pure strategies (C, D) and (D, C) and one equilibrium in mixed strategies where the action C is selected with probability

[13] A larger sample of participants was used with the aim of increasing the power of the Exploratory Factor Analysis and the validation of the Social Metacognition Scale. Overall, data were collected from 122 individuals (age range 20-79, *M* = 43.09 years, *SD* = 19.80; 69 female).

0.6. The payoffs associated with these three equilibria are (9,3), (3,9), and (5.4,5.4) respectively. However, in this game players can do even better using third party recommendations. Suppose the distribution of recommended strategy profiles is

Recommended play		*Player 2*	
		D	*C*
Player 1	*D*	0	$1/3$
	C	$1/3$	$1/3$

and players are given only their suggested strategy. Applying this correlated equilibrium distribution over the possible outcomes of the game, the expected payoff is $\frac{19}{3} > 5.4$. That is, the proposed correlated equilibrium is payoff-enhancing compared with the Nash equilibrium in mixed strategies. However, the set of correlated equilibria is wider. Define the probabilities of the outcomes (C,C), (C,D), (D,C), and (D,D) as α, β, γ, and δ respectively. Each player should maximise their expected payoff given the signal (recommendation) they receive. If Player 1 is recommended to play C, then the conditional probability that the chosen outcome is (C,C) is $\frac{\alpha}{\alpha+\beta}$, whereas the conditional probability that the chosen outcome is (C,D) is $\frac{\beta}{\alpha+\beta}$. Under the belief that Player 2 will follow the received recommendation, Player 1's conditional expected payoff is $7\,\frac{\alpha}{\alpha+\beta} + 3\,\frac{\beta}{\alpha+\beta} = \frac{7\alpha+3\beta}{\alpha+\beta}$ from following the C recommendation and $9\frac{\alpha}{\alpha+\beta} + 0\,\frac{\beta}{\alpha+\beta} = 9\frac{\alpha}{\alpha+\beta}$ from ignoring the recommendation and choosing D. Player 1 will then prefer to follow the C recommendation if $\frac{7\alpha+3\beta}{\alpha+\beta} \geq 9\frac{\alpha}{\alpha+\beta}$, that is $3\beta \geq 2\alpha$.

With a similar reasoning, we obtain the four conditions for a correlated equilibrium:

- Player 1 will prefer to follow the C recommendation if $3\beta \geq 2\alpha$;
- Player 1 will prefer to follow the D recommendation if $2\gamma \geq 3\delta$;
- Player 2 will prefer to follow the C recommendation if $3\gamma \geq 2\alpha$;
- Player 2 will prefer to follow the D recommendation if $2\beta \geq 3\delta$.

A correlated equilibrium is the distribution of the probabilities α, β, γ, and δ which satisfies the four inequalities above and $\alpha + \beta + \gamma + \delta = 1$.

Procedure. Participants were divided into 13 sessions – 8 sessions with 6 participants and 5 sessions with 10 participants – and no one took part in more than one session. All experimental sessions consisted of 40 rounds, the first 20 with recommendation and the last 20 without recommendation. At the beginning of each session, participants were given a consent form and a set of written instructions. After reading the instructions and signing the consent form, subjects were asked to solve a quiz to assess their understanding of the instructions. Each quiz was then graded by the experimenter and any incorrect answers were discussed.

In line with Duffy and Feltovich (2010), we tried to use a neutral terminology in the instructions, referring to partner/opponent as 'the player you are matched with'. Furthermore, we did not force participants to follow the recommendations. Players were instructed about the outcome probability distribution and the recommendations given during the game only conveyed information about their part of the recommended strategy profile and not the other players' part. Only after choosing the preferred action, they were shown the recommendation received by the opponent. Furthermore, subjects were not given information about the results of any other pairs of subjects, either individually or in aggregate.

The experiment was run with the software z-Tree (Fischbacher, 2007) on networked computers in a psychology laboratory consisting of multiple individual testing booths. To avoid incentives for reputation, participants were randomly paired, according to a round-robin matching format. They were not allowed to communicate with each other and were not given identifying information about their opponents in any round.

A round of the game *with* recommendations (rounds 1 to 20) began by showing participants their recommended action, which was randomly drawn from the appropriate aforementioned outcome distribution. Then, they were asked to choose one of the two available actions. After all participants made their decision, each subject was shown the following information: own recommendation, own choice, opponent recommendation, opponent choice, own payoff, and opponent's payoff. After observing the results, participants were redirected to the following round. In a round of the game *without* recommendations, the sequence of play was the same except for the recommendations.

At the end of round 40, the very last round, participants were asked to answer some questions to describe what their intentions and strategies were during the game with and without recommendation. They then filled in the Social Metacognition Scale and answered a few demographic questions.

At the end of the experiment, one of the 20 rounds with recommendations and one of the 20 rounds without recommendations were randomly chosen. Each subject received their earnings from these two rounds, at an exchange rate of £0.50 per point, together with a £5 show-up fee. Sessions typically lasted 60 minutes and total earnings per participant averaged about £10.

Results

SMS scale validity. In order to study the factor structure of the Social Metacognition Scale, an Exploratory Factor Analysis (EFA) was performed with SPSS version 22. First of all, we computed the Pearson correlation matrix between the 63 items of the SMS. A few items with only one or two correlations with other items exceeding .3 were identified and removed. The anti-image correlation matrix suggested reasonable factorability. Furthermore, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy on the remaining items of the SMS was .69 and the Bartlett's test of sphericity was significant ($\chi^2(1225) = 2998.13$, $p < .001$), indicating that the matrix was suited to factor analysis (Worthington & Whittaker, 2006).

A principal axis analysis was performed on the data, following a standard approach to conducting an EFA (Costello & Osborne, 2005; Worthington & Whittaker, 2006). A three-factor and a five-factor competing solutions were initially suggested by Cattell (1966)'s scree test. An Oblimin (oblique) rotation was performed to clarify the data structure. An oblique rotational method was chosen as the obtained factors were hypothesised to be related, based on previous theoretical considerations (Efklides, 2008). The EFA was also used to inform the exclusion and retention of items (Worthington & Whittaker, 2006). A priori criteria for factor loadings were set to .32. Items were discarded if they either did not load well onto any factor or had significant cross-loadings onto other factors.

The three-factor model was chosen as final solution after considering the internal consistency of the obtained factors and the interpretability of the obtained factor solutions (a more detailed description of item extraction and differences between the two models can be found in the Supplementary Material; Worthington & Whittaker, 2006). The pattern matrix obtained for the three-factor solution consisted of 43 items. It revealed a first factor consisting of 13 items, a second factor consisting of 14 items, and a third factor consisting of 16 items. The factor loadings of the items of the SMS are displayed in Table 6.1.

Table 6.1

Pattern Matrix for the Social Metacognition Scale

Scale Item	Factor 1	2	3
41. I often remind others to contribute their ideas.	.67		
73. I offer to help others during a group work.	.67		
26. I call in others for help when I need it.	.64		
27. I ask for clarification if I do not understand something.	.63		
35. When working on a group project, I often help others who have difficulties in understanding the group task.	.61		
25. When working in a group, I often give feedback to contributions made by others.	.59		
3. When working on a collaborative project I discuss thoughts with other group members.	.57		
38. When making plans with other people, I try to make sure our plans are realistic.	.56		
19. When working on a collaborative project I compare thoughts with other group members.	.52		
56. When working with other people, I try to make sure we set learning goals and allocate time for various activities.	.51		
72. When working on a group project, I often try to work with others to complete our task.	.45		
40. When working on a group project, I often feel pleased if others remind me of the time remaining to finish our work.	.45		
5. Before starting working on a group project, we set goals to guide what steps we would take.	.42		
39. When working on a group project, I often try to remind others of the time remaining to finish our work.	.41		
22. When working on a collaborative project, I try to make sure we all make efforts to achieve our set goals.	.38		
62. I am comfortable working with a group.	.38		
59. It takes me a long time to understand other people's thoughts and feelings.		.68	

52. I can often understand how people are feeling even before they tell me.	.61	
33. I have trouble figuring out my friends' feelings.	.59	
16. My gut feeling about what someone else is thinking is usually very accurate.	.57	
53. People's thoughts are a mystery to me.	.56	
32. Other people's thoughts and feelings are confusing to me.	.55	
9. I can tell how someone is feeling by looking at their eyes.	.51	
15. I can make good predictions of other people's behaviour when I know their beliefs and feelings.	.50	
1. I can easily deduce someone's intentions.	.50	
12. It's really hard for me to figure out what goes on in other people's heads.	.47	
58. Understanding what's on someone else's mind is never difficult for me.	.46	
20. I usually know exactly what other people are thinking.	.35	
31. I can mostly predict what someone else will do.	.33	
65. I often think about other people and their behaviour.		.68
64. I find it important to understand reasons for behaviour.		.63
49. I do not like to waste time trying to understand in detail other people's behaviour.		.60
57. Understanding the reasons for people's actions helps me to forgive them.		.55
2. When interacting with someone else I try to understand their thoughts.		.55
63. When I'm upset at someone, I usually try to "put myself in his shoes" for a while.		.53
11. I'm often curious about the meaning behind others' actions.		.50
17. In an argument, I keep the other person's point of view in mind.		.43
60. Two people can see the same image and interpret it differently.		.42
43. I try to look at everybody's side of a disagreement before I make a decision.		.42

54. I pay attention to the impact of my actions on others' feelings.			.41
18. I believe that people can see a situation very differently based on their own beliefs and experiences.			.39
37. If I'm sure I'm right about something, I don't waste time listening to other people's arguments.			.33
28. I take into account the ideas and suggestions of others.			.32
Eigenvalue	7.98	4.30	3.38
Percentage of variance	18.57	10.00	7.86
Crombach's Alpha	.87	.83	.83

Note. Item numbers correspond to the original 73-item SMS.

Inspection of the item contents revealed that the three factors were related to the expected dimension and represented the originally hypothesises subscales. The first factor was robust, with a high eigenvalue of 7.98, and it accounted for 18.57% of the variance in the data. It is clear from Table 6.1 that these items all relate to the ability of monitoring and controlling cognitive performance in the context of social interactions. This factor loaded onto reported levels of ability to adapt actions and behaviour to different social environments and co-regulate performance in collaborative contexts. As a consequence, in light of the contents of the items, the factor was labelled "Metacognitive Skills". The second factor had an eigenvalue of 4.30 and accounted for 10% of the variance in the data. Items loading onto this factor related to the ability to take into account and make an estimate of the mental states of others and think about other people's actions and outcomes. This factor was thus labelled "Metacognitive Judgements". The third factor had an eigenvalue of 3.38 and accounted for 7.86% of the variance in the data. This factor related to the ability to build knowledge on social interactions, enhancing in turn the ability to understand how to behave in the specific environment. In line with the reference model of social metacognition proposed by Efklides (2008), this factor was labelled “Metacognitive Knowledge”.

Internal consistency for each of the scales was examined using Cronbach’s alpha. The three factors demonstrated a high degree of internal consistency. The α coefficient for metacognitive skills was .87, while the coefficients for metacognitive judgements and metacognitive knowledge were both .83. The Cronbach’s α for the entire questionnaire was .78. Overall, the factor analysis indicated that three distinct factors were underlying participants’ responses to the SMS and that these factors were internally consistent.

Behavioural analysis. Each subject played 40 rounds (20 rounds with recommendations and 20 round without recommendations), giving us a total of 3920 observations, 1960 for each of the two conditions. In what follows, we first illustrate how we categorised the experimental sessions on the basis of social metacognition and then present the main results. We start from the game with recommendations, describing first behaviour at the aggregate level and then behaviour at the individual level. We then present the results for the game without recommendations.

Classification of the experimental sessions based on social metacognition. In order to understand whether social metacognition can explain the convergence towards a correlated equilibrium, we classified the experimental sessions based on the scores of social metacognition obtained at the SMS. More precisely, we used two different methods. In the first method, we computed the mean level of social metacognition in each session and then compared the obtained scores with the average score of social metacognition among all the sessions. The sessions with a score higher than the average were classified as characterised by a high level of metacognitive ability at the social level. Those sessions whose score was lower than the average score were classified as low in social metacognition. Sessions 4, 6, 7, 9, 10, 12, and 13 emerged as the groups of participants with a high level of social metacognition.

As a robustness check, we used a second method to classify the experimental sessions. We computed the average score of social metacognition across all participants and then counted for each session how many participants had a score higher than the average one. We then computed the proportion of highly metacognitive individuals by dividing the obtained number of participants by the total number of players in each sessions. Session 4, 5, 6, 7, 12, and 13 emerged as the groups in which the number of participants with high levels of social metacognition was strictly greater than half of the number of participant in the corresponding session. In these sessions, the game was characterised by a higher amount of pairs constituted by metacognitive individuals playing with each other.

Sessions 4, 6, 7, 12, and 13 scored highly in both measurements. Sessions 1, 2, 3, 8, and 11 scored poorly with both methods.

Aggregate behaviour with recommendations. To check whether participants were close to the correlated equilibrium we chose the absolute value as measure of distance. For each session we computed the distance between the frequency distribution over the outcome and the suggested correlated equilibrium distribution (see Figure 6.2). The graphs display on the vertical axis the distance from the correlated equilibrium (i.e., the zero line) whereas on the horizontal axis we considered all the 20 rounds, only the last 15 rounds and only the 10 last rounds.[14]

[14] The method is standard in the literature and the rationale is that individuals need time to familiarise themselves with the experimental procedure.

Figure 6.2a (6.2b) refers to the sessions that scored high (low) in social metacognition with both the methods described above.

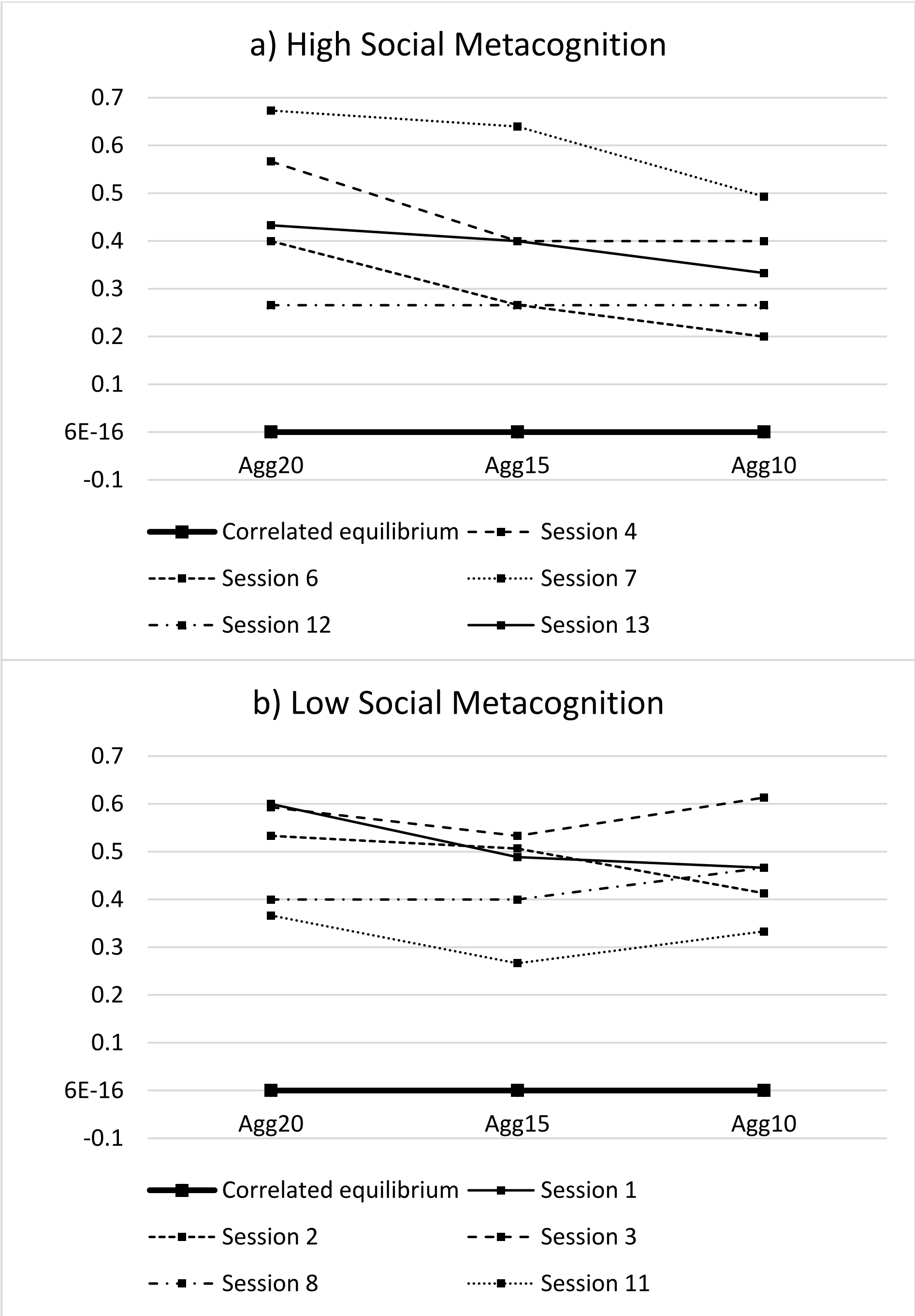

Figure 6.2. Distance from the correlated equilibrium and aggregate behaviour in the rounds with recommendations of the groups classified as high (Figure 6.2a) and low (Figure 6.2b) in social metacognition according to both the methodologies previously described. Agg20 refers to all 20 rounds, Agg15 excludes the first 5 rounds, Agg10 excludes the first 10 rounds.

From a graphical inspection, it appears that the aggregate average behaviour over the 20 rounds did not differ much between the two groups. However, when only the last 10 rounds were considered, the sessions identified as high on social metacognition seemed to be closer to the suggested correlated equilibrium. This could suggest that the learning behaviour (at an aggregate group level) in following the recommendations was higher for those sessions in which social metacognition was higher.

An independent t-test confirmed that excluding the first ten rounds of the game, there was a significant difference between high and low metacognitive groups in the distance from the correlated equilibrium ($t(11) = 2.21$, $p = .05$, Cohen's $d = 1.33$). More precisely, on average, groups with high social metacognition were significantly closer to the suggested correlated equilibrium ($M = .47$, $SE = .04$) than groups with a low level of social metacognition ($M = .34$, $SE = .04$). Despite not significant when considering all the rounds ($t(11) = .84$, $p > .05$, Cohen's $d = .50$) or excluding only the first five rounds ($t(11) = .74$, $p > .05$, Cohen's $d = .45$), the results suggested a moderate effect of high social metacognition on the closeness to the suggested correlated equilibrium.

Figure 6.3 shows the aggregate behaviour of the sessions that resulted high and low in social metacognition with both the methods described above and behaviour in sessions 5, 9, and 10 (i.e., the sessions that resulted high in social metacognition in only one of the two methodologies; we refer to them as Mid social metacognition groups).

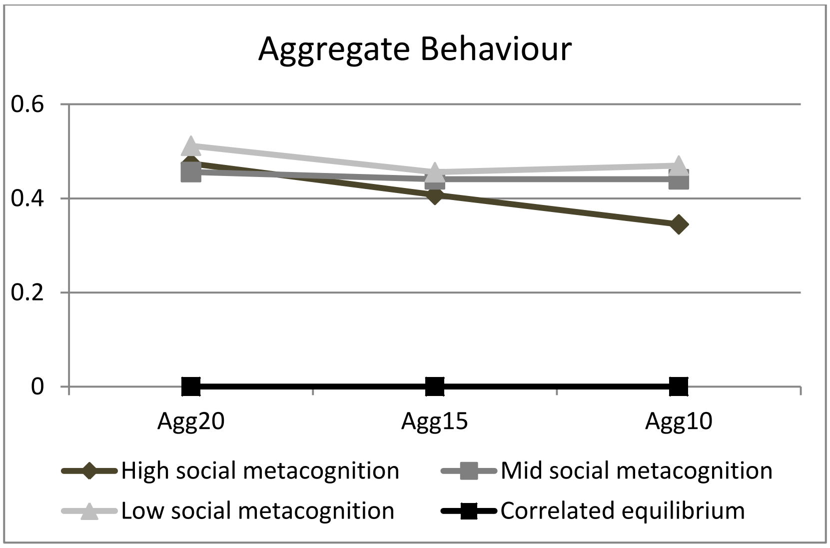

Figure 6.3. Aggregate behaviour in rounds with recommendation of the sessions classified as high/low in social metacognition with both methods of classification and those classified as high only in one of the two methods. Agg20 refers to all 20 rounds, Agg15 excludes the first 5 rounds, Agg10 excludes the first 10 rounds.

It can be seen from the graph that the distance from the correlated equilibrium is smaller for the experimental sessions that were rated as high in social metacognition (smaller distance from the zero line). More interestingly, whereas there was not an evident difference between sessions at the beginning of the game, the distance from the correlated equilibrium for the groups with a low level of social metacognition remained fairly constant over time, whereas the groups with a higher level of social metacognition converged towards the correlated equilibrium as they proceed in the game. On the contrary, the distance from the correlated equilibrium in sessions 5, 9, and 10 seemed to remain fairly stable throughout the game with recommendations.

As a robustness check, we drew the same graphs with the classifications obtained with either of the two methods to assess the level of social metacognition. The same pattern is observable if we cluster groups 4, 6, 7, 9, 10, 12, and 13 against groups 1, 2, 3, 5, 8, 11 (method 1; see Figure 6.4) or if we aggregate groups 4, 5, 6, 7, 12, and 13 against groups 1, 2, 3, 8, 9, 10, and 11 (method 2; see Figure 6.5).

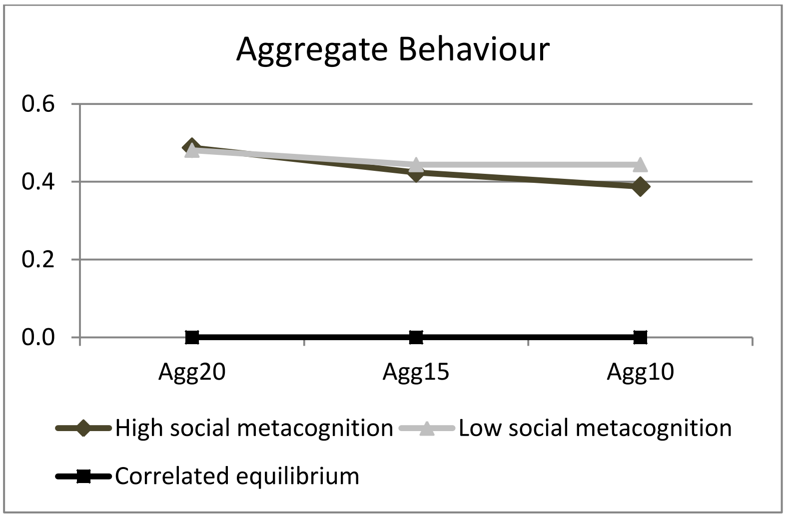

Figure 6.4. Aggregate behaviour in rounds with recommendation of the sessions classified as high/low in social metacognition according to Method 1. Agg20 refers to all 20 rounds, Agg15 excludes the first 5 rounds, Agg10 excludes the first 10 rounds.

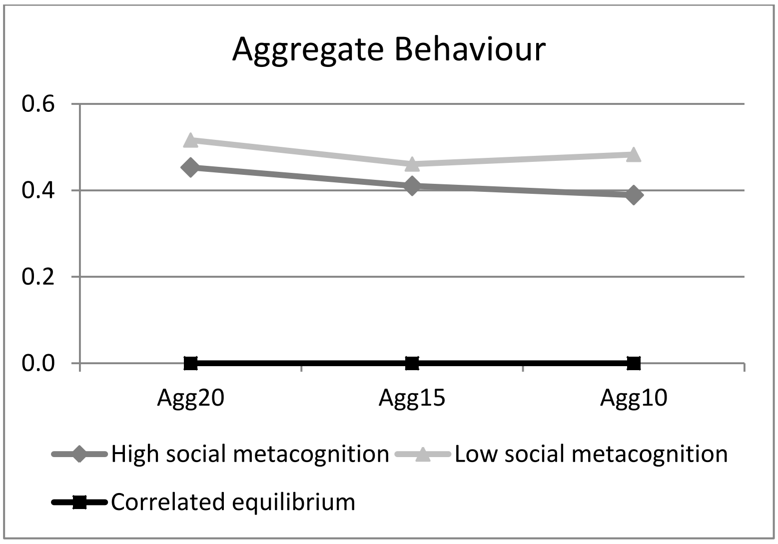

Figure 6.5. Aggregate behaviour in rounds with recommendation of the sessions classified as high/low in social metacognition according to Method 2. Agg20 refers to all 20 rounds, Agg15 excludes the first 5 rounds, Agg10 excludes the first 10 rounds.

That is, the frequency distribution of the outcome at the aggregate level was closer to the suggested correlated equilibrium whenever the total level of social metacognition in a group was higher than the average score of social metacognition among all sessions (i.e., method 1) or when the number of individuals with high levels of social metacognition in a session was higher than half of the number of individuals in the session (i.e., method 2).

In accordance with the aggregate behaviour observed in the graphs above, we also observed a difference in the average payoffs earned by participants, which despite not significant, was higher in the sessions with high social metacognition (5.87) and gradually lower for the sessions scored as mid (5.84) and low (5.76) in the level of social metacognition.

Individual behaviour with recommendations. Having studied play at the aggregate level, we were next interested in individual behaviour, and particularly in investigating how participants treated the recommendations they received and the earned payoffs.

No significant correlations were found between social metacognition and number of followed recommendations (even if we excluded the first five and the first ten rounds of the game; see Supplementary Materials). However, we took into account a possible *group composition effect.* More clearly, we argue that individuals with high social metacognition were more likely to follow recommendations if they were in a group where the level of social metacognition/number of individuals with high metacognition was higher. As a consequence, we also looked at the mean number of recommendations followed in the different sessions. In line with our expectations, we found that, on average, individuals with high social metacognitive abilities followed the recommendations more than individuals with low scores of social metacognition only if they were playing in the sessions classified as high on social metacognition with both (Figure 6.6) or at least one of the two methods

(Figure 6.7). An odd result from Figure 6.6 is the higher proportion of recommendations followed by the groups classified as mid social metacognition. That was due to session 5, which represented an outlier, following the recommendations 80% of the times, a much higher rate than the average of all the sessions (*M* = 065, *SD* = .07).

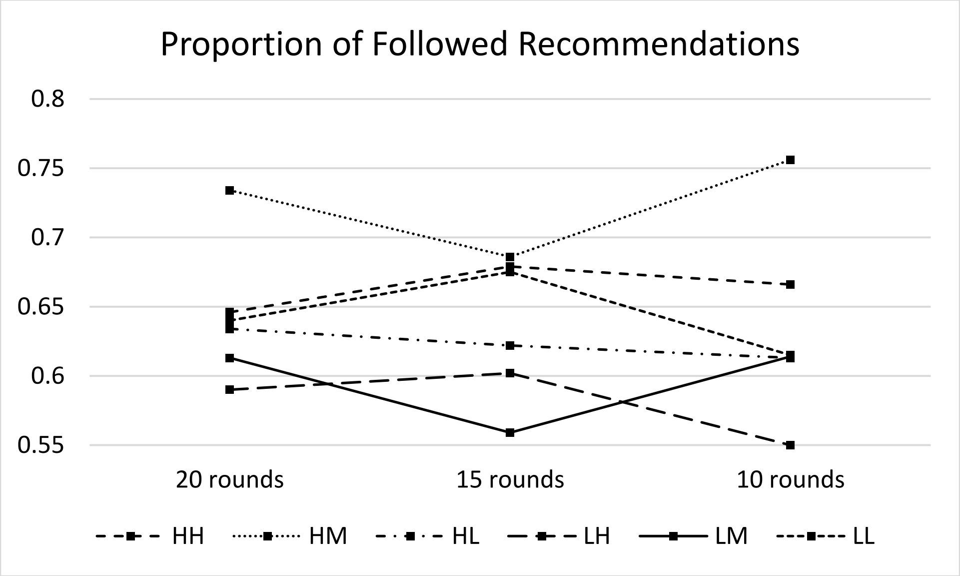

Figure 6.6. Proportion of recommendation followed on average by participants with high/low social metacognition according to both classification methods. The first letter in the label refers to the individual level of social metacognition whereas the second letter in the label refers to the level of metacognition in the session (H = high, M = mid, L = low). The continue lines refer to participants with high metacognition; the dashed lines refer to participants with low metacognition.

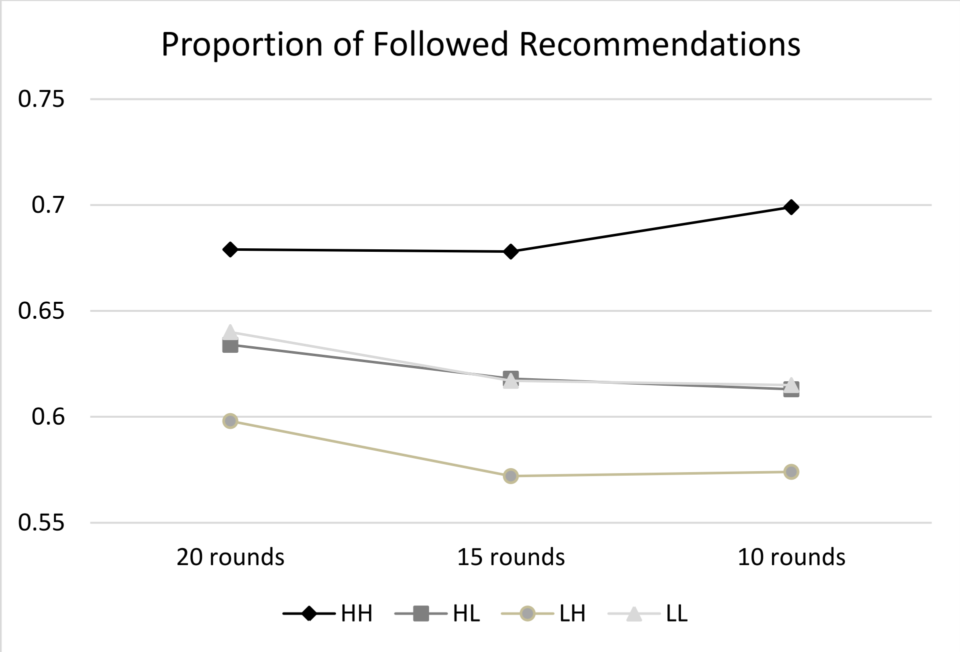

Figure 6.7. Proportion of recommendation followed on average by participants with high/low social metacognition according to either the first or the second classification method. The first letter in the label refers to the individual level of social metacognition whereas the second letter in the label refers to the level of metacognition in the session (H = high, L = low).

We next moved to the analysis of the earned payoffs[15]. No significant correlations were found between social metacognition and earned payoffs in the game, either with or without recommendations (even if we excluded the first five or ten rounds of the game).

Aggregate behaviour without recommendations. In order to investigate behaviour in the rounds without recommendations and examine whether participants in the different sessions played a correlated equilibrium, we checked whether the choices made by participants satisfied the four inequalities that represent the necessary conditions for the correlated equilibrium (see the Method section).

Again, we investigated whether and how behaviour changed if considering 20, 15, and 10 rounds, mindful of the learning processes that took place during the

[15] With ‘earned payoff’ we refer to the payoff realised in the game and not the monetary gain that participants earned for participating in the experiment.

game. We found that players in several experimental sessions played a correlated equilibrium (see Table 6.2). However, the average payoff earned in the session was consistently higher than the expected payoff of the mixed-strategy Nash equilibrium (i.e., 5.4) only for groups 7 and 13, which were the only two sessions - playing a correlated equilibrium - that scored high on social metacognition with both our methodologies.

Table 6.2

List of Sessions Playing a Correlated Equilibrium and Related Average Payoff

	Session	Average Payoff
20 rounds	3	5.33
	7	5.54
	10	4.98
	13	5.68
15 rounds	1	5.40
	2	5.13
	3	5.23
	7	5.53
	13	5.58
10 rounds	1	5.33
	2	5.40
	7	5.64
	10	5.13
	13	5.87

Discussion

Economic theory postulates that rationally behaving individuals make decisions in the attempt to maximise their well-being. Consequently, a rational policy maker should consider it in defining optimal policies to maximise social welfare. The heavily quoted Nash equilibrium can aid, as it allows to identify the possible results of social interactions when individuals cannot correlate their strategies. However, the result of a group interaction cannot be detached from the abilities and personal characteristics of the single individuals shaping it. Psychology theories can aid in this regard admitting that individual differences and characteristics could lead to different group compositions and divergent results from the social interactions. Also, the group itself could be the result of specific characteristics common to the individuals who are part of it. Then, if at an 'aggregate level' the absence of (possibly) correlated choices appears marginal for the society as a whole, this is not anymore the case if the social ability to correlate decisions is a teachable skill, as it is for metacognition (e.g., Kramarski, Mevarech, & Lieberman, 2001; Pennequin, Sorel, & Mainguy, 2010; Schraw, 2001).

The present study started from the previous considerations and aimed to investigate the link between two theoretical concepts: social metacognition and the correlated equilibrium. Social metacognition is the ability to monitor and control one's own and other's cognitive processes. Creating a representation of the mental states of others, it enables individuals to select responses or actions in social environments. As regulatory process, it helps interacting individuals reach an understanding of each other and regulate accordingly cognitive and metacognitive processes (Volet, Vauras, et al., 2009). The correlated equilibrium is a solution concept in non-cooperative game theory, possibly payoff-enhancing with respect to the (mostly common used) Nash equilibrium, but with the 'inconveniency' of requiring the presence of a *choreographing* mechanism to be implemented.

We started our conjecture arguing that individuals with high social metacognitive skills could understand the distribution of probability reflecting the correlated equilibrium and use their abilities to interrelate their decisions on better outcomes. We hypothesised that the construct of social metacognition was a good candidate in explaining how individuals can play a correlated equilibrium, even in the absence of a third party. Hence, we postulated that social metacognition works *as if* it is the correlation device. One of the aims of our study was therefore to point to the role of individual differences in social metacognition in economic decision-making.

We investigated aggregate and individual behaviour in a Chicken game, played with and without recommendations. We used the same game as in Duffy and Feltovich (2010) and the recommendations given to participants were drawn from a probability distribution (correlated equilibrium) which was payoff-enhancing compared with the distribution resulting from the Nash equilibrium in mixed strategies. We built on Cason and Sharma (2007), who observed that experienced players play differently compared to inexperienced individuals. Hence, we argued, from the observed results, that individuals playing in the sessions with higher levels of social metacognition use the provided recommendations to dynamically improve their strategies in coordinating them with the opponents' strategies.

The main findings combined with prior research provide an insightful picture of the role of social metacognition in game theory. We found that groups characterised by a higher level of social metacognition are more likely converge to the suggested correlated equilibrium in the game, even if we did not find a significant difference in following the recommendation among individuals with different levels of ability. This suggests that individuals with higher social metacognitive abilities are better able to interrelate their behaviour whenever they interact with other socially metacognitive individuals.

The finding that interactions among individuals with high social metacognitive skills tend to converge to a correlated equilibrium confirms the importance of taking into account individual differences in understanding the rationality of behaviour.

Close to our view is De Neys et al. (2011) who showed that high metacognitive control abilities are associated with a more rational behaviour. They found that individuals with higher metacognitive control abilities play more in line with the predictions of classic game theory and are more likely to accept unfair offers in the Ultimatum game. In a similar vein, we found that individuals with higher social metacognitive skills tend to behave rationally, converging towards a correlated equilibrium which is payoff-enhancing compared to the Nash equilibrium in mixed strategy. However, as not all individuals with higher metacognitive abilities always accept unfair offers (De Neys et al., 2011), it appears admissible that not all individuals with high social metacognitive skills follow recommendations and play a correlated equilibrium. This point is underlined by the lack of significant correlations between the level of social metacognition and the number of recommendations followed in the game.

The particular interest of this paper was then to explain how the correlation equilibrium as solution concept can be implemented even where it appears 'unnatural' to admit the presence of a third party or incentive by players in defining a correlation device. Duffy and Feltovich (2010) found that when subjects do not receive recommendations, their play is close to the Nash equilibrium in mixed-strategy, a common finding in behavioural economics. The authors commented that it might be difficult to identify theoretical rationales for observable correlated equilibria that do not rely on external, third-party signals. In line with our prediction, we observed that two of the groups of players characterised by a higher level of social metacognition did play a spontaneously (rounds without recommendations) arisen correlated equilibrium and their earned payoff was higher than the payoff of the mixed-strategy Nash equilibrium.

Admittedly, our study is far from providing an exhaustive picture of the psychological factors that play a role in economic decision-making. For instance, our game consisted of only 20 rounds without recommendations, which might not be enough for most subjects to learn the game and coordinate behaviour. It would be interesting to rerun the study with a higher number of interactions to check whether with more periods there is a clearer convergence of play towards correlated equilibria that are payoff-enhancing compared with the mixed-strategy Nash equilibrium.

Also other potential limitations to the current study must be acknowledged. First, we relied on a self-report measure for social metacognition. This provides only a subjective measure of the construct, which may be liable to error biases linked with social desirability, impairments in the introspective abilities, mistaken understanding of the items, etc. In future studies, more objective measurements could also be implemented to assess social metacognition. For instance, research may take advantage from neural measures able to disentangle brain activity associated with metacognition and provide a non-invasive index of metacognitive processes that does not rely on subjective reports.

Yet, as mentioned previously, we found that not all individuals with high social metacognitive skills follow recommendations and play a correlated equilibrium. The rationale for this could derive from the presence of low cognitive skills, which even if accompanied by high social metacognitive capacities might not suffice to learn the game and coordinate behaviour with that of the other players. Cognition is an important variable that has been linked to metacognition (Scarampi, Fairchild, Palermo, & Hinvest, 2018) and is associated with behaviour in non-cooperative games (De Neys et al., 2011). Hence, it is likely that high cognitive abilities interact with metacognitive skills, leading to a better performance at the game. Future empirical work on the topic of correlated equilibrium might look more in depth at cognition as moderating variable of the relationship between metacognition and decision-making in strategic interactions.

Despite the limitations, we believe that our study constitutes an advancement in the understanding of the determinants of behaviour in strategic interactions. Further research in the field is extremely valuable, as disentangling the role that metacognition, as teachable skill, has on playing the correlated equilibrium has considerable policy implications. It has been stressed that institutions and policies depend upon the use of correlation devices (Gintis, 2009). As a consequence, society as whole can benefit from decisions made by agents that rationally follow correlated signals. Illustrative is the well-known example of the traffic light, which is a signal allowing for a much more efficient flow of traffic than if drivers were to navigate road intersections without such correlating devices. However, if often an external correlation device is not 'technically' feasible, metacognition, instead, has been proved to be a teachable skill (Schraw, 2001) and can thus lead to better decision outcome if appropriately trained.

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Complementary to Chapter 6

Chapter 6 discussed the main findings obtained in a study investigating the role of social metacognition in strategic interactions, without focusing on age differences in these processes. Nevertheless, one of the aims of the study reported in the chapter was the investigation of age-differences in the role played by metacognition in social decision-making. As a consequence, whereas Chapter 6 discussed some relevant results found on the more general role of social metacognition in guiding individuals towards interrelated strategies that are utility-enhancing, the focus of this commentary is on the relationship between social metacognition, decision-making, and ageing.

Since an association between metacognition and age was found in the study reported in the third chapter of this thesis, a further interesting research question addressed in the study was whether older adults play according to the correlated equilibrium more often than younger adults because of their higher metacognitive ability, and despite the cognitive decline.

In what follows, the available literature on the effects of ageing on social decision-making is addressed, with a focus on research investigating age differences in the effect that different aspects of social metacognition have on behaviour in strategic interactions. The main results of the study on the age effect of social metacognition on the correlated equilibrium are then presented and discussed.

As mentioned in the literature review of Chapter 6, experimental research on social metacognition and theory of mind has focused mainly on its development in children and its impairment in populations with neurological or psychiatric disorders such as brain damage (Winner, Brownell, Happe, Blum, & Pincus, 1998), schizophrenia (Frith, 1992), or autism (Baron-Cohen, Leslie, & Frith, 1985). Only recently the interest has shifted towards developmental changes in later adulthood. The existing literature is however rather scattered and characterised by conflicting results. Whereas the first study available on the topic has found increased mentalising abilities in older adults (Happé, Winner, & Brownell, 1998), subsequent research has either shown no age-differences in mentalising (Girardi, Della Sala, & MacPherson, 2017; Keightley, Winocur, Burianova, Hongwanishkul, & Grady, 2006; Saltzman, Strauss, Hunter, & Archibald, 2000) or reported a significant inferior performance of older participants compared to young adults (Bailey, Henry, & Von Hippel, 2008; Castelli et al., 2010; Maylor, Moulson, Muncer, & Taylor, 2002; Pardini & Nichelli, 2009).

Conflicting results also exist in the literature investigating age differences in social decision-making behaviour. Kovalchik, Camerer, Grether, Plott, and Allman (2005) have studied age effects in the Beauty Contest Game, one of the simplest games used in behavioural economics to study interdependent decision-making, where the ability to anticipate how the other subjects are going to play is an essential skill to win the game. The authors have found that younger and older adults play in a similar manner, suggesting that ageing does not compromise the ability to reflect on the intentions of others. A few further studies have investigated age-related differences in the Ultimatum game, finding conflicting results. Whereas Nguyen et al. (2011) have found no age-related differences in the rate of accepted offers, Harlé and Sanfey (2012) and Roalf, Mitchell, Harbaugh, and Janowsky (2012) have shown that whether younger and older adults do not differ in responding to fair offers (i.e., 50% of the pie), older adults tend to reject more unfair offers (e.g., 30% of the pie) than younger adults. Still, Bailey, Ruffman, and Rendell (2013) have demonstrated that, in some circumstances, older adults make more 'economically rational' Ultimatum Game decisions than their younger counterparts by rejecting fewer unfair offers from young proposers.

Mindful of the two conflicting literatures described above and recognising that the inability to accurately attribute mental states to others and reflect on them may also impact upon older adults' economic decision-making behaviour, it seems relevant to investigate whether age-differences in social decision-making may be determined by differences in social metacognitive abilities. The first study in the ageing literature examining the effect of social metacognition on social decision-making is that of Beadle et al. (2012). The authors have investigated the effect of social metacognition, and more precisely mentalising abilities, on respondent behaviour and found that whereas there is no difference between young and older adults with low mentalising abilities, when comparing older and younger adults with high mentalising abilities, older adults tend to behave more rationally and accept more unfair offers than young individuals. As stressed by the authors, older adults with high social metacognitive skills may have used their ability to understand others' mental states to maximise their own gain and obtain a higher payoff. The results are in line with those from De Neys, Novitskiy, Geeraerts, Ramautar, and Wagemans (2011), who have shown that there is a positive association between metacognition and higher rates of acceptance of unfair offers.

The finding that metacognition is associated with rational behaviour highlights the relevance of further investigating the relationship between ageing, social metacognition, and economic decision-making. If high social metacognitive competences can be taught, leading individuals to better decision outcomes, then they might be used to buffer against the cognitive decline and sustain decision-making in later adulthood. With the aim of shedding further light on the interrelation among these processes, the current study focused on another class of non-cooperative games, namely the Chicken game, to study whether younger and older adults differ in their social metacognition and in how they follow recommendations to coordinate behaviour towards a correlated equilibrium.

Participants

A total of 53 young adults (age range 21-35, *M* = 26.11 years, *SD* = 3.10; 31 female) and 45 older adults (age range 55-79, *M* = 64.13 years, *SD* = 7.35; 24 female) participated in the study.

Results

Between groups comparisons were used to investigate the existence of significant differences in the different components of social metacognition and the total score of the variable in young and older adults. A Mann-Whitney U test was used and the results showed that there are no significant differences in metacognitive judgements and metacognitive knowledge in the two samples. However, older adults have significantly higher metacognitive skills than younger adults (young: *Mdn* = 5.19, *Range* = 3.25−6.56; older: *Mdn* = 5.63, *Range* = 3.75−6.81; *U*(53,45) = 1539.50, *Z* = 2.48, *p* = .013, *r* = .25). There was also a significant difference between younger (*Mdn* = 4.95, *Range* = 3.43−5.80) and older adults (*Mdn* = 5.16, *Range* = 3.80−5.98) in the total score of social metacognition; *U*(53,45) = 1508.50, *Z* = 2.25, *p* = .024, *r* = .23. The results suggest that older adults have better regulatory skills than younger adults in social interactions and have higher social metacognitive abilities overall.

In order to analyse age-differences in decision behaviour in our experiment, we used a Mann-Whitney U test. No significant differences emerged between younger and older adults in the number of recommendations followed and in the earned payoffs.

Discussion

The current study investigated age-related differences in the effect that social metacognition has on social decision-making. Building on previous research showing that older adults use their mentalising abilities to maximise their own gain and play in line with the predictions of classic economic theory (Beadle et al., 2012; Kovalchik et al., 2005), we were interested in studying age effects in a different set of non-cooperative games, where players can coordinate their behaviour and play a correlated equilibrium.

We failed to find age-differences in whether participants followed the given recommendations and in the earned payoffs. In line with previous literature, (e.g., Nguyen et al., 2011) this result suggests that older adults have spared social decision-making abilities and their behaviour does not differ from that of young adults.

Furthermore, we investigated age-differences in the different facets of social metacognition, with the aim of shedding further light on the effects that age has on our social functioning. We found that older adults have comparable ME and MK to younger adults, and enhanced MS. This finding is in line with the results obtained by Happé et al. (1998) and suggests that older adults are better able than younger individuals at predicting others' intentions and have an increased ability to select appropriate responses or actions in social environments. They seem to be better than their younger counterparts at using the information about others' mental states acquired with monitoring processes to predict behaviour and regulate cognitive performance. This result is also consistent with the socio-emotional selectivity theory (Carstensen, Isaacowitz, & Charles, 1999), which suggests that with advancing age, individuals tend to selectively allocate more resources to socio-emotional contents, rather than on self- and future-oriented goals.

Despite the relevance of the results, a few limitations can be identified. The cross-sectional design of the study questions whether the observed age-related difference regarding social metacognition are truly age-relate or hide some cohort effects. Older adults taking part in the current study were highly educated and may not be representative of the entire population. Furthermore, we did not control for general intelligence, which might have played a role in determining choice behaviour. Still, cognitive abilities are known for being affected by ageing and, at the same time, impacting upon choice behaviour. Thus, it would be interesting to further study age-differences in these processes in non-cooperative games.

We did not investigate the effects of group composition in terms of age. The socio-emotional selectivity theory (Carstensen et al., 1999) has shown that older adults tend to become very selective in their social interactions, choosing long-standing, high-quality relationships and focusing on emotionally close partners. This might lead to increased social metacognitive skills in interactions with familiar partners and decreased mentalising abilities in situations involving unfamiliar social partners. To confirm this hypothesis, it would be interested to look at the existence of differences in behaviour in sessions constituted entirely by older adults (or younger adults) and groups with a mixed composition.

In conclusion, although previous empirical evidence has suggested that social metacognition is an essential prerequisite for successful decision-making in strategic interactions (Beadle et al., 2012), this study adds to the existing literature, demonstrating a relationship between social metacognition and adaptive social decision abilities in later adulthood.

Knowing that metacognition is a teachable skill, this study has relevant policy implications, as the association between high social metacognition and rational decision-making in older adults points to the possibility that older adults might increase their mentalising abilities to buffer the cognitive decline that comes with age and maintain sound decision abilities. The quality of social skills has been studied mainly in samples of healthy young and middle aged-adults (Singer et al., 2016). Nevertheless, it is particularly relevant for older adults. If information processing in decision-making is facilitated by social metacognition as suggested by Reiter, Kanske, Eppinger, and Li (2017), a further interesting possibility is that older adults can be trained to use their relatively intact social metacognitive abilities to support decision-making. Accordingly, an interesting future research avenue is the investigation of training interventions to improve social metacognition and their effectiveness for social decision-making.

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Chapter 7

General Discussion

Aims of the Thesis

Life expectancy is increasing worldwide and population is expected to age rapidly in the coming years. The demographic shift to an older society will have several major economic and social implications (Bloom, Canning, & Fink, 2010; United Nations, 2017). As a consequence, it is relevant to study how older adults make economic and social decisions (Lim & Yu, 2015). This is even more relevant because whereas ageing is associated with a decline in cognitive ability, it is well known that it also correlates with accumulated experiences and therefore possibly with metacognition. The aim of this thesis was to study these interrelated aspects, with a focus on both the individual and the social level.

Despite the wide interest in metacognition developed in the last four decades, there is little neuroscience and psychology research on the role of metacognition in reasoning and decision-making (Ackerman & Thompson, 2017). Even less attention has been paid to the topic in the field of ageing-related research. In spite of these observations, the research discussed in this thesis sought to examine the relationship between metacognition and ageing in the context of financial decision-making. After a review of the literature of behavioural sciences and psychology on metacognition and ageing, this thesis was organised around the theoretical framework proposed by Efklides (2008). The research discussed in this thesis focused on several aspects of decision-making, ranging from individual financial capacity to risk preferences and social strategic interactions. Furthermore, it aimed at further investigating the neural markers of metacognition and its relationship with cognitive abilities. Accordingly, the overall aim of this research was to explore the hypothesis that individuals can use metacognition – a teachable skill – to improve their wellbeing and, more broadly, society welfare. The empirical findings presented in this thesis corroborate and extend the understanding of the age-related changes in the effect that metacognition has on financial decision-making by focusing on five main aspects:

1. Providing a summary of the main findings across the literature on ageing, decision-making, and metacognition (Chapters 1 and 2).

2. Developing a new methodology for the assessment of metacognition in the context of decision-making (Chapters 3 and 6).

3. Investigating whether metacognition can buffer against the physiological cognitive decline that comes with age and provide an alternative route to sound financial decisions (Chapters 3 and 4).

4. Providing further evidence of the neural correlated of metacognition and the related effects of ageing (Chapter 5).

5. Investigating whether metacognition can attenuate the coordination problem in non-cooperative interactions at the social level (Chapter 6).

Summary of Findings

Chapter 1. *An Interdisciplinary Review of Research on Decision-Making with a Special Focus on Age Differences*

The narrative literature review presented an overview of key theories of decision-making. It summarised the current state of the art in the literature on age-related chances in the cognitive and emotional processes that underlie decision-making and provided a reflection about different results obtained in previous studies.

Chapter 2. *Elucidation of the Construct of Metacognition, its Functioning, Age-Related Changes, and Possible Assessment Methods*

The second chapter provided a further literature review, aimed at identifying on the one hand the evolution of the theoretical framework for metacognition; on the other hand, it provided a review of the methodologies used to assess metacognition. The relative small number of studies and the conflicting results on the evolution of metacognition during the adulthood were critically analysed and represented the starting point for discussing a new methodology used in this thesis to measure metacognition.

Chapter 3. *Age Differences in the Effect of Metacognition on Financial Decision-Making*

The quantitative study investigating the role of metacognition as moderator of the relationship between cognitive ability and financial decision-making found significant differences between young and older adults. More interestingly, the main results highlighted how different metacognitive components play a different role in the decision-making process and how their influence depends on age and on individual levels of cognitive ability.

Chapter 4. *The influence of cognitive and metacognitive abilities on risk aversion. A comparison between young and older adults*

The theory discussed and the obtained results confirmed the hypothesis that metacognitive awareness contributes to explain the variability in risk attitude between younger and older adults. More precisely, the findings indicated that rather than depending on ageing, differences in risk attitude between young and older adults can be justified taking into account cognitive and metacognitive abilities.

Chapter 5. *Age differences in the neural markers of metacognition: Evidence from a financial decision-making task*

The EEG study conducted with younger and older adults aimed at uncovering how metacognitive experiences develop in time when making a decision. The main results showed a significant relationship between the amplitude of N2 and Pe, waveforms associated with cognitive control and error processing, and subjective ratings of metacognitive experiences. Furthermore, relevant differences were found between older and younger adults in the amplitude of the ERPs associated with error detection processes. The results provided evidence for brain activity signals that represent a non-invasive index of metacognitive experiences. Yet, they shed light on metacognitive components that undergo relevant changes with ageing, and other spare processes on which older adults can rely to operate appropriate monitoring and control processes in decision-making.

Chapter 6. *Social Metacognition: A Correlational Device for Cooperation*

Finally, a behavioural study investigated the role of metacognition in the context of strategic social interactions. The main results showed that in strategic non-cooperative interactions, individuals with higher levels of social metacognition can attain results which are welfare-improving with respect to the theoretical results predicted by game theory. It appears that age does not impact upon the findings and the results suggested that the social component of metacognition can work as a device able to correlate individuals' actions, reducing the coordination problem.

Integration of Findings

Decision-making processes are not a recent area of study, but most of the available research has focused on the cognitive and emotional processes that underlie choice behaviour. A review of the literature on age differences in decision-making has highlighted a lack of research into the psychological mechanisms that can offset age-related cognitive declines and provide an alternative route to sound economic and social decisions. Most studies have focused mainly on the cognitive decline that may degrade decision competence. Moreover, the approach adopted in most studies aligned to the *homo oeconomicus* suggested by classic economic theories and looked at decisions as purely rational processes aimed at identifying the optimal option through a deliberate evaluation of all the possible alternatives.

Only more recently, researchers have shown that domain-specific knowledge and expertise can foster older adults' decision-making (Li et al., 2015). Crystallised intelligence increases over the lifespan as a reflection of experience (Mata, Schooler, & Rieskamp, 2007) and sustains older adults' choice behaviour by allowing a faster and less rigorous consideration of the information related to the possible options, without altering the quality of the outcome of decision-making (Mather, 2006).

The research project discussed in this thesis aimed to add to this distinction by understanding whether older adults can engage in metacognitive processes which, strengthened by the use of spared crystallised intelligence and past experiences, can compensate the natural physiological decline in fluid intelligence. If the metacognitive processes used by older adults can be identified and those same processes are predictive of successful decisions, then also younger adults could potentially likewise learn metacognitive strategies to improve their decision making performance. Researchers have overlooked the role of metacognitive awareness in decision-making, especially in the age-related literature. To fill this gap, this research project explored the role of metacognition in different decision-making aspects, ranging from individual financial capacity to risk preferences and choice behaviour in strategic interactions. Furthermore, a new methodology was developed with the aim of disentangling the functional aspects of each metacognitive component in the context of decision-making.

In order to obtain a clear picture of the role of metacognition, its components and its interaction with cognition, the enriched model of metacognition proposed by Efklides (2008) was chosen as a reference. This was made in light of the ability of the model to consider different aspects disregarded by other theoretical approaches and attempt to combine previous models of metacognition into a more comprehensive and precise representation of the different facets of metacognition and their levels of functioning. In line with the idea of having a comprehensive theoretical reference model, this research project aimed at developing a novel methodology to assess the different metacognitive facets of metacognition theorised by Efklides in the context of decision-making. Existing instruments available in the literature were adapted and validated for the assessment of metacognition at both the individual and the social level.

In line with the existing literature stressing the cognitive decline that characterises old age (see Salthouse, 2010 for a review), the results of the study presented in Chapter 3 showed that young adults have higher levels of cognitive abilities than their older counterparts. Furthermore, older adults have significantly more accurate metacognitive experiences than younger adults. This finding falls within the ongoing debate on the development of metacognitive experiences in later adulthood and supports previous studies finding that ageing does not affect the accuracy of metacognitive judgements used to monitor the ongoing cognitive processing (e.g., Hertzog & Dunlosky, 2011). More interestingly, the main results of the study discussed in Chapter 3 highlighted how an increased skilfulness in each metacognitive facet can be either beneficial or detrimental on decision-making depending on age and individual levels of cognitive ability.

The study discussed in Chapter 4 went more in depth on a specific aspect of decision-making – i.e., risk preferences – and the main findings showed a strong association between risk behaviour and metacognition. The results support the relevance of studying metacognition in the context of decision-making and adds to the ongoing debate on the relationship between ageing and risk preferences (see Bonsang & Dohmen, 2015), suggesting that rather than depending on ageing, differences in risk attitude between young and older adults can be justified taking into account cognitive and metacognitive abilities. More precisely, the study showed that highly metacognitive young adults tend to be more risk lovers whereas highly metacognitive older adults tend to be more risk averse.

After investigating behavioural differences in the relationship between metacognition and ageing in decision-making, the study presented in Chapter 5 investigated the neural bases of metacognition and the related age differences in a financial task. Behavioural results from this experiment showed that older adults are slower than younger adults, supporting previous research on the cognitive declines associated with ageing (see Bott et al., 2017). The study failed to find significant differences in the accuracy of metacognitive judgements in younger and older adults, supporting the idea discussed in Chapter 3 that metacognitive experiences can represent a spared monitoring process that may be used to improve performance in later adulthood. This result is partially supported by the lack of significant differences in the N2, waveform associated with metacognitive monitoring processes. On the contrary, older adults had a (almost significant) larger negative deflection in the ERN time window and a significantly smaller positive Pe than younger adults. This seems to support the claim made by Schreiber, Endrass, Weigand, and Kathmann (2012) and the idea that the compensatory activity associated with a slightly larger N2 in older adults leads to a smaller availability of resources for sub-functions of the monitoring system, such as error processing.

The main findings of the study are also relevant for the general literature on the neural markers of metacognition, as they showed a significant relationship between the amplitude of N2 and Pe, waveforms associated with cognitive control and error processing, and subjective ratings of metacognitive experiences. These results provide evidence for brain activity signals that represent a non-invasive index of metacognitive experiences.

The last study discussed in the thesis aimed at investigating the role of social metacognition in strategic interactions and the existence of significant age differences. Overall, the study presented in Chapter 6 showed that in strategic non-cooperative interactions, the social component of metacognition can work as a device able to correlate individuals' actions, reducing the coordination problem. Individuals with higher levels of social metacognition can attain results which are welfare-improving with respect to the theoretical results predicted by game theory.

Furthermore, the results showed that there are no significant differences in social metacognitive judgements and metacognitive knowledge in the younger and older adults. However, older adults have significantly higher metacognitive skills than younger adults. There was also a significant difference between younger and older adults in the total score of social metacognition. These results support the findings of the other studies discussed in the thesis and suggest that older adults have better regulatory skills than younger adults in social interactions and have higher social metacognitive abilities overall. The study used a set of non-cooperative games, where players can coordinate their behaviour and play a correlated equilibrium. In line with previous literature showing that older adults use their mentalising abilities to maximise their own gain and play in line with the predictions of classic economic theory (Beadle et al., 2012; Kovalchik, Camerer, Grether, Plott, & Allman, 2005), we failed to find age-differences in whether participants followed the given recommendations and in the earned payoffs. This result suggests that older adults have spared social decision-making abilities and their behaviour does not differ from that of young adults. Again, this strengthens the possibility that metacognition can be used to buffer against the cognitive decline and sustain decision-making in later adulthood.

In summary, the findings of this thesis align with Li et al. (2015) and confirm that an analysis investigating only the effects of age on decision quality would be simplistic and misleading. Instead, more attention should be paid to the interplay between metacognitive and cognitive processes. In fact, a more in depth analysis has revealed that each component of the meta-level of Efklides' model has a different effect on the decision quality, depending on age and cognitive ability. Metacognitive and cognitive abilities have been demonstrated to play an important role also in another relevant aspect of decision-making; that is, risk preferences. The results of the PhD project here outlined demonstrated that age-differences in risk attitudes can possibly be explained by changes in cognitive and metacognitive skills. More precisely, metacognition seems to lead younger adults to an increase in risk-taking behaviour and older adult to more conservative decisions.

Yet, another relevant finding, confirmed by both a behavioural and a neuroscientific study, is that older adults can rely on metacognitive experiences that are as accurate as those of their younger counterparts, if not superior. Also in the context of social decision-making, the current research showed that older adults have better regulatory skills than younger adults and higher social metacognitive abilities. The analysis of the influence of social metacognition on behaviour in strategic interaction confirmed that higher skills are associated with a more rational behaviour.

The results outlined above, and more deeply discussed in the chapters of this thesis, confirmed a cognitive decline in older adults' fluid intelligence and the outlined results are in line with Li et al. (2015), who suggested guidelines for designing effective interventions and decision aids across the lifespan. They proposed, as a possible avenue to improve older adults' financial decisions, to reduce the dependence on fluid intelligence. As example, it might be possible to accomplish it by reducing the financial options proposed to older decision makers and help future generations with training programs aimed to increase metacognition and its reinforcing relationship with crystallised intelligence, and the use of them more than fluid intelligence.

Limitations of this Research

The research conducted is one of the first to explore the role of metacognition as moderator in financial decisions and strategic non-cooperative interactions. Nevertheless, there are limitations that in addition to the ones reported in each paper of this thesis are rather general and need to be addressed.

First, it is well known, as one of the central topic in the literature, that the assessment of metacognition is challenging for several reasons, including the impossibility of directly observing it and the complexity of the construct, which relies on a number of different types of knowledge and skills. Although this thesis attempted to incorporate these aspects within a new methodology to measure metacognition, all the studies presented have measured metacognition via self-report questionnaires and rating scales. As a consequence, also here apply the limits that self-report procedures exhibit (Nisbett & Wilson, 1977). In particular, there was no mean to identify whether or not the subjects taking part in the experiments answered consistently and truthfully, revelling the processes truly activated during their reasoning.

Second, this thesis explored age-related differences using a cross-sectional design and separating the sample pool between older and younger adults. The inability to cover the entire adult lifespan and the possible influence of cohort effects should be taken into account when considering the generalizability of the main results. A further research project able to involve participants of all ages, or even with a longitudinal design, can better elucidate the evolution of the different metacognitive facets and their role in reasoning and decision-making over the lifetime.

Research Contributions

This research made contributions to knowledge in three ways: theoretically, methodologically, and in terms of practical implications.

Theoretical Contribution. The first theoretical contribution of this research project consisted in the investigation of the underlying components of metacognition in decision-making and the understanding of the differences in the extent to which people of different age monitor and control their own reasoning and decision-making. The research focused on the interplay between cognitive and metacognitive process in two key aspects of decision-making: individual financial capacity and risk attitude. Furthermore, the research discussed in this thesis contributed to the understanding of the brain mechanisms affecting the metacognitive monitoring and control processes involved in financial decisions and their changes over the adult lifespan. Also, with a social empirical study, the thesis contributed to the understanding of the role that the social component of metacognition plays in social strategic interactions, contributing to the literature on social decision-making and the evolution of this ability with advancing age.

Methodological Contribution. As stressed above, metacognition is a concept which involves several skills and hence it is theoretically defined as a multidimensional construct. As noted by Efklides (2008), beside the theoretical implication of differentiating the different facets of metacognition, it is evident that also the methodology used to investigate metacognition needs to be enriched.

One of the main aims of this research was to propose an experimental method to measure metacognitive abilities during the resolution of a decision-making task, both at the individual and the social level. Although the focus of this project was on financial decision-making, the instruments used to analyse metacognition consisted of some questions that refer to making decisions in general and some more specific questions that can be applied to decision-making tasks that differ from the financial one created for this project. As a consequence, the methodology is expected to be applicable in other contexts involving decision-making.

Most previous research has used self-report questionnaires for metacognitive knowledge, rating scales for metacognitive experiences, and thinking-aloud protocols for metacognitive skills. The methodology implemented in the research here outlined incorporated self-report questionnaires, realistic decision-making scenarios and a neuroscientific technique; i.e., the electroencephalography.

Moreover, whereas most self-report measures of metacognitive experiences are static (i.e., prospective or retrospective) this thesis suggested a new methodology able to evaluate the accuracy of metacognitive judgements taking into account prospective and retrospective ratings together. This was done guided by the rationale that individuals with high metacognitive abilities should not only be able to provide accurate metacognitive judgements (i.e., in line with their performance at the ongoing task), but also be consistent in the judgements they make before and after performing a task.

Practical Contribution. The findings of this thesis provide a platform for the development of interventions and policies at both the individual and the social level. The rationale for focusing on financial decisions is the need for research able to improve decisions and provide strategies to develop skills in financial decision-making. Previous research has shown that metacognition is a teachable skill (see Hertzog & Dunlosky, 2011) and training programs can be developed to help individuals improve their decision-making abilities and their financial performance by enhancing their metacognition; that is, becoming aware of their reasoning processes, more competent at monitoring their own reflective reasoning, and able to counteract the biased tendencies that drive behaviour. Not only can interventions be beneficial for older adults to buffer against the cognitive decline, but also younger individuals can take advantage of a better understanding of how metacognition impacts upon the decision-making process. Nevertheless, the main findings of this thesis stressed that the development of interventions has to be performed on several levels. In particular, the influence of metacognition on performance implies positive possibilities for the improvements of decision-making, provided that interventions and programs are developed taking into account the different effect that each metacognitive facet has depending on cognitive abilities and age of the individuals they are aimed to.

Another practical implication in line with the prescriptive models of decision-making is the possibility for financial advisory businesses to utilise the measures of metacognition developed in this project as an assessment tool. Since metacognition has an impact on risk preferences and financial capacity, firms can include a measurement of metacognitive abilities into risk profile assessments, with the aim of more successfully tailor advice to the person to whom it is addressed.

Lastly, in studying how metacognition could affect results of non-cooperative strategic interactions, we defined a different framework that policy makers should consider in defining incentive mechanisms. This aspect could be relevant at a micro level where, for instance, firms can define new strategies to improve workers' metacognitive abilities, reducing the coordination problem that may arise from group work. Yet, at a macro level, training aimed to improve metacognition and therefore the ability to interrelate decisions at a social level can reduce the welfare loss coming from a stronger competition.

Future Research

Evidence-based studies on the role of metacognition in decision-making are still somewhat limited and future research is required to better understand the functions of the different facets of metacognition and how they can in turn be used to develop trainings to support decision-making across the lifespan. Specifically, future research could:

- Further investigate the interactions among the different facets of metacognition during task processing and across different tasks and contexts. More research in this direction can dig into the role of each metacognitive component in the different stages of the decision process, rather than on the single outcome. This can also shed further light on how metacognition regulates the use of System 1 intuitive processes and the engagement of more deliberative System 2 interventions.

- Conduct further cross-level analyses combining individual and social levels of metacognition. One of the studies discussed in this thesis focused on non-cooperative strategic interactions and attempted to analyse how individuals' social metacognition can reduce the wellbeing loss deriving from strategic interaction. It would be interesting to further explore the formulated hypotheses analysing the interrelationship between metacognitive self- and social regulatory mechanisms. Furthermore, research can investigate the mechanism of self-regulation, co-regulation, and other-regulation in other social decision contexts and discern how metacognition is involved in cooperative games and collaborative decision-making tasks.
- Develop and using behavioural and physiological indicators able to capture and evaluate the dynamic nature of metacognition (e.g., eye-tracking, biomarker indicators, etc.).
- Further investigate the neural bases of metacognition. The investigation of metacognition at the neural level is essential for the development of robust objective measures of metacognition. It also represents a necessary step for the understanding of metacognitive failures that occur after brain lesion or psychiatric disorder.
- Develop a unified approach to measure metacognition. The different facets of metacognition are often measured as single components and the conclusions about metacognition at the individuals' level are envisioned taking into account the result of the single parts. This reveals the need for the

development of new methodologies and the creation of procedures aimed at providing a unique measure of metacognition as a whole.

- Related to the previous point, define and evaluate interventions and their outcomes. Most interventions available today aim at improving academic performance and motivation in students. Further programs can be developed to aid decision-making and help individuals recognising the misleading biases resulting from inappropriate heuristic use.
- Redefine the available instruments to assess metacognition and testing them in real-world decision contexts. Research born from the collaboration between universities and industry can enlighten and extend, for example, what is already known about the role of metacognition in financial businesses and firms or how to develop financial services aids relying on metacognition to support individual investment and savings decisions.
- Conduct longitudinal studies to better understand the evolution of the different components of metacognition over the lifetime and increase internal and external validity of scientific research on metacognition and ageing.

Conclusion

Life expectancy is increasing, but due to the cognitive decline that comes with age and the complexity that characterises today’s world, and particularly the financial instruments, the ability to make good decisions with advancing age can be compromised. This highlights the compelling need for studies to better understand how older people make economic and social decisions. Nevertheless, there is a significant gap in understanding how the higher level of cognition – metacognition – is related to decision-making and what the effects associated with ageing are. This thesis attempted to fill the gap by investigating whether metacognition can buffer against cognitive decline and support older adults' financial decision-making.

The key findings suggested that metacognitive abilities provide an alternative route to sound financial decisions – one that can improve with age. However, it is fundamental to keep into consideration the interplay between metacognitive and cognitive skills to better define practical solutions.

This research has inevitably some limitations that need to be considered, including the cross-sectional design of the studies. In fact an investigation of the evolution of metacognition throughout the adult lifespan could bring further insights not only about the development of the different facets of metacognition, but also about the interplay between cognitive, emotional and metacognitive processes in decision-making.

This is one of the first empirical investigations of the age-related effects that metacognition has on financial decision-making. Not only do the conclusions put forward by this project make a theoretical contribution in the age-related literature, but they also have practical benefit within domains in which age-related changes in metacognition in financial decision-making are of interest, from policy making to financial services. Further research in this direction is warranted.

Interventions on metacognition can enable individuals to reflect on their abilities and carefully consider what are the task requirements and the most appropriate strategies to solve the situation at hand (Hertzog & Dunlosky, 2011). Age-specific decision aids and interventions that build upon the results of this thesis can help individuals improve their self-awareness and regulatory processes, enhancing in turn their competences in making decisions, not only in cognitively demanding situations such as during a financial decision, but also in their everyday life.

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Supplementary Materials Chapter 3

The Adapted-Metacognitive Awareness Inventory (a-MAI)

Instructions: We would like you to respond to the questions in this packet by indicating how true or false each statement is about you. If a statement is always true, select the number 4 under the corresponding statement. Your responses are scored anonymously, so please answer as truthfully as you can.

1 = Never; 2 = Sometimes; 3 = Often; 4 = Always

1. I ask myself periodically if I am meeting my goals.	①	②	③	④
2. I consider several alternatives to a problem before I answer.	①	②	③	④
3. I try to use strategies that have worked in the past.	①	②	③	④
4. I pace myself while solving a problem in order to have enough time.	①	②	③	④
5. I understand my intellectual strengths and weaknesses.	①	②	③	④
6. I think about what I really need to do before I begin a task.	①	②	③	④
7. I know how well I did once I finish a test.	①	②	③	④
8. I set specific goals before I begin a task.	①	②	③	④
9. I slow down when I encounter important information.	①	②	③	④
10. I know what kind of information is most important to analyse when solving a task.	①	②	③	④
11. I ask myself if I have considered all options when solving a problem.	①	②	③	④
12. I am good at organizing information.	①	②	③	④
13. I consciously focus my attention on important information.	①	②	③	④
14. I have a specific purpose for each strategy I use.	①	②	③	④
15. I do best when I know something about the topic.	①	②	③	④
16. I am good at remembering information.	①	②	③	④
17. I use different strategies depending on the situation.	①	②	③	④
18. I ask myself if there was an easier way to do things after I finish a task.	①	②	③	④

19. I have control over how well I perform in a task.	①	②	③	④
20. I periodically review to help me understand important relationships between concepts.	①	②	③	④
21. I ask myself questions about the material before I begin.	①	②	③	④
22. I think of several ways to solve a problem and choose the best one.	①	②	③	④
23. I check what I've done after I finish.	①	②	③	④
24. I ask others for help when I don't understand something.	①	②	③	④
25. I can motivate myself to work when I need to.	①	②	③	④
26. I am aware of what strategies I use when I solve a problem.	①	②	③	④
27. I find myself analysing the usefulness of strategies while solving a task.	①	②	③	④
28. I use my intellectual strengths to compensate for my weaknesses.	①	②	③	④
29. I focus on the meaning and significance of new information.	①	②	③	④
30. I create my own examples to make information more meaningful.	①	②	③	④
31. I am a good judge of how well I understand something.	①	②	③	④
32. I find myself using helpful strategies automatically.	①	②	③	④
33. I find myself pausing regularly to check my comprehension.	①	②	③	④
34. I know when each strategy I use will be most effective.	①	②	③	④
35. I ask myself how well I accomplished my goals once I'm finished.	①	②	③	④
36. I ask myself if I have considered all options after I solve a problem.	①	②	③	④
37. I try to translate new information into my own words.	①	②	③	④
38. I change strategies when I fail to understand.	①	②	③	④
39. I use the organizational structure of a task to help me solving it.	①	②	③	④
40. I read instructions carefully before I begin a task.	①	②	③	④
41. When solving a task, I ask myself if it is related to what I already know.	①	②	③	④
42. I re-evaluate my assumptions when I get confused.	①	②	③	④

43. I organize my time to best accomplish my goals.	①	②	③	④
44. I perform better when I am interested in the topic.	①	②	③	④
45. I try to break performing down into smaller steps.	①	②	③	④
46. I focus on overall meaning rather than specifics.	①	②	③	④
47. I ask myself questions about how well I am doing while I am handling a new task.	①	②	③	④
48. I ask myself if I did as much as I could have once I finish a task.	①	②	③	④
49. I stop and go back over new information that is not clear.	①	②	③	④
50. I stop and reread when I get confused.	①	②	③	④

Subscales:

Metacognitive knowledge:

Items 5, 6, 10, 12, 13, 14, 15, 16, 17, 25, 26, 28, 31, 32, 34, 39, 43, 44 [18]

Metacognitive skills:

Items 2, 7, 9, 11, 18, 19, 20, 21, 23, 27, 29, 33, 35, 36, 37, 38, 41, 42, 45, 47, 48 [21]

Items excluded from the scale after the factor analysis:

Items 1, 3, 4, 8, 22, 24, 30, 40, 46, 49, 50 [11]

Questions selected from the Metacognitive Experiences Questionnaire (MEQ)

Prospective version:

Instructions: Read each statement and put an X on the appropriate circle on the right side of this page.

1 = Not at all; 2 = A little; 3 = Enough; 4 = Very

1. How difficult do you think (or feel) the problem is?	①	②	③	④
2. How much effort do you think you need to exert in order to solve the problem?	①	②	③	④
3. How much time do you think you need in order to solve the problem?	①	②	③	④
4. How correctly do you think you can solve the problem?	①	②	③	④
5. How much do you think you need to "think" in order to solve the problem?	①	②	③	④

Prospective version:

Instructions: Read each statement and put an X on the appropriate circle on the right side of this page.

1 = Not at all; 2 = A little; 3 = Enough; 4 = Very

1. How difficult do you think (or feel) the problem was?	①	②	③	④
2. How much effort did you need to exert in order to solve the problem?	①	②	③	④
3. How much time did you need in order to solve the problem?	①	②	③	④
4. How correctly do you think you solved the problem?	①	②	③	④
5. How much did you need to "think" in order to solve the problem?	①	②	③	④

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Sample questions from the financial task

- In your opinion, which of the following is the best option for a one year investment?

	Investment 1	Investment 2
Investment type	Fixed-rate bond	Bank account
Interest rate	1.8%	1.5%

I choose:

□ Investment 1

□ Investment 2

- Suppose you want to invest 1000 pounds for one year. Which of the following options would you choose?

	Investment 1	Investment 2	Investment 3	Investment 4
Interest rate	5%	6.3%	6%	2.8%
Monthly fee to maintain the account	£2	£3	£2.5	£0

I choose:

□ Investment 1

□ Investment 2

□ Investment 3

□ Investment 4

□ Either Investment 1 or Investment 2, which are equivalent

□ Either Investment 3 or Investment 4, which are equivalent

Supplementary Materials Chapter 6

Table 1

Listing of Original SMS Items

1. I can easily deduce someone's intentions
2. When interacting with someone else I try to understand their thoughts
3. When working on a collaborative project I discuss thoughts with other group members
4. I find it difficult to see things from other people's points of view
5. Before starting working on a group project, we set goals to guide what steps we would take
6. When there is disagreement in a group, I either give up or do other things
7. I can be wrong about what other people want
8. Other people can be wrong about what other people want
9. I can tell how someone is feeling by looking at their eyes
10. When I work with others and the task is not interesting, I often manage to keep on contributing my ideas until we finish the task
11. I'm often curious about the meaning behind others' actions
12. It's really hard for me to figure out what goes on in other people's heads
13. Since we all depend on life circumstances, it is meaningless to think of other people's intentions or wishes
14. I believe other people are too confusing to bother figuring out
15. I can make good predictions of other people's behaviour when I know their beliefs and feelings
16. My gut feeling about what someone else is thinking is usually very accurate
17. In an argument, I keep the other person's point of view in mind
18. I believe that people can see a situation very differently based on their own beliefs and experiences

19. When working on a collaborative project I compare thoughts with other group members

20. I usually know exactly what other people are thinking

21. I pay attention to my feelings

22. When working on a collaborative project, I try to make sure we all make efforts to achieve our set goals

23. I carefully evaluate the correctness of other people's ideas

24. I take for granted the correctness of the ideas suggested by others

25. When working in a group, I often give feedback to contributions made by others

26. I call in others for help when I need it

27. I ask for clarification if I do not understand something

28. I take into account the ideas and suggestions of others

29. In order to know exactly how someone is feeling, I have found that I need to ask them

30. I believe that there is no RIGHT way of seeing any situation

31. I can mostly predict what someone else will do

32. Other people's thoughts and feelings are confusing to me

33. I have trouble figuring out my friends' feelings

34. In a group I look over others' work to see if I understand what each member is doing

35. When working on a group project, I often help others who have difficulties in understanding the group task

36. I do not like to think about my problems

37. If I'm sure I'm right about something, I don't waste time listening to other people's arguments

38. When making plans with other people, I try to make sure our plans are realistic

39. When working on a group project, I often try to remind others of the time remaining to finish our work

40. When working on a group project, I often feel pleased if others remind me of the time remaining to finish our work
41. I often remind others to contribute their ideas
42. When a group project is difficult, I either give up or do other things
43. I try to look at everybody's side of a disagreement before I make a decision
44. During a group work, I often fail to contribute to the task because I'm thinking of other things
45. I am willing to consider other ways of doing things
46. I show my agreement with my collaborators' ideas when working towards a common goal
47. I show my disagreement with my collaborators' ideas when working towards a common goal
48. I believe there's no point trying to guess what's on someone else's mind
49. I do not like to waste time trying to understand in detail other people's behaviour
50. I often ask myself questions to find out whether I've learnt what I want to learn
51. Previous ideas or opinions of others can influence how I interpret their behaviour
52. I can often understand how people are feeling even before they tell me
53. People's thoughts are a mystery to me
54. I pay attention to the impact of my actions on others' feelings
55. How I feel can easily affect how I understand someone else's behaviour
56. When working with other people, I try to make sure we set learning goals and allocate time for various activities
57. Understanding the reasons for people's actions helps me to forgive them
58. Understanding what's on someone else's mind is never difficult for me
59. It takes me a long time to understand other people's thoughts and feelings
60. Two people can see the same image and interpret it differently

61. I stay calm when a collaborator tells me that I have made a mistake
62. I am comfortable working with a group
63. When I'm upset at someone, I usually try to "put myself in his shoes" for a while
64. I find it important to understand reasons for behaviour
65. I often think about other people and their behaviour
66. I can describe significant traits of people who are close to me with precision and in detail
67. I like to think about the reasons behind my actions
68. Sometimes I do things without really knowing why
69. I do not want to find out something about myself that I will not like
70. When working with other people, I often feel so bored that I quit before we finish what we planned to do
71. My intuition about a person is hardly ever wrong
72. When working on a group project, I often try to work with others to complete our task
73. I offer to help others during a group work

Exploratory Factor Analysis

- Items excluded a priori because vague, poorly written, or not capturing the construct of social metacognition in full:

13 – 14 – 21 – 36 – 48 – 50 – 51 – 67 – 68 – 69

- Items excluded because no correlation > .3:

4 – 24 – 29 – 30 – 45 – 55

- Items excluded because only 1 or 2 correlations > .3:

7 – 8 – 23 – 34 – 44 – 47 – 66

The scree plot suggested a solution with 5 factors or a solution with 3 factors.

- Five-factor solution:

Principal axis factoring with Oblimin rotation:

Items 10 – 54 – 61 were removed because no loading >.32 on any factor

Item 56 was removed because cross loading >.32 on two factors

Solution:

Factor 1: Items 3 – 5 – 19 – 22 – 25 – 26 – 27 – 35 – 38 – 41 – 73

Factor 2: Items 1 – 9 – 12 – 15 – 16 – 32 – 33 – 52 – 53 – 59

Factor 3: Items 2 – 11 – 17 – 18 – 49 – 57 – 60 – 63 – 64 – 65

Factor 4: Items (-)20 – (-)31 – (-)39 – (-)40 – (-)56 – (-)58 – (-)71

Factor 5: Items 6 – 28 – 37 – 42 – 43 – 46 – 62 – 70 – 72

- Three-factor solution:

Principal axis factoring with Oblimin rotation:

Items 6 – 10 – 42 – 46 – 61 – 70 – 71 were removed because no loading >.32 on any factor

Solution:

Factor 1: Items 3 – 5 – 19 – 22 – 25 – 26 – 27 – 35 – 38 – 39 – 40 – 41 – 56 – 62 – 72 – 73

Factor 2: Items 1 – 9 – 12 – 15 – 16 – 20 – 31 – 32 – 33 – 52 – 53 – 58 – 59

Factor 3: Items 2 – 11 – 17 – 18 – 28 – 37 – 43 – 49 – 54 – 57 – 60 – 63 – 64 – 65

Correlation table between Social Metacognition and Followed Recommendations

Table 2

Spearman Correlation Coefficients between Social Metacognition and Number of Followed Recommendations

Variable	1	2	3	4	5
1. Age	–				
1. Social Metacognition	.24*	–			
2. Recommendations (20 rounds)	-.11	-.11	–		
3. Recommendations (15 rounds)	-.09	-.09	.95**	–	
4. Recommendations (10 rounds)	-.11	-.05	.87**	.92**	–

Note. * $p < 0.05$, two-tailed. ** $p < 0.01$, two-tailed.