This thesis is dedicated to my father Israel, and to the memory of my mother Ester.

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COMPENSATORY MECHANISMS IN DECISION MAKING BY OLD ADULTS

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ABSTRACT

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COMPENSATORY MECHANISMS IN DECISION MAKING BY OLD ADULTS

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This thesis investigated the effect of cognitive ageing on the use of two compensatory mechanisms in decision-making by old adults. These mechanisms are allocation of increased processing time and information selectivity. The experiments examined whether old adults process and use information about outcome probability and outcome payoff when making decisions under uncertainty. Using a questionnaire-based method, Experiment 1 demonstrated that old adults used probability and payoff in hypothetical decisions taken from real-life situations. Employing a more controlled decision-making task, Experiments 2 to 6 examined how allocation of time and information selectivity in decision-making by old adults were affected by variations in cognitive demands. Experiment 2 revealed that old adults allocated more time than young adults under a condition that placed high demands (when outcomes of decisions are known) versus a condition that placed low demands (decision outcomes are unknown). In both conditions the decisions made by the old adults were comparable to young adults' decisions, and were not affected by the outcomes experienced. Experiment 3 examined whether old adults' decisions were affected by decision outcomes that carry probabilistic information different from the one expressed in each trial (i.e., biased outcomes: positive and negative). In addition, the experiment examined whether processing these outcomes was accompanied by allocation of more time on the part of the old adults. The data showed that both old and young adults were similarly affected by biased outcomes but the former allocated more time for making their decisions. Varying only payoff information (i.e., approach, avoidance, and control), Experiment 4 showed that both young and old adults made use of payoff information, though the old adults used payoff to a lesser extent. Experiment 5 showed that under increased task demands (i.e., when both probability and payoff were varied), participants from both age groups demonstrated selectivity in ignoring payoff information. Making the payoff information more explicit, Experiment 6 showed that old adults were more selective than young adults. The young adults incorporated probability and avoidance payoff in their decisions whereas the old adults based their decisions on probability only. It was concluded that cognitive limitations of old adults resulted in compensatory use of time allocation and information selectivity strategies.

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Preface: aims, structure, and contributions

Introduction

How do old adults make decisions? This question is of a particular importance becasue retirement age brings with it important and complex decisions that individuals must deal with effectively. These may include decisions about financial issues, health care, and living arrangements, all of which have a substantial effect on quality of life. Based on cognitive ageing research it would be reasonable to believe that the decision-making abilities of old adults would be impaired. It is well established that old age is accompanied by deterioration in various cognitive abilities. Compared with young adults (age 20-30), old adults (age 65 and over) are less able to hold and manipulate information in working memory (e.g., Babcock & Salthouse, 1990; Gick, Craik, & Morris, 1988; Morris, Gick, & Craik, 1988; Salthouse & Babcock, 1991; Wingfield, Stine, Lahar & Aberdeen, 1988), they are slower at the rate with which they process information (e.g., Birren, 1965; Birren, Woods, & Williams, 1980; Cerella, 1985; Cerella, Poon, & Williams, 1980), and they are less able to filter out irrelevant information (e.g., Hasher & Zacks, 1988). We might expect that these losses would severely reduce old adults' ability to make sensible decisions. Nonetheless, there are demonstrations in the cognitive ageing literature that old adults may find ways to compensate for cognitive decrements, enabling them to retain high levels of performance in complex everyday tasks (Charness, 1981a, 1983; Dror, Katona, & Mungur, 1998; Johnson, 1990, 1997; Salthouse, 1984; Walsh & Hershey, 1993).

Aims and structure of the thesis

The purpose of this thesis is to examine the effects of cognitive limitations in old age on decision-making performance. In particular, the thesis aims to investigate how cognitive limitations in old age influence the employment of two compensatory mechanisms in decision-making. These are allocation of increased processing time and selectivity of information (see Sections 1.4.2 and 1.4.3). The topic of this thesis encompasses two research areas, one of cognitive ageing and the other of decision-making. Although each of these areas has been thoroughly investigated in the past, very little work has been done to integrate both areas. Therefore, the first two background chapters are devoted to introducing these two research areas, while Chapter 3 integrates them.

Chapter 1 describes the concepts of cognitive ageing research and the notion of cognitive compensation in old age. Chapter 2 introduces concepts of decision-making and oulines different theoretical approaches to decision-making. Chapter 3 provides a review of research findings in the area of ageing and decision-making which are relevant to the experiments reported in Chapters 4 to 9. The chapter concludes by setting the rationale for this thesis. In Chapter 10 a summary and discussion of the findings are presented. Theoretical, practical and methodological implications are discussed.

Contributions

In this thesis an initial attempt has been made to understand the role of cognitive compensation in old age within the context of such a complex task as decision-making. Previous research provided demonstration of compensation in complex tasks, such as, typing (Salthouse, 1984) and chess (Charness, 1981b). These studies were concerned with compensation that is developed through extensive experience and proficiency in performing these tasks. For example, to counterbalance the age-related decline in a skill relevant to the task (e.g., motor speed in typing), old typists might develop a new skill to perform the task (e.g., looking further ahead on the text to anticipate the words to be typed). Utilising the new skill for task performance enables the old individual to reach high levels of performance (Salthouse, 1984). Different from previous research, this thesis demonstrates non-skilled compensation in decision-making, that is, a compensation which develops not a result of expertise with a particular decision-problem. Although such a compensation has been previously demonstrated in memory (e.g., Backman, 1989), this thesis focuses on non-skilled compensation in a more complex task, namely decision-making. The data that are reported in this thesis demonstrate for the first time the use of such compensation in the domain of decision-making.

In particular, this thesis provides new data pertaining to the allocation of increased decision time as a mechanism that allows old adults to reach sound decisions in the face of cognitive decline. In addition, the thesis includes new data demonstrating the limitations of old adults when faced with decision-problems they have never encountered before. These limitations involve the failure to make use of all relevant information (information selectivity) in making quality decisions.

Further to demonstrating age differences in decision-making performance, this thesis provides an account for such differences. Past research has not empirically distinguished between internal (cognitive) and external (e.g., experiential) factors as underlying age-differences in decision-making. This thesis made a first attempt to investigate the effects of cognitive limitations in old age on decision performance in isolation from the effects of external factors. This attempt has shown that cognitive limitations do indeed influence the use of information selectivity and allocation of increased decision time in old age.

The work reported in the thesis also has practical implications. First, the data showed that old adults may be limited in their ability to make quality decisions in that they may fail to incorporate important information such as payoff. These limitations are apparent under increased cognitive demands. An awareness of such limitations is important for old individuals when faced with decisions affecting them, their family or their community. Second, knowledge of decision-making limitations can guide the development of decision-making aids for old adults.

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1. Cognitive ageing and compensation

1.1. Introduction

The purpose of Chapter 1 is to present the concept of cognitive compensation and its relevance to cognitive functioning in old age. The chapter is constructed as follows: First, an historical overview of cognitive ageing research is presented to establish the phenomenon of cognitive ageing. Next, two theoretical accounts of cognitive ageing are described. Lastly, the concept of cognitive compensation in old age is presented, focusing on two compensatory mechanisms, allocation of increased processing time and information selectivity in old age.

1.2. The phenomenon of cognitive ageing: An historical overview

How does ageing affect the cognitive abilities of old people?[1] Empirical studies aimed at answering this question date back as far as the 1920s and 1930s. At that time, cognitive abilities were seen as the products of *intelligence*. Intelligence was conceptualised as a general capacity, denoted *g* (Spearman, 1927), and assumed to mediate performance on tasks involving such different cognitive abilities as verbal, numerical, and visuo-spatial abilities.

1.2.1. The psychometric approach

As a means of measuring intelligence researchers have made use of psychometric tests. Psychometric tests are means of evaluating cognitive functioning for the purpose of

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[1] Broadly, old adults are people over 65 years of age. The definition of old age will be discussed in more detail in Chapter 3 (see section 3.6.1).

predicting intellectual functioning in everyday situations. These tests consists of various tasks, such as arithmetical reasoning, comprehension, general knowledge, knowledge of word meaning and spatial reasoning. These tests are assumed to tap into a variety of everyday intellectual functioning.

Psychometric tests were originally developed as a procedure for identifying children with special education needs (Binet & Simon, 1905, as cited in Kausler, 1991). Later on, psychometric tests were developed to be used with military personnel and for academic selection. Scores on such tests are determined by the number of correct responses produced within a time limit. This score is compared to the average total score of a specific age group to determine the intelligence score of an individual of this age.

As interest in the effects of old age on intelligence grew, researchers made use of psychometric tests to examine changes in intelligence with age (for a review of these tests see Schaie, 1996). Age differences were determined by comparing the average intelligence scores gained by people of different ages. Results from different psychometric tests have typically demonstrated an overall decline in performance with increasing age. However, the rate of decline in performance exhibited a differential pattern across different tests of intelligence (e.g., Schaie & Willis, 1993; for a review see Schaie, 1996). In general, scores on verbal tests appeared to show less decline than scores on spatial and reasoning tests.

1.2.1.1. Crystallised intelligence versus fluid intelligence

Growing evidence for differential effects of ageing on performance across different psychometric tests led to elaboration of the definition of intelligence (Horn, 1982; Horn & Cattel, 1976). These researchers suggested that intelligence is not a single entity; rather it consists of two specialised skills, referred to as *crystallised intelligence (Gc)*, and *fluid* *intelligence (Gf)*.[2] Crystallised intelligence is based on acquired knowledge and involves familiar material. It is measured in tasks including verbal comprehension and general information tests. Fluid intelligence, on the other hand, consists of the ability to perform novel tasks involving unfamiliar material. It is measured in tasks utilising memory, reasoning, and spatial abilities.

Horn and colleagues (Horn, 1982; Horn & Cattel, 1976) suggested that ageing affects crystallised and fluid intelligence differently: Fluid intelligence tends to decline with age, whereas crystallised intelligence remains stable or may even improve. For example, in a study by Hayslip and Sterns (1979), an old group scored a mean of 29% correct responses whereas a young group scored 46% on measures of fluid intelligence. On measures of crystallised intelligence, however, the old group scored 97% correct responses compared to 90% scored by the young group. Other studies have provided further support to the differential effects of ageing on crystallised and fluid intelligence (e.g., Cunningham, Clayton, & Overton, 1975; Hayslip & Sterns, 1979).

Over the years there has been extensive use of psychometric tests across different ages and large samples. The findings from the psychometric tests, therefore, provide a means of documenting the phenomenon of cognitive ageing (Salthouse, 1991). However, the use of psychometric tests has often been criticised. One criticism is that these tests assess a blend of different cognitive abilities without distinguishing between different aspects of cognition (Salthouse, 1991). In an attempt to refine existing tests, researchers have developed test

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[2] Other theorists even proposed further divisions of intelligence. Sternberg (1988) proposed three inter-related aspects of intelligence related to the internal world of the individual, to the external world (the individual's relations with the environment), and to utilizing experience. Gardner (1983) further proposed seven types of intelligence: linguistic, musical, logical (mathematical), spatial, bodily (kinesthetic), intra-personal, and inter-personal.

batteries to distinguish between several cognitive abilities. For example, the Primary Mental Abilities battery developed by Thurstone and Thurstone (1941, 1947) consists of five measures of ability: verbal meaning, space, reasoning, and number and word fluency. Nevertheless, these tests have been the subject of a further criticism - namely, that they provide only descriptive information of age-related cognitive changes, and do not advance the understanding of the cognitive mechanisms that underlie those changes (Rabbitt, 1993).

1.2.2. The experimental approach

Differing from the psychometric approach, which is concerned with describing age differences, another line of research on ageing and cognition has been developed using the experimental approach. In contrast to the psychometric approach, the goal of the latter approach is to identify the specific cognitive mechanisms that are prone to age effects and which are responsible for age-related decline in performance (Kausler, 1991). For example, a researcher might speculate that age-related deficits in reasoning might be mediated by age-related declines in working memory. To test this hypothesis the researcher may introduce in a reasoning task an independent variable placing varying demands on working memory. Supporting evidence for the hypothesis would show an interaction of the independent variable with age. For example, Salthouse, Mitchell, Skovronek, & Babcock (1989) manipulated the demands placed on working memory in a reasoning task. In this study working memory demands were manipulated by varying the number of premises that need to be held and manipulated in working memory when performing the reasoning task. An interaction between those demands and age was found and taken as an indicator that reduced working memory mediated the degraded performance of old adults in the reasoning task.

Some researchers (e.g., Crawford & Stankov, 1983; Horn, 1982; Stankov, 1988) have suggested that the use of psychometric tests and experimental tests can be used as complementary tools with which to study cognitive ageing. The joint use of these tests can answer questions regarding the role of cognitive processes in determining performance on psychometric tests. It is argued, therefore, that examining the relationships between performance on psychometric tests and performance on cognitive tasks may offer a means of confirming the commonality of the processes evaluated by the two kinds of tests (Stankov, 1988). One such convergent finding is that performance on tasks involving fluid intelligence is negatively affected by age. More specifically, with increased age there is a decline in cognitive functioning as reflected by increased error rate as well as a slowing of response (for reviews see Birren & Schaie, 1996; Craik & Salthouse, 1992; Salthouse, 1991).

1.3. Theories of cognitive ageing

Theories accounting for the reported declines in cognitive performance with increased age are distinguished as *macro* and *micro approach*es (Salthouse, 2000a). These approaches differ with respect to the localisation and the quantity of mechanisms responsible for cognitive decline. The macro approach assumes that there are few, general, processing resources that are affected by ageing. Each resource affects a range of cognitive abilities related to that resource. The micro approach postulates that ageing affects multiple specific abilities, each of which is responsible for performance in a specific cognitive task. The macro and the micro approaches are introduced in the following sections.

1.3.1. The macro approach

The macro approach assumes that there are few processing resources each of which affects related cognitive abilities, and therefore these abilities are held to be dependent on the efficiency of this resource. Relations between cognitive abilities, which are related to the same processing resource, are thus assumed to exist. Central to the macro approach are the concept of *resource* and the notion of *information-processing*, which are grounded in the information-processing approach to cognition. These concepts will now be introduced, followed by a description of the assumptions of the macro approach - commonly referred to as the *reduced processing resources* approach.

1.3.1.1. *The information-processing approach to cognition: Basic concepts*

One theoretical framework for the study of cognition is the information-processing approach. Information-processing refers to the idea that information from the environment (i.e., a stimulus) is passed through a number of separate processing stages, during which the stimulus is transformed into a response (i.e., an output) (McClelland, 1979; Smith, 1968; Sterenberg, 1969; for a review see Massaro & Cowan, 1993). This theory posits a set of representations and operations (i.e., processes) that transform the representations. Information is transmitted forward in time with the output of one operation providing an input to the next operation. The operation in each stage is assumed to take time to complete.

The information-processing approach postulates that individuals are limited in their information-processing capabilities (Dawes, 1976). The human processor has often been conceptualised as possessing a "pool of resources". Resources are broadly conceived as limited pools of energy or mental capacity (Hirst & Kalmer, 1987). Kail and Salthouse (1994) identified three characteristics of a processing resource: Firstly, that it has a limited quantity, and secondly, that it affords cognitive processing. Greater amounts of processing resource enhance cognitive performance. Thirdly, it is required for a wide range of cognitive processes, but is not the only determinant of cognitive performance: Other factors, which are not resource dependent, are also held to contribute to cognitive performance (e.g., prior knowledge, experience, motor speed).

- Types of processing resources

Only a few resource theorists (e.g., Cerella, 1985) believe that a single resource underlies cognitive processing. However, the accepted view is that the human processor is composed of several specific independent resources (Kail & Salthouse, 1994; Navon & Gopher, 1979; Wickens, 1984). Within this view, three types of processing resources have been specified: working memory (Baddeley & Hitch, 1974; Craik, 1977), attention (Freidman & Polson, 1981; Kahneman, 1973; Wickens, 1980), and speed of processing (Cerella, 1985; Salthouse, Rogan, & Prill, 1984).

Working memory is a short-term memory system involved in tasks that require simultaneous maintenance and processing of information (Baddeley, 1986; Baddeley & Hitch, 1974, 1994). According to Baddeley and colleagues (e.g., Baddeley, 1986; Baddeley & Hitch, 1974, 1994), working memory has three components: the central executive which is assumed to be an attentional system limited in capacity. This system controls two other "slave" systems, the phonological loop system that is responsible for storing and processing auditory speech information, and the visio-spatial sketchpad that is responsible for maintaining and manipulating visual information. These three systems are assumed to operate independently. Working memory is therefore assumed to play a central role in a variety of cognitive tasks such as mental computation, reasoning, and spatial imagery (Baddeley, 1986). Working memory is limited by the duration within which information can be maintained (approximately 10 to 20 seconds, although information can be lost if it is not rehearsed). Limitations are also applied to the amount of information working memory can hold: Working memory can store between five to nine unrelated items (Miller, 1956). Recently, Cowan (2001) reviewed studies suggesting that working memory capacity is limited to maintaining four unrelated items.

Attention as a resource refers to the capacity available for the performance of concurrent tasks and processing information in parallel. Limitations to attentional resource are demonstrated when people are required simultaneously to perform two tasks that rely upon the attentional resource (i.e., divided attention), or when people are asked to ignore irrelevant information when performing a cognitive task (i.e., selective attention).

Speed of processing as a resource refers to the speed with which cognitive processes are executed. The assumption is that faster processing results in improved cognitive performance, whereas slower processing may lead to diminished performance (Salthouse, 1985a, 1985b). Limitations on processing speed are demonstrated when the accuracy of performance is affected by external time constraints (e.g., Salthouse, 1996). More detailed discussion of each resource will be provided later in relation to cognitive ageing.

- Task factors affecting performance

Performance in a cognitive task is determined not only by available resources but also by task factors. Cognitive tasks vary in the processing demands they place on resources for optimal performance. Resource theory implies that when the processing demands of a task exceed the overall amount of processing resources available, deficits in performance will be manifested.

According to Navon & Gopher (1980) processing demands of a task[3] are determined by the amount of information that needs to be processed (or the number of processes required to perform a task) as well as by the processing duration allowed to perform a task. An example for the amount of information to be processed in a decision-making task is the number of possible choices from which a person has to select only one. Processing duration, or the time allocated to process information in a cognitive task, may be limited either because the task requires a speeded response or because the stimuli are available for processing for only a brief period.

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[3] Processing demands are often referred to as the 'difficulty' or 'complexity' of a task. The terms 'difficulty' and 'complexity' are often used synonymically in the literature to refer to "the number of processing operations required to perform a task" (Salthouse, 1991, p. 309). However, Salthouse (1985a, 1988a) has argued for a distinction between the terms. He uses the term 'difficulty' to refer to the time required to perform a processing operation and the probability of error associated with performing a given operation. 'Complexity' is used to refer to the number of processing operations.

To measure how performance is affected by manipulations of task demands, accuracy and response times (RTs) are used (Navon & Gopher, 1980). In tasks allowing limited processing duration the use of an accuracy measure is most relevant, because limited duration can lead to incomplete performance. For tasks that do not limit processing time, RTs measures are particularly relevant (Navon & Gopher, 1980). Resource theory predicts that tasks that place high demands on processing produce reduced accuracy, because within a limited amount of time more processes need to be completed in order to perform a task. Similarly, these tasks are expected to produce increased RTs because an increased number of processes requires more time to complete relative to a small number of processes. Examples of empirical support for the above predictions will be provided in the next section.

1.3.1.2. The reduced processing resources approach

The concepts and theoretical framework of processing resources has been employed in research into cognitive ageing. In an attempt to explain cognitive performance decline in tasks involving fluid intelligence, Salthouse (1988a, 1988b, 1991) has proposed that old adults possess reduced processing resources that limit their performance. The *reduced processing resources* framework builds on two assumptions: First, many cognitive processes require the operation of a few processing resources. Second, with increased age there is a reduction in the quantity of processing resources. Based on these assumptions, Salthouse (1988a, 1988b, 1991) hypothesised that increased demands on a processing resource that exceed its limited capacity should be expected to limit performance of old adults, resulting in larger decrements in performance compared with young adults.

This hypothesis was supported by the *complexity phenomenon*. According to this phenomenon, the magnitude of the difference in performance between young and old adults increases as the complexity (i.e., the processing demands) of the task increases. As noted earlier, complexity of a task is assumed to increase processing demands because more processing operations are required to perform a task. The complexity phenomenon has been reported in many studies mostly with regard to the measure of response speed (for a review see Bashore, van der Molen, Ridderinkhof, & Wylie, 1997). However, some studies have also demonstrated the complexity phenomenon using error rate measures (e.g., Dror & Kosslyn 1994; Salthouse et al., 1989). Examples of complexity effects are provided below.

Although the concept of reduced processing resources seems appealing for accounting for a large range of age differences by a small number of factors, it has been subject to the criticism that it is based on circular reasoning (e.g., Salthouse, 1988b, 1988c; Salthouse et al., 1989). Reduced resources are inferred because cognitive impairment is evident. This impairment is then explained in terms of reduced quantity of processing resources.

To avoid this circularity, researchers often make use of correlational methods that aim to quantify the contribution of limited resources to age differences in cognitive performance. One such method is that of *statistical control* (Salthouse, 1991, 1994), which identifies three related variables; increased age, processing resources, and cognitive performance. By accounting for the relations between the three variables (i.e., age and cognitive performance versus resource and cognitive performance), this method attempts to estimate the extent to which processing resources contribute to age differences in cognitive performance. Using this method, the variance shared by age and cognitive performance is initially computed. Next, the variance in a variable assumed to reflect processing resource is held constant (i.e., controlled), and then the variance shared by age and cognitive performance is computed once again. The conclusion that this resource mediates the decline in performance in the specific cognitive task can be made if controlling for the resource variable reduced or removed the age-related variance in cognitive performance. For example, Salthouse et al. (1989) examined the role of age and working memory in reasoning ability. Age, a measure of working memory, and a measure of reasoning performance were subject to analyses of statistical control. When age was considered alone it accounted for 0.278 of the variance in reasoning performance. After removing the variance associated with performance on the memory measure, age accounted for 0.119 of the variance in the measure of reasoning performance. The finding that the age-related variance that accounts for reasoning performance was reduced after removing the variance associated with the working memory measure suggested that working memory capacity mediated reasoning performance.

- Types of processing resources

Salthouse (1985a, 1988a, 1988b, 1988c) proposed that ageing negatively affects the three processing resources identified in resource theory: working memory, attention, and speed of processing.

- Working memory

As noted before, working memory is limited in the amount of information and in the duration during which information can be maintained. Old adults are said to be further limited in their working memory capacity. This implies that old adults are expected to show poorer performance relative to young adults in tasks that involve the operation of working memory.

Age differences in working memory capacity have been studied using *memory span measures*. Various span measures have been employed in the study of ageing. These include simple span measures (e.g., forward and backward digit span, letter span, and word span) as well as complex span measures (e.g., sentence span). In the forward digit span, a series of digits is presented to a participant on every trial. The participant's task is to recall the digit in the same order they were presented. Over the trials the participant is presented with series in which the number digits they contain gradually increases. The participant's forward digit span is defined as the length of the longest series that he/she can recall in the right order without error. Using this measure a number of studies have reported small age differences (see Kausler, 1994, for a review). In general, young adults' forward digit span is about 6.5 to seven, and old adults' forward digit span is about six to 6.5. The small age differences may be attributed to the fact that the forward digit span task involves only the capacity for passively storing information, and does not involve the manipulation of information in working memory, which may be prone to age effects (Craik, 1977). A digit span task which is considered to involve active processing (and so involves greater processing demands) is the backwards digit span. In this task the digits should be recalled in the reverse order to which they were originally presented. In a review of studies where young and old adults were administered forward and backward digit span tasks, Babcock and Salthouse (1990) report larger age differences on backward digit span tasks relative to the forward digit span tasks.

Variations of the forward and backward digit span tasks are the letter span and word span tasks, in which the items in the series to be recalled are letters or words rather than digits. Age differences in word span have been found in number of studies (Kausler & Puckett, 1979; Salthouse & Babcock, 1991; Wingfield et al., 1988). For example, Wingfield et al., (1988) reported that young adults had a mean word span of six and the old adults had a mean of five words. Age differences have also been found using more complex span measures, such as the sentence span test (Daneman & Carpenter, 1980). In the sentence span test participants listen to a series of sentences and have to recall the last word of each sentence. However, the most pronounced age differences have been demonstrated on a modified version of the sentence span measure that calls for an active processing of sentences (e.g., verifying the sentences for being true or false) while holding in memory the last word of each sentence presented in a series (e.g., Gick et al., 1988; Morris et al.,1988; Wingfield et al., 1988). For example, in a study by Wingfield et al., (1988) young adults scored a mean of four words correctly recalled, whereas old adults scored a mean of 2.5 words in the modified sentence span. Less pronounced differences were found in the original sentence span: Young adults scored a mean of six words and old adults scored a mean of five words. However, no age differences were found on a digit span measure in this study (both age groups scored a mean of seven words).

The magnitude of age differences is also expected to increase with increased demands on working memory. Variations in working memory demands are often achieved by manipulating the complexity (i.e., the processing demands) of the task. Interactions between age and complexity have been found in working memory tasks (Light & Anderson, 1985; Spilich, 1983; Wright, 1981). Gick et al., (1988), for example, used the verification sentence span task, and manipulated complexity of the task by varying the difficulty of the sentences to be verified (the sentences could be either positive or negative) and the number of sentences in a series. They found a significant interaction between sentence complexity and age, showing that increases in sentence complexity affected old adults to a greater extent than young adults, as measured by the proportion of final words recalled. More specifically, old adults' recall performance was impaired to a greater degree than that of the young adults when tested on negative sentences. However, there was no interaction between age and the number of sentences in each set.

In other cognitive tasks which encompass the operation of working memory, researchers have reported the complexity effect when working memory load was varied. Salthouse et al. (1989) found a complexity effect in two tasks, integrative reasoning and spatial imagery (paper folding). In the reasoning task, complexity was manipulated by varying the number of premises that an individual has to hold and manipulate in working memory. In the paper-folding task, complexity was manipulated by varying the number of paper folds that participants had to produce mentally. Salthouse et al. (1989) found that as complexity increased (i.e., load on working memory increased) old adults made more errors than the young adults. The authors proposed that these effects could be attributed to a failure on the part of the old adults to maintain early information (i.e., early folds in the paper folding task) during the processing of subsequent information (i.e., later folds).

- Attention

It has been proposed that increased age may be related to a reduction in the available quantity of attention (e.g., Hasher & Zacks, 1979). The assumption is that cognitive tasks vary in the demands they impose on attention. One aspect of attention is the capacity to divide attention between two concurrent tasks (Burke & Light, 1981). It is hypothesised that relative to young adults, old adults will show greater decline in cognitive performance on tasks that require divided attention. Evidence supporting this hypothesis has been provided by studies using dual-task procedures in which participants are required to perform two tasks simultaneously (a primary and a secondary task). These studies (e.g., Craik & McDowd, 1987; Salthouse & Saults, 1987) have reported that relative to young adults, old adults exhibit a larger increase in RTs during the secondary task.

Another aspect of attention is the ability to inhibit irrelevant information (i.e., selective attention). Hasher and Zacks (1988) proposed that old adults have diminished inhibitory functioning which may be responsible for their degraded performance in various cognitive tasks. The proposal is that old adults are not as efficient as young adults at filtering irrelevant information and are therefore more distracted by it. Evidence for this proposal has been reported using a number of different paradigms in which participants are required to focus on a target stimulus and ignore a distractor stimulus. Among these paradigms are *stroop* tasks, and *negative priming* tasks. In a stroop task textual colour name is printed in a colour ink which is different from the colour to which the word refers. Participants are required to name the colour in which the names are printed, and RTs of naming are measured. The stroop effect is demonstrated by an increase in RTs when there is a conflict between the colour ink and the colour name as compared with when the colour name and the colour ink are identical. Cohen, Dustman, and Bradford (1984) and Comalli, Wapner, and Werner (1962) found that RTs of naming words with a conflicting colour ink and colour name increased with advanced age.

In a negative priming task participants are required to respond to a target stimulus presented simultaneously with a similar distractor stimulus. On critical trials, the distractor stimulus becomes the target stimulus. RTs on these trials are longer than on trials presenting a target which was not previously a distractor or a target. This effect is referred to as negative priming, and is typically found among young adults. This effect is said to result from inhibition of the previously presented distractor. Old adults often fail to exhibit negative priming in a variety of tasks (e.g., Hasher, Stoltzufs, Zacks, & Rympa, 1991; Kane, Hasher, Stoltzufs, Zacks, & Connelly, 1994). Failure to produce negative priming in old age is assumed to reflect deficits in the ability to inhibit processing of irrelevant stimuli.

- Speed of processing

A robust finding of cognitive ageing research is the slowing of old adults' responses across a broad range of cognitive tasks (Birren, 1965; Birren et al.,1980; Cerella, 1985; Cerella et al.,1980; Fisk, McGee, & Giambra, 1988; Salthouse, 1982, 1985a, 1985b; for a review see Birren & Fisher, 1995). Two determinants have been proposed to underlie this slowing: *peripheral slowing* and *central slowing*. Peripheral slowing refers to slowing in sensory-motor processes, such as stimulus detection and motor speed. This slowing can be evident in many cognitive tasks, though it does not influence mental processes. This view implies that the magnitude of the difference in response speed between young and old adults should stay constant across varying task complexity (i.e., task demands) (Welford, 1977). The peripheral slowing can be captured in the following *additive model* of slowing

$$RTo = RTy + b,$$

where RTo is the mean RT of old adults, RTy is the mean RT of young adults, and b represents the age deficit, which is a constant increment in RT of old adults across task complexity (see left panel of Figure 1 below).

A different view from the peripheral slowing hypothesis was proposed by Birren and colleagues (e.g., Birren 1965; Birren et al., 1980). They proposed that slowing of response with age is a result of the slowing down of the central nervous system (CNS) functioning. According to this view, slowing of information-processing is responsible for slowing in speed of response in all perceptual and cognitive processes. This proposal was supported by finding of the complexity phenomenon; namely, that old adults are slowed down to a greater extent relative to young adults as task demands increase (e.g., Cerella et al., 1980; Salthouse, 1985b). The logic is that as demands of the task exceed the limited processing resources of old adults, there is a reduction in the rate with which information is processed. This view can be captured by the *multiplicative model*, as follows,

$$RTo = mRTy$$

where m represents age deficit, which is a factor increasing RT of old adults by a constant proportion across task complexity (see right panel of Figure 1 below).

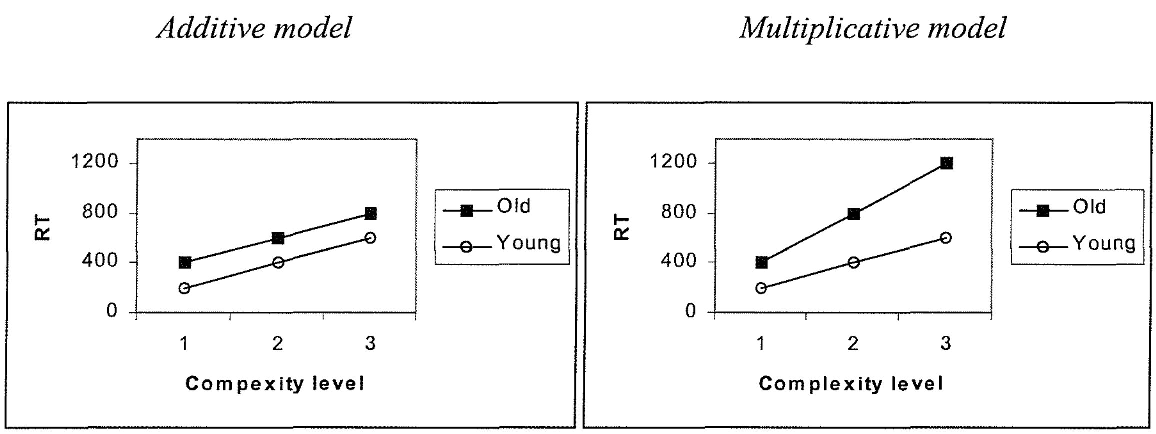

Figure 1: Hypothetical data of RT as a function of task complexity with two models: the additive model and the multiplicative model.

The pattern of results hypothesised by the multiplicative model has been reported in many studies (for a review see Bashore et al., 1997), supporting the hypothesis that the speed at which information is processed is an important factor underlying age differences in cognitive performance (Kail & Salthouse, 1994).

The theory of speed of processing assumes that the speed with which a cognitive operation is accomplished affects the quality of cognitive performance. Specifically, quicker execution of cognitive processing leads to better performance, and slower rate of processing leads to degraded performance. A slower rate of processing is hypothesised to result in (1) the loss of early products of processing during the execution of subsequent processing and (2) cognitive operations cannot be completed in time because they are executed too slowly (Salthouse, 1991, 1996).

Two statistical methods have been used to examine the hypothesis that a general speed processing resource is responsible for degraded cognitive performance in old age as measured by speed of response. These methods are those of *systematic relations* and statistical control that has been described above. The systematic relations method involves determining whether there is a systematic relationship between the mean RTs of participants of different ages. The assumption is that if speed is a general processing resource mediating age differences in response speed, old adults will perform a cognitive task more slowly by a constant multiple, m, such that: RT old = mRT young. This assumption postulates that the relations between RTs of young and old adults should be highly systematic (i.e., correlation between RTs of young adults and RTs of old adults will be close to 1). Systematic relations have been reported in many studies (e.g., Bashore, Osman, & Heffley, 1989; Cerella, 1985, 1990; Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1985b).

To summarise, the macro approach postulates that few general resources mediate age-related declines in various measures of cognitive performance. These resources include working memory, attention and speed of processing.

1.3.2. *The micro approach*

The micro approach attempts to specify which cognitive abilities are prone to the negative effects of ageing. The assumption of this approach is that these abilities are unrelated, predicting that some will be more prone to ageing effects than others. Research stemming from the micro approach is based upon models of specific types of cognition. The majority of research conducted using this approach has focused on memory abilities, although some research has been done in the area of reasoning and spatial abilities. Below I will provide some examples of research based on the micro approach. The focus here is on a number of memory abilities which are of relevance to decision-making in general and to the specific decision-making tasks employed in this thesis.

1.3.2.1. Examples of micro based research: Memory abilities

In general, memory performance declines with ageing. Nonetheless, the magnitude of decline depends on the specific memory task by which it is measured; on some tasks old adults show considerable loss whereas on other tasks, little or no decline is observed. Memory is commonly divided into sensory memory (information retained for a second or less), short-term memory (information retained up to 30 seconds), and long-term memory (information retained from minutes to years) (Atkinson & Shiffrin, 1968). In the following sections I provide examples of dissociation in the magnitude of age differences between different measures of memory.

- Long-term memory: Episodic memory and semantic memory

Tulving (1972, 1983) distinguished between two types of long-term memory; namely, *episodic memory* which consists of memory for events that have occurred in the past, and *semantic memory* which consists of factual information which is highly overlearned. Generally, measures of semantic memory such as general knowledge (Nyberg, Backman, Erngrund, Olofsson, & Nilsson, 1996) and vocabulary (Salthouse, 1982) reveal small age differences. Similarly, old adults are as capable as young adults with regard to their ability to use semantic information (Light, 1992; Light & Burke, 1988). However, other aspects of semantic memory seem to be more susceptible to age effects. For example, old people exhibit more failures in word finding tasks (Burke, MacKay, Worthley, & Wade, 1991) and name retrieval tasks (Cohen & Faulkner, 1986). More consistent evidence on age-related deterioration is reported in tests of episodic memory. For example, old adults show degraded performance in recognition and free recall tasks of various stimuli such as, single words or prose passages, spatial locations, pictures, faces and activities (for reviews see Burke & Light, 1981; Craik & Jennings, 1992; Light 1991; Smith, 1996).

Finding of a dissociation between episodic memory and semantic memory were also reported by Riby, Perfect, and Stollery (2000) who compared young and old adults' RTs in tasks of episodic retrieval and semantic retrieval that incorporated either a dual-task or a single task. They found that old adults were disadvantaged by the dual-task in the episodic retrieval task but not in the semantic retrieval task. The authors proposed that these findings supported the hypothesis that age effect in dual-tasking is task specific.

Although there are variations in the magnitude of age differences between episodic and semantic memory, Craik (1999) has argued that it is not clear whether this distinction can explain the existence of age differences in memory, because of differences in the specificity of the information to be remembered. Whereas episodic information is typically specific pertaining to the "where" and "when" elements of an event, semantic information is general in that it presents information which can be aggregated from several episodes and that there are many ways to express it. Salthouse (1991) has argued that variations in the pattern of age differences between semantic and episodic memory may be attributed to the amount of learning rather than to age per se. Semantic information is overlearned whereas episodic information is rather novel and thus, old people have more opportunities for learning semantic information.

- Automatic and effortful processing

One explanation of cognitive degradation in old age was proposed by Hasher and Zacks (1979, 1984) who distinguished between *effortful processing* and *automatic processing*. An effortful process is an intentional, conscious process that requires the operations of working memory. An automatic process occurs without intention, without conscious awareness, and bypasses working memory. These processes have become automatic as a result of extensive experience such as reading and mental arithmetic.

According to Hasher and Zacks (1979, 1984), effortful processing becomes less effective with old age. There is large number of studies reporting pronounced decline on cognitive tasks such as free recall which requires effortful, self-initiated processing on the part of the participants (see above). Automatic processes, on the other hand, are less likely to degrade with age. For example, old adults do not differ from young adults in their ability to perform simple arithmetic operations (Pesta, Sanders, & Nemec, 1996; Rogers & Fisk, 1991), and in their ability to estimate frequency of event occurrence such as assessing how often a word was presented in a list of many words (Hasher & Zacks, 1979; Kausler, 1994; Kausler, Wright, & Hakami, 1981; Sanford & Maule, 1973).

Nevertheless, it is important to recognise that tasks may involve a mixture of automatic and effortful processes, and thus it is difficult to distinguish between the two. For example, one criterion of automaticity is that the process is unintentional. Evidence that a process is automatic would show that there is no difference in performance between intentional and unintentional conditions. However, some studies have reported that this criterion was not fulfilled in tasks measuring the memory of frequency of occurrence. For example, Kausler et al. (1981) found that intentionality improves the accuracy of frequency judgements.

A new method developed by Jacoby, Toth, and Yonelinas (1993) allows the effortful and automatic operations in memory to be teased apart within the same experimental task. Using this method Jacoby *et al.* provided evidence showing that automatic aspects of memory (memory for words presented earlier) was not affected by age, whereas age negatively affected the effortful aspect of memory (recollection).

1.3.2.2. *Methods used in the micro approach*

The micro approach predicts that some tasks will produce more profound age differences than other tasks (i.e., dissociation). Support for this hypothesis comes from the finding of interaction between age and task in an analysis of variance (ANOVA) (see Perfect & Maylor, 2000). For example, the study of Riby, et al. (2000), mentioned above, made use of such a procedure. Their results showed an interaction between age and memory task, suggesting that old adults had a greater deficit in the episodic memory task than in the semantic memory task.

Another way of demonstrating dissociation between performance on different tasks comes from studies reporting age differences in one task but not in another task. For example, Dror and Kosslyn (1994) demonstrated that old adults are affected by the processing demands of the task on certain aspects of mental imagery but not on others. The authors required participants to perform four different tasks, each involving different processes of mental imagery: image generation, image maintenance, image inspection, and image transformation. In each task the complexity of the stimuli or the task were varied. The results showed that overall, the old group had higher error rate and longer RTs. However, the magnitude of age differences in these measures was more profound with higher complexity on image generation and image transformation tasks, as reflected in an interaction between age and complexity. On tasks of image maintenance and image inspection the old adults showed the same rate of increase with complexity as the young adults did; that is, no interaction between age and complexity was evident. The authors concluded that different aspects of mental imagery are selectively affected by ageing.

1.4. Cognitive compensation in old age

Although old age involves deterioration of processing resources and of basic cognitive abilities – both of which affect performance in cognitive tasks - various studies show that old adults are nevertheless as capable as young adults in performing everyday complex cognitive tasks such as solving problems (Charness, 1981a, 1983) and making decisions (e.g., Dror, et al., 1998; Johnson, 1990, 1997; Walsh & Hershey, 1993). These observations raise an important theoretical question originally pointed out by Rabbitt (1977, p.623):

> "In view of the deterioration of memory and perceptual motor performance with advancing age, the right kind of question may well be not 'why are old people so bad at cognitive tasks', but rather, 'how, in spite of growing disabilities, do old people preserve such relatively good performance?'"

A possible hypothesis proposed by various researchers (e.g., Backman, 1989; Baltes, 1987; Berg, Klaczynski, Calderon, & Strough, 1994; Charness, 1981b; Salthouse, 1984) is that old adults may compensate for decrements in basic cognitive functioning by developing strategies that allow the preservation of a high level of performance.

1.4.1. Defining compensation

The concept of compensation has been employed in a variety of domains in psychological research ranging from neuroscience, sensory handicaps and deficits in cognitive functioning (e.g., adults' ageing, reading difficulties, autism and schizophrenia) to interpersonal interactions (see Backman & Dixon, 1992 for a review). In the cognitive domain, Backman and Dixon (1992, p. 272) have formulated the following definition of compensation:

> "Compensation can be inferred when an objective or perceived mismatch between accessible skills and environmental demands is counterbalanced (either automatically or deliberately) by investment of more time or effort (drawing on normal skills), utilisation of latent (but normally inactive) skills, or acquisition of new skills, so that a change in the behavioral profile occurs, either in the direction of adaptive attainment,

maintenance, or surpassing of normal levels of proficiency or of maladaptive outcome behaviors or consequences".

This definition implies that compensation originates in a mismatch between the skills a person has and the processing demands placed by a given task. The mismatch can result from a real or perceived deficit that a person possesses or from increased task demands. The goal of compensation is to reduce or remove this mismatch between the expected level of performance and the actual level of performance. Three constructs of this mismatch can be identified: Actual skill/ability the individual possesses, the demands of a given task, and a goal of successful performance (i.e., expected level of performance).

Several mechanisms that aim to remove this mismatch have been identified, and are all involved in some sort of modification in one of the mismatch constructs: Modification of skill, modification of the demands of the task, or modification of the goal. This mismatch and its constructs are represented in Figure 2. The arrows represent a potential modification of constructs aiming to reduce the mismatch.

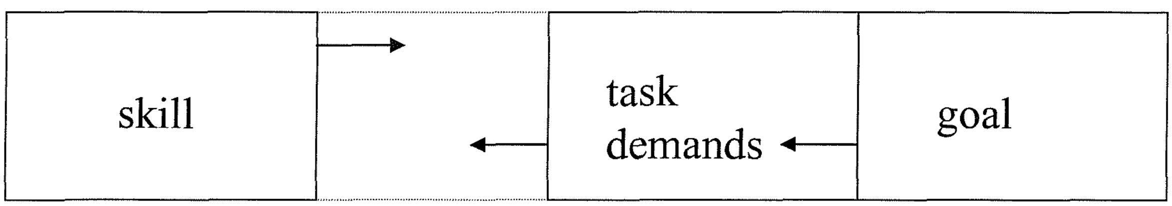

Figure 2: The three constructs of the mismatch between actual skill, task demands and the individual's expected level of performance (goal)

Research in the area of cognitive compensation in old age has mostly focused on compensation via modification of skill. One way in which modification of skill can lead to compensation is via *substitution*. Substitution refers to the development of a new skill allowing the individual to perform a task for which the relevant skill is deficient. Compensation by substitution takes considerable time to develop through extensive experience. A demonstration of substitution has been provided by studies of ageing and skilled performance in chess (Charness, 1981a, 1981b) and in typing (Salthouse, 1984). In these studies the authors report age-related deficits in task relevant basic capacities (e.g., incident recall of chess positions, overall typing rate). However, these deficits were overcome by the old participants by means of developing superiority in other skills, which were relevant to the task (e.g., planning further ahead, anticipation of characters, context utilisation).

This thesis is concerned with non-skilled compensation that occurs via modification in task demands. To reduce the mismatch between the expected level of performance and the actual level of performance, old adults may attempt to reduce the processing demands placed by the task. Minimising the processing load placed by the task may allow old people who are not expert in a particular cognitive activity to optimise their performance in a cognitive task. Reducing task demands may result in performance which is at the expected level (i.e., reaching the original goal). For example, old adults may be able to attain the same level of performance using cognitive strategies that provide cognitive support (i.e., using memory aids), or utilising more processing time to perform a task (see section 1.4.2). Nevertheless it is also possible that reducing task demands could result in a performance level below the original expected level.

Two compensatory mechanisms aiming at reducing task demands will be examined in this thesis: One is the allocation of increased processing time, and the other is the use of information selectivity. Information selectivity is conceptualised here in terms of a simplified strategy, which places reduced demands on processing. Using selectivity, task demands are reduced as a result of processing only a subset of available information. These two mechanisms, allocation of increased processing time and selectivity, are reviewed in the following subsections. This review focuses on examples from the cognitive ageing literature in general. Examples specific to decision-making are provided in Chapter 3.

1.4.2. Allocation of increased processing time

Old individuals become slower in their RTs when performing various cognitive tasks (see section 1.3.1.2). A common finding is that the magnitude of age differences in RTs increases as a function of task complexity (e.g., Cerella et al., 1980; Dror & Kosslyn, 1994; Salthouse, 1985b). Some researchers have proposed that allocation of more time in performing a given task may serve as a compensatory mechanism to cope with slow information-processing (e.g., Backman & Dixon, 1992; Brebion, Smith, & Ehrlich, 1997). According to Backman and Dixon (1992) this type of compensation can be inferred when maintenance of cognitive performance is achieved through investing more time in task performance. Jennings, Nebes, and Yovetich (1990) have used cardiovascular as well as RT measures to test the hypothesis that old adults allocate more attentional resources than do young adults in memory maintenance tasks. In their study, young and old participants performed a serial memory task (i.e., recalling a series of integers in the correct order) with high and low levels of memory load (i.e., items presented early or later in the series, respectively). The results showed that, compared to the young participants, the old participants exhibited both slower RTs and increased heart rate in the high memory load condition. These results indicated that the old participants had allocated more time to memory maintenance, in particular during the high memory load condition. Nevertheless, this extra allocation of time in the old group failed to yield a level of performance equivalent to the young group. The old participants recalled fewer items than did the young participants, in particular when the memory load was high.

Brebion et al.(1997) showed that old adults utilise more time to perform a working memory task, resulting in some increase in accuracy performance. The task was a dual memory task, in which participants were required to detect incongruous sentences (i.e., meaningless sentences produced by placing a word that grammatically fits the sentence but makes the sentence meaningless), and then to recall sets of words (2, 4, or 6) which had been presented prior to the sentence. The data showed that overall, the old participants recalled fewer words than the young participants, but attained a better score for detection of incongruous sentences. The data also showed that although the old group's score was higher, their processing times were longer.

1.4.2.1. Explanations to account for allocation of more time: general slowing or conservative response criteria?

The slowing exhibited by old adults could be accounted for by two explanations, *general slowing* or *conservative response criteria.* According to the general slowing hypothesis, with ageing, all stages of processing (central processes) in a cognitive task are assumed to be slower (e.g., Cerella, 1985; Myerson et al., 1990). The conservative response criteria hypothesis postulates that age-related slowing is mediated by a more conservative criteria that old adults employ (e.g., Salthouse, 1979; Salthouse & Somberg, 1982; Strayer, Wickens, & Braune, 1987). According to this interpretation, slowing is attributed to response-related processes rather than to central processes. This hypothesis assumes that old adults place greater emphasis on accuracy than do young adults (e.g., Birren, 1964; Botwinick, 1973). When shifting from an easy to a more difficult condition young adults may be slower in their RTs as well as less accurate. Their increased RTs may not be sufficient to preserve the level of accuracy achieved during the easy condition. Old adults, on the other hand, may try to maintain accuracy, and in doing so may slow their RTs to a greater extent than the young adults. According to the response criteria explanation, under high task demands, the two age groups differ only in terms of the accuracy criteria they employ.

In an attempt to tease apart the response criteria hypothesis and the general slowing hypothesis, several studies have examined whether young and old adults trade accuracy for speed by manipulating the instructional emphasis on speed versus accuracy. Salthouse (1979) studied ageing and speed/accuracy trade-offs in a simple discrimination RT task in which young and old participants were required to say whether two patterns of lighted lamps were same or different. The importance of speed over accuracy was emphasised by explicit instructions, as well as by providing a higher level of incentive for fast responses (i.e., responses that were faster than a deadline) relative to a lower level of penalty for incorrect responses. The data showed that the old participants were slower than the young participants, and that accuracy level was comparable between the age groups. These findings suggested that the slowing of the old adults could not be attributed merely to a greater emphasis on accuracy as opposed to speed.

Hertzog, Vernon, and Rypma (1993) examined speed/accuracy trade-offs in young and old adults using a more complex task of image rotation. They manipulated speed/accuracy instructions emphasising speed, accuracy, or both using a within-subject design. Their data showed that young participants traded accuracy for speed whereas old participants did not. Specifically, when speed was emphasised, the young participants demonstrated decreased accuracy. The old participants also speeded their responses under this condition, but without a decrease in accuracy. These findings suggested that the old participants were more cautious in their responses than the young participants. However, the old adults also showed an overall slowing of RT, a larger magnitude of slowing as a function of angle of rotation, as well as increased error rate with long angles of rotation (i.e., when more rotation operations were required). Therefore, the authors concluded that although the response criteria influence had contributed to age differences in RT in mental rotation performance, it was not the only determinate of those age differences.

The role of both central and response-related processes in age-related slowing was also demonstrated by Strayer et al., (1987). In this study participants performed a memory search task under different speed/accuracy instructions. Accuracy, RT, and P300 latency were measured (the P300 component of the event related potentials is assumed to reflect delays in peripheral and central processing, but is unaffected by response processes such as, selection and execution of response). Consistent with the findings of Hertzog et al. (1993) the data showed that imposing instructions emphasising speed led to a decrease in accuracy in the young group but not in the old group. The old group were also found to be slower to respond compared with the young group. These data suggested that the old participants had responded with more conservative criteria. The extent of slowing of the old group was much stronger in the RT data as compared with the P300 latency, suggesting that RT slowing was a result of slowing of peripheral, central, and response selection processes.

To conclude, studies examining the contribution of response related factors and central factors to slowing in old age have demonstrated that both central and response-related factors have a role in this slowing.

1.4.3. Use of simplified performance strategies

A strategy can be defined as "one of several alternative methods for performing a particular cognitive task" (Salthouse, 1991, p.197). The information-processing approach to cognition postulates that different strategies impose different demands on processing resources (e.g., Hasher & Zacks, 1979; Shiffrin & Schneider, 1977), with more effective strategies placing higher demands on processing resources (e.g., Bjorklund & Harnishfeger, 1987). Researchers have speculated that limitations on information-processing in old age may induce a shift towards employing less demanding strategies that require less processing effort or less time to execute.[4] Use of simplified strategies often results in degraded performance (Cohen, 1988; Backman, 1989; Craik, 1977; Craik & Rabinowitz, 1984; Perlmutter & Mitchell, 1982). The review below includes studies showing that old adults generally perform memory tasks using simplified and less demanding strategies. A more

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[4] Selection of strategies can be made implicitly (Reder & Schunn, 1996) or via an explicit, conscious choice (e.g., Borkowski, Carr & Pressley, 1987) in that individuals may consciously choose a strategy that matches their abilities.

specific review, focusing on the use of selectivity as a simplified strategy in old age, will be presented in Chapter 3 in relation to decision-making.

Verhaeghen and Marcoen (1994) examined the relations between age differences in ordered list recall, measures of processing resources, and strategy use. Participants had to study and then recall a list of 25 words in the correct order. Strategy use was inferred on the basis of the participants' self-reports subsequent to the completion of the recall task. The old participants showed inferior performance on the list recall task as well as on measures of processing resources. Age differences were found in some self-reported strategies: The strategies of associating words (i.e., making a meaningful connection between words during study) and of testing/repetitions (i.e., testing own memory for the studied words) were used more by the young adults. To examine the relations between age, processing resources and strategy use, path analyses were employed. The results showed that age differences in the use of effective memory strategies (i.e., associating items and testing/repetition) were found to be dependent on processing speed and associative memory. The authors concluded that the efficiency of processing speed of processing and of associative memory placed constraints on strategy selection and that this, in turn, affected recall performance.

Reder, Wible, and Martin (1986) showed that old adults are more likely to use a strategy that requires little effort in making verification decisions in a memory task. The authors distinguished between *plausibility strategy* and *direct retrieval strategy*. The plausibility strategy consists of "using available information to infer or reason that a statement is true" (Reder et al., 1986, p.73), whereas the direct retrieval strategy requires "searching memory for a specific fact" (Reder et al., 1986, p.73). The difference between these two strategies is conceptualised by those authors in terms of automatic and effortful processes. The authors assumed that the plausibility strategy requires little conscious attention, whereas the direct retrieval strategy requires more cognitive effort. The authors examined age differences in the use of these strategies using a verification memory task. Participants read stories and were then presented with statements pertaining to the content of the stories. Half of the participants were asked to discriminate between previously presented plausible statements and plausible statements that have not been presented previously (direct retrieval task). The other participants were asked to discriminate between plausible and implausible statements (plausibility task). The results showed that the old participants were more accurate than the young adults when using the plausibility strategy, and worse when using the direct retrieval strategy. The old adults tended to adopt the plausibility strategy to a greater extent than the young adults when performing the direct retrieval task. This was reflected in the old adults attaining the same level of accuracy as the young adults in response to previously presented statements but being less accurate than the young adults in response to plausible statements that have not been previously presented (direct retrieval task). This pattern of results was proposed to emerge for the old adults because when the plausibility strategy was employed in the direct retrieval task, previously presented statements were accurately accepted but non-presented statements were incorrectly accepted.

Recently, Rogers, Hertzog, and Fisk (2000) examined age differences in the use of strategies in an associative learning task. Young and old participants were presented with a series of noun pairs which they had to study. Next, a probe pair was presented, and participants had to decide whether the probe pair matched one of the pairs presented earlier in the series. The task can be performed by the use of a *scanning strategy* (scanning the set of noun pairs) or by a *memory retrieval strategy* (learning the noun pairs and retrieving them from memory). The latter is more taxing but more effective than the former. Throughout the practice trials participants also performed a recognition task and a recall task in which they had to recall as many noun pairs as possible. Noun pairs were related by either consistent mapping (CM) or varied mapping (VM) relations. CM noun-pairs are linked by associative relations, and thus recall performance requires associative learning. VM noun-pairs are linked by arbitrary relations; thus, recall performance requires visual search. To classify the participants as users of scanning or direct retrieval strategies, the authors classified retrievers as participants who made more than 90% of their CM responses faster than their VM responses. Scanners were defined as participants who made less than 80% of their CM responses faster than their VM responses. The authors also made use of individual differences measures (e.g., measures of processing speed). The results indicated that old adults were more likely to use the scanning strategy, whereas young adults tended to use the retrieval strategy. Recall and recognition performance was affected by differences in strategies. The old participants who tended to use scanning strategy had a lower recall and recognition scores and were slower on measures of information-processing speed than the old participants who tended to use direct retrieval strategy. Consistent with Verhaeghen and Marcoen (1994), the authors concluded that age differences in strategy use can be seen as a result of differences in processing speed capacity.

The laboratory-based studies reviewed above have all reported the employment of less demanding and less effective cognitive strategies by old adults. There are reports, however, showing that in everyday life old adults tend to employ memory strategies known to enhance performance. Using metacognitive methods, Cavanaugh, Grady, and Perlmutter (1983) examined the use of memory strategies by old adults in everyday situations. They asked young and old participants to write a diary documenting their memory failures as well as the memory aids they used. The results showed that more memory failures were reported by old than young adults, and that the former used more internal (e.g., rehearsal, association, organization) as well as external (e.g., lists, calendars) memory aiding strategies to overcome memory failures. Dixon and Hultsch (1983) found the same findings for external aids. In their study, young and old participants responded to questions assessing the use of various memory strategies. Compared with young adults, old adults reported greater use of physical reminder strategies (e.g., writing notes or writing appointments on a calendar). On the other hand, the young adults reported higher use of retrieval strategies than the old adults. Backman, Mantyla, and Herlitz (1990) have speculated that the use of internal and external memory aids by the old adults may reflect their attempt to compensate for objective or perceived memory difficulties.

In sum, the studies reviewed above demonstrated age differences in strategy use in a variety of memory tasks. Most of the studies reported the use of simplified and less demanding strategies by old adults that result in an inferior performance.

1.4.4. Why study age-related compensation in decision-making?

Decision-making is a domain to which the notion of compensatory mechanisms is of great relevance. First, decision-making is a complex process that involves the operation of working memory, attention, and processing speed as processing resources. However, despite the fact that these processes are prone to the effects of ageing, old adults are nevertheless able to make sound decisions (e.g., Dror et al., 1998; Johnson, 1990; Walsh & Hershley, 1993). It is therefore interesting further to understand how old adults can maintain competent, complex, cognitive performance in making sound decisions in the face of declines in processing resources. Although this issue is of theoretical significance, the literature tapping into compensatory mechanisms of ageing in decision-making is somewhat limited.

Second, decision-making as an everyday cognitive activity encompasses both cognitive and external factors such as experience. Although a number of studies have demonstrated age differences in decision-making, these studies have not distinguished between effects of pure cognitive process and effects of experience in accounting for their findings. This thesis aims to examine the role of cognitive factors in decision-making in old age.

Third, decision processes are involved in a variety of cognitive domains, from low level processes involved in perception to higher order cognitive activities such as memory and categorisation (Dror, Busemeyer, & Basola, 1999). A fuller understanding of the decision processes in old age would enable us to interpret age differences in cognitive functioning in other domains of cognition.

Fourth, decision-making is an everyday task that old adults engage in at the individual level as well as at the society level (Dror et al., 1998). Many essential jobs requiring decision-making are held by old adults (e.g., judges, ministers, etc.). Understanding the limitations and advantages of old age in the ability to make sound decisions would allow us to determine to what extent old adults are capable of decision responsibilities which have implications for themselves and their families as well as for the society.

Finally, research into age differences in decision-making may also hold implications for decision-making theory. By investigating age differences in decision-making one could gain better understanding of decision processes in general. There is a large amount of research into the adaptive nature of decision-making suggesting that individuals select decision strategies that minimise the demands placed on processing resources while maintaining accurate decisions (e.g., Ben-Zur & Breznitz, 1981; Jacoby, Speller, & Kohn, 1974; Payne, 1976; Payne, Bettman, & Johnson, 1988; Payne, Bettman, & Johnson, 1993). It is therefore of interest to investigate this issue in the ageing population, which exhibits the ability to adapt to cognitive limitations in other domains of cognition such as memory. These investigations could provide insights into the role of cognitive processes in decision-making and the adaptive nature of those processes.

To conclude, studying compensation in decision making can provide a better understanding of compensatory mechanisms in old age; an understanding of decision processes and of the role of cognitive factors in decision-making in old age; and a wider understanding of the role of cognitive processes in decision-making in general.

2. Decision-making

2.1. Introduction

Chapter 2 aims to introduce some of the main concepts and theoretical accounts in decision-making research. The chapter opens by differentiating two types of decisions: decisions under certainty and decisions under uncertainty. Next, a distinction between normative and descriptive approaches to decision-making is described. Two descriptive approaches to decision-making are then presented: The *process* approach and the *sequential sampling* approach.

2.2. Types of Decisions

Decision-making theorists distinguish between decisions under certainty and decisions under uncertainty (Luce & Raiffa, 1957). According to Luce and Raiffa (1957), decisions under certainty produce a single outcome that is known to the decision-maker. A consumer choice (e.g., which car to buy) is an example of a decision under certainty, because a customer can gather information about the product, being able to know in advance the outcome of his / her decision before making a decision to buy it. A decision under uncertainty produces one of two or more possible outcomes. This implies that the decision-maker cannot predict the final outcome of a decision before making that decision (e.g., whether an outcome would be positive or negative). Having more information about the possible outcomes cannot eliminate uncertainty. Deciding whether or not to buy a share in the stock market is an example of a decision under uncertainty. Decision-problems under uncertainty are characterised by their outcome payoff (i.e., how much is gained or lost) and by the probabilities of those outcomes (i.e., what is the probability of gaining or losing). The probability of outcomes may be either stated, estimated by the decision-maker, or unknown. [5] In this thesis I focus on decision-making under uncertainty.

Uncertainty appears to affect the choice preference of a decision-maker. When asked to choose between a certain and an uncertain gain individuals tend to prefer the certain gain. For example, Kahneman and Tversky (1979) asked participants to choose between winning \$3000 for sure and winning \$4000 with a probability of 80% or nothing. Most participants (80%) chose the sure option. Certain outcomes, however, are avoided when losses are involved. When asking participants to choose between loosing \$3000 for sure and loosing \$4000 with a probability of 80%, Kahneman and Tversky (1979) found that the majority of their participants (92%) chose the uncertain option. The authors proposed that people tend to give more weight to certain outcomes than to uncertain outcomes: certain gains are more desirable than uncertain gains and certain losses are more aversive than uncertain losses.

Tversky and Shafir (1992) showed that people find it difficult to make decisions when uncertainty exists. They asked participants to imagine that they had just gambled on a toss of a coin, having an equal chance of winning \$200 or of losing \$100. Participants were told either that they had won, lost, or that it was not known whether they had won or lost. They were then asked to decide whether or not to gamble again. Most participants decided to gamble again when they were told the outcome of the gamble (either that they had won or lost). When the outcome of the first gamble was unknown most participants decided not to gamble. Dror et al. (1998) and Dror et al. (1999) showed that when people have to make decisions they tend to devote more time to making decisions under uncertainty relative to decisions not involving uncertainty.

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[5] A distinction is often drawn between decisions under uncertainty and decisions under risk. The former are decisions for which outcome probability is unknown, and the latter are decisions for which outcome probability is stated or can be estimated.

2.3. Normative and descriptive approaches to decision-making

One major distinction in decision-making theory is that drawn between the *normative approach* and the *descriptive approach* to decision-making. The normative approach is concerned with how people should make optimal or rational decisions, and therefore provides principles of a rational choice. The descriptive approach, however, is focused on how people actually make decisions, and takes into account the cognitive limitations by which people are constrained as well as the role of these limitations in decision-making performance. In this thesis I employ the descriptive approach, although the normative approach is also considered for the purpose of examining the extent to which young and old adults' actual decision-making deviates from normative principles. The sections below provide a brief overview of some of the models stemming from these approaches.

2.3.1. The Normative approach: Expected Value and Subjective Expected Utility models

von Neumann and Morgenstern (1947) developed the *Expected Value model* of decision-making under uncertainty. According to this model an optimal decision is a choice that maximises the expected value (EV) (i.e., choosing a decision alternative that produces the maximum expected value). The EV of each alternative is the sum of the products of the values (i.e., payoff) and probabilities associated with each possible outcome. This can be expressed mathematically as follows:

$$EV = p_1v_1+p_2v_2+p_nv_n$$

Where p is the probability of an outcome, and v is the gain or loss associated with the outcome. The numbers represent the possible outcomes that a decision alternative can produce.

For example, consider the two gambles below:

Gamble A:

Probability of winning is 0.6 and the amount to win is £16

Probability of losing is 0.4 and the amount to be lost is £4

Gamble B:

Probability of winning is 0.6 and the amount to win is £4

Probability of losing is 0.4 and the amount to be lost is £16

The EV of Gamble A is $(0.6 \times 16) + (0.4 \times -4) =$ £8, and the EV of Gamble B is $(0.6 \times 4) + (0.4 \times -16) =$ -£4. Because Gamble A has a higher EV, it would be predicted that people should choose Gamble A rather than Gamble B.

The EV principle has been challenged following the recognition that people possess subjective representations of probabilities and values. This recognition also led to the development of the *subjective expected utility principle* (SEU) (Edwards, 1954, 1961) in which subjective values replace the objective values.

A series of studies by Tversky and Kahneman (1981, 1986) provided examples in which people violated the SEU principle in their decision-making behaviour. This finding led to the recognition that information-processing limitations place constraints on decision-making behaviour.

2.3.2. *The Descriptive approach: The information-processing approach to decision-making*

The information-processing approach conceptualises decision-making in terms of "information-processing systems that take anticipated future consequences as input and after processing this information for some period of time, produce an action as an output" (Busemeyer, 1993, p.181). Another assumption of the information-processing approach is that information-processing capacity is limited (Dawes, 1976). Simon (1955) posited the concept of *bounded rationality* to refer to the notion that limits of cognitive processing place constraints on a decision-maker's ability to produce optimal decisions. This implies that when the capacity of information-processing is overloaded, people rely on simple decision strategies (i.e., often referred to as heuristics) to reduce the processing demands of the task (e.g. Payne et al., 1988). These simplifications involve disregarding some of the information available in the decision-problem so as to reduce the processing demands of the task. Nevertheless, the use of heuristics may produce good decisions, although it may also increases the chance of making an error (Payne, 1997).

Two approaches of decision-making concerned with the information-processing nature of the decision process are presented in the following sections. These are the *Process approach* and the *Sequential Sampling approach*.

2.3.2.1. *The process approach*

The process approach to decision-making is concerned with the psychological processes that underlie decision-making. According to the process approach (e.g., Johnson & Payne, 1985), decision-makers employ a range of decision strategies that differ in the demands they place on processing and the accuracy they produce. A decision-maker selects decision strategies based on the processing demands of a task. Because the decision-maker is limited in processing resources, shifts from more demanding strategies to simplified strategies are expected under conditions of increased processing demands.

- Methodology used by process studies

Decision strategies are defined in terms of the type of information used and the order in which information is searched during the decision process. Process studies require participants to make a decision among a set of decision alternatives, each of which is composed of a number of attributes (for reviews, see Abelson & Levi, 1985; Maule & Svenson, 1993; Payne et al., 1993; Svenson, 1979). For example, participants may be presented with different cars from which they have to choose one car to purchase. Each car is described on several attributes (e.g., cost, size, riding comfort). To explore the types of strategies employed during decision-making (i.e., the type of information used and the order in which information is searched), process approaches use three methods: Firstly, *monitoring eye fixation*. Participants are presented with all the attributes of each alternative on a computer screen and their eye movements are recorded (e.g., Rosen & Rosenkoetter, 1976). The second method is called the *process tracing technique*. In this method the decision-maker is presented with information arranged on a matrix consisting of alternatives and attributes for each alternative. The attribute information is hidden, however, and the decision-maker has to request it. The matrix can be presented on cards that the decision-maker turns over, or on a computer screen upon which the mouse is used to reveal information. The order in which information is searched is recorded (e.g., Payne et al., 1988). The third method makes use of *verbal protocols*. In this method participants are required to verbalise their thoughts continually throughout the decision process. These verbalisations are recorded using a tape recorder to allow later analysis of the thought process (e.g., Payne, Braunstein, & Carroll, 1978).

- Types of decision strategies

Process studies have demonstrated a variety of strategies that decision-makers use (for reviews see Abelson & Levi, 1985; Svenson, 1979). A distinction commonly drawn is between *compensatory* and *non-compensatory* strategies. [6] Compensatory strategies involve the combination of all information available (i.e., attributes) about each alternative. This combination entails that a good feature of one attribute can compensate for a poor feature of another one (Maule & Svenson, 1993). For example, in choosing a house to buy, a decision-maker may accept a house which is less attractive than another but in a better location. Each house in the set of houses is given an overall rating based on its attributes. Alternatives are then compared on the basis of the ratings they produce, and the one with the highest rating is chosen. Non-compensatory strategies involve processing a subset of information while other information is ignored. An example of non-compensatory strategy would be the choice of an alternative that has the highest rating on one or more attributes, for example, choosing to buy a specific house because it fulfills one important requirement (e.g., good location) while ignoring other attributes such as, cost, size, etc,. Compensatory strategies are said to be more complex and to place more processing demands than non-compensatory strategies. The latter reduce information-processing demands by ignoring potentially relevant information, and are therefore less likely to lead to optimal decisions (Einhorn & Hogarth, 1981).

One type of non-compensatory decision strategy is *selectivity of information*. Selectivity of information is defined as "a reduction in the total amount of information processed" (Maule & Edland, 1997, p.193). Selectivity can be exhibited in either *filtration* or *omission*. Filtration refers to "a reduction in the proportion of total attribute information that is processed" (ibid, p.193). Example of this would be the processing of only the negative information of alternative attributes (Wright, 1974), or of important information only (see

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[6] Note the difference between the term compensatory strategy and compensatory mechanism used in this thesis. Compensatory strategy refers to a type of decision strategy that combines information from different attributes. Compensatory mechanism refers to cognitive compensation aimed at reducing the gap between expected and actual performance (see section 1.4.1).

Edland, 1993). Omission involves ignoring whole dimensions of information: For example, disregarding attribute information across all choice alternatives (see Maule & Mackie, 1990 for evidence of omission in young adults under time pressure conditions).

- Conditions determining the types of strategies used

As noted above, the assumption of the process approach states that limitations on information-processing resources lead decision-makers to use decision strategies that reduce the processing demands of a task. To explore the conditions under which various strategies are used, process studies manipulate the demands of a decision-making task by manipulating its complexity. Decision complexity is manipulated by varying the number of available alternatives, the number of attributes associated with each alternative, or the time allocated to reach a decision. In general, process studies have demonstrated a shift from demanding to less demanding strategies as a function of increasing complexity of a task (for reviews see Abelson & Levi, 1985; Svenson, 1979) as well as a result of time pressure conditions (for a review see Svenson & Maule, 1993). Payne (1976), for example, showed that when faced with two alternatives people use compensatory strategies, examining each alternative on all attributes; however, when faced with multi-alternative decision task, people shift to using non-compensatory strategies, such as the *conjunctive strategy*. The conjunctive strategy refers to participants' reduction of the number of alternatives available to them by disregarding unsatisfactory alternatives and examining the attributes only for those alternatives that are to be considered. Information search can also be reduced by the use of non-compensatory strategies when people are faced with an increased number of attributes (Jacoby et al., 1974). When time constraints are placed on the decision task, people use various simplified strategies. For example, people tend to consider only important information, or only negative information about alternatives (Ben-Zur & Breznitz, 1981; Payne et al., 1988). People also tend to accelerate processing, and to shift from compensatory to non-compensatory strategies under time constraints (Payne et al., 1988).

Given the compensatory nature of decision-making posited by the process approach, it is interesting to investigate the possibility that old adults, given their limited resources, will exhibit decision behaviour consistent with the use of simplifying strategies, which reduce information-processing demands.

2.3.2.2. *The sequential sampling approach*

Different from the process approach to decision-making, the sequential sampling approach (e.g., Busemeyer, 1985; Busemeyer & Townsend, 1993; Ratcliff, Spieler, & McKoon, 2000) specifies a mechanism for determining how long the decision process lasts. The sequential sampling approach posits that at any given moment during the decision process a decision-maker attends one of many features (i.e., referred to as samples) related to outcomes of decision's alternatives. For example, suppose a researcher is considering pursuing research in a domain novel to her. In deciding whether or not to do so, the researcher might consider the pros and the cons of each decision. At some stages during the decision process the decision-maker focuses on features in favour of changing to a new line of research (e.g., it is an interesting area, more students will be interested in working with me, it will broaden my knowledge). At other times she focuses on features against that decision (e.g., it is better to put my efforts in the research area I have been pursuing so far so I can deepen my knowledge, it will take me some time to learn the new research area). Each feature activates either for or against each decision alternative, producing a preference-state for each alternative. This activation produces a move towards one of the two decisions' thresholds each of which corresponds to a decision. In the above example, the positive decision threshold corresponds to a decision to start research in a new domain, and the negative threshold corresponds to a decision not to do that. The activation process continues until one preference-state exceeds one of the thresholds, at which point the corresponding decision is chosen. If the features in favour of moving to a new research area outweighed the features against this decision, the researcher would choose to start researching the new domain.

The decision process is controlled by adjustments to a decision threshold. The decision threshold can represent a cautious decision criterion or a lax decision criterion. Suppose, for example, that the researcher has already established her research record in her research domain, she can have a rather lax criterion for deciding to move to a new research area. Having a lax decision threshold results in faster decision than having a cautious threshold because fewer features are sampled during the decision process. Thus, different from the process approach, the sequential sampling approach postulates that the decision process is controlled by adjustments to a decision threshold, rather than by switching between strategies (see section 2.3.2.1).

Figure 3 presents the sequential sampling model (SSM) of a hypothetical decision process.

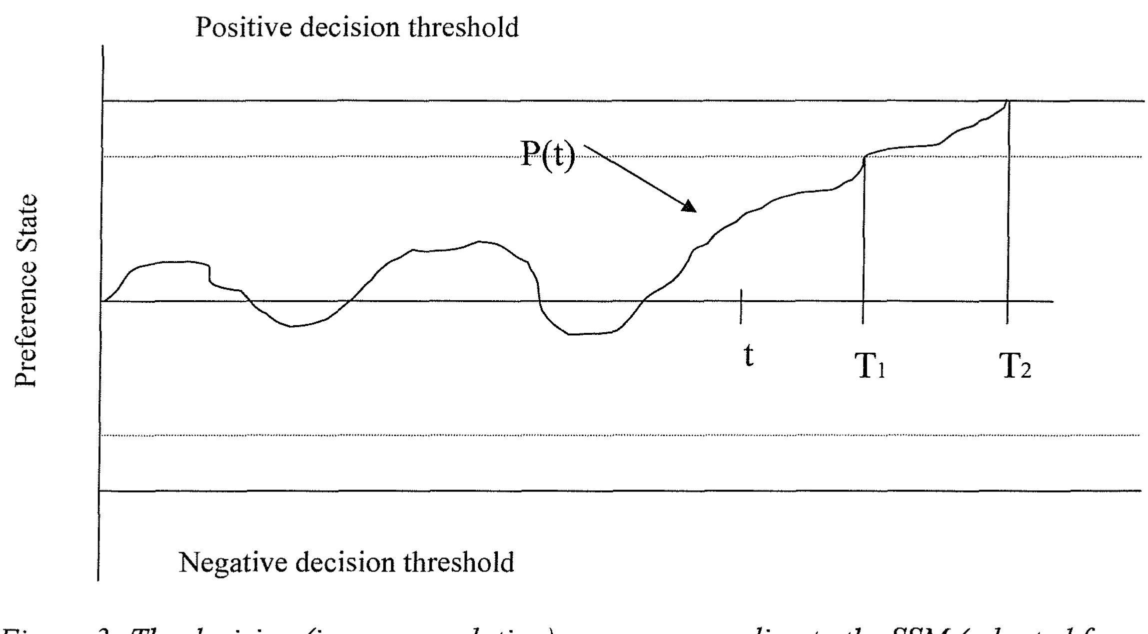

Figure 3: The decision (i.e., accumulation) process according to the SSM (adapted from Dror et al., 1999).

The model illustrates the decision (accumulation) process. This process is represented by the noisy curve, illustrating the changes in preference-state over time. At any moment during decision time ‘t’, samples are activated for and against each decision alternative (i.e., decision threshold), producing a preference-state ‘P(t)’. The decision process proceeds until it reaches a decision threshold ‘T2’. The positive threshold corresponds to a decision to take an action, and the negative threshold corresponds to a decision to avoid an action. When the decision threshold become relaxed (e.g., under time pressure), the decision process takes less time ‘T1’. The relaxed decision threshold is represented in the figure by the dotted horizontal lines.

- Predictions derived from the SSM

The SSM provides predictions for choice probability as well as for decision time. [7] Here I focus on predictions for decision time because the SSM is used in this thesis for that purpose. According to the SSM, decision time is determined by the number of samples (i.e., amount of information or features) that are activated as well as by the level of the decision threshold. The greater the number of samples to be sampled, the longer it takes to reach a decision. In addition, high threshold (i.e., cautious criterion) would result in slow decision because a large number of samples would have to be sampled before a decision could be made. A low threshold (i.e., lax criterion) would result in a fast decision because it would allow very few samples to be sampled.

- Evidence supporting the SSM

Busemeyer and Townsend (1993) have provided a comprehensive overview of the supporting evidence for these predictions, and I will therefore concentrate on a recent study by Dror et al. (1999), which the empirical work reported in this thesis employs as its experimental paradigm.

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[7] Note that the process approach does not specify a mechanism to allow making predictions regarding decision time.

Dror et al. (1999) have provided evidence that the amount of information processed and the level of the decision threshold both affect decision time. In this study the number of samples as well as the decision threshold level were manipulated. Participants were required to play a card game similar to blackjack. The objective of each trial was to maximise the total sum of cards' values without exceeding a combined value of 21. Exceeding a total of 21 constitutes a bust outcome and maximising the total without exceeding 21 constitutes a no-bust outcome. On every trial participants were presented with two cards, and a third card belonging to the opponent (i.e., the computer). The risk level of each trial was varied with respect to the sum of the first two cards presented to the participant. Cards producing a low sum had low risk of exceeding 21, and cards with moderate sum had moderate risk. Cards with high sum had a high risk. The number of samples was varied with respect to the risk level of a decision, which the participant could estimate. Very low and very high risk levels possess very low uncertainty, and entail a small number of samples to process because only one possible outcome (i.e., either no-bust or bust outcome) is possible. However, in the moderate risk levels uncertainty is high, because there are two alternative outcomes with equal probability of occurring. This implies that more samples are sampled during the decision process under moderate risk levels. Consistent with the predictions of the SSM, RT data showed that participants took longer to make a decision at the moderate risk levels than under either low or high risk levels.

In Dror et al.'s (1999) study the level of the threshold was also varied. This was done by manipulating the time constraints under which participants had to make a decision. Participants were required to play the game under both time pressure (i.e., participants were instructed to respond as quickly as possible) and no time pressure (i.e., participants were instructed to respond in their own pace) conditions. According to SSM, under time pressure conditions the decision threshold is reduced, allowing less amount of information about the possible outcomes to be accumulated, and thus, decision time is reduced. The findings of Dror et al. (1999) supported this prediction by showing that time pressure decreased RTs across all risk levels but, in particular, at the moderate risk levels where uncertainty is at maximum.

The SSM will be used in this thesis to provide predictions regarding decision time. This will allow examination of whether age differences exist with regard to decision-making process and in particular, whether old adults process the information available in the decision-problem (e.g., payoff information). In Chapter 3 studies that examine the effects of ageing on decision-making are reviewed.

3. Decision-making and ageing

3.1. Introduction

Chapter 3 aims to provide an overview of research relevant to the empirical work reported in Chapters 4 to 9. The chapter opens with a review of research on decision-making and ageing, focusing on the effects of ageing on decision time, final decisions, and on decision strategies employed. The chapter concludes by specifying the rationale of this thesis which outlines the general methodology used and provides an overview of the experiments reported.

3.2. The effects of ageing on decision time and final decisions

A consistent finding is that old adults take longer to make decisions on a variety of decision-making tasks. Johnson (1997) examined young and old adults' performances on a decision task that involved choosing an apartment to rent from among eight alternatives. Participants could ask for information about various attributes of each apartment (e.g., cost, appliances, square footage). The results showed that, relative to the young participants, the old participants took loner to view each piece of information. No age differences in final decisions (i.e., the apartment chosen) were found, however. Similarly, Walker, Fain, Fisk, and McGuire (1997) found that old adults were slower in making driving-related decisions (such as, route selection), although they made the same decisions as young adults. Similarly, Dror et al. (1998) asked participants to make decisions when playing a card game, and found that although the old adults made the same decisions as young adults, their decisions took longer to make.

In contrast to the studies cited above, Meyer, Russo, and Talbot (1995) found that old women were quicker to make a hypothetical decision about treatment for breast cancer than younger women, although there were no differences in the treatment decisions made by participants in the two age groups. The finding that old women made decisions faster than the young women can be explained by the finding that the old women required less information before making decisions and were less occupied with evaluation of the available information. Alternatively, old women's faster decision-making may have reflected a decline in physical and emotional resources. Thus, old adults may be less tolerant of uncertainty and more motivated to reach a decision in order to avoid anxiety and tension (Keller, Leventhal, Prohaska, & Leventhal, 1989; Leventhal, Leventhal, Schaefer, and Easterling, 1993).

3.2.1. Possible explanations for decision slowing in old age

Two alternative explanations can account for the findings that old adults take longer to make a decision than young adults. One explanation proposes that such slowing reflects slowing of central processes. The other proposes that this slowing reflects a slowing of peripheral processes, such as slowing of motor speed or stimuli encoding (see Chapter 1). Evidence for the central slowing hypothesis would show that slowing of old adults becomes more profound under high levels of task demands (known as the complexity effect, see Chapter 1). This slowing may serve to compensate for declines in processing capacity in old adults, allowing them to preserve the accuracy of their decisions. This explanation would suggest that no age differences in final decisions would be observed. Evidence for the peripheral slowing hypothesis, however, would show no effects of task demands on old adults' slowing. That is, slowing would be of the same magnitude under both high and low task demands.

So far, only Dror et al. (1998) have provided data allowing comparison of these hypotheses. In that study, participants performed a decision-making task (playing a card game) under different levels of risk, from no risk to very high risk. Consistent with previous research, the results showed that old adults made the same decisions as young adults, but that old adults required more time to make those decisions: The slowing observed was constant across all risk levels. Because the different risk levels provided different levels of uncertainty (i.e., processing demands), with moderate risk levels providing greater demand than low or high risk levels (see section 2.3.2.2), the findings could be interpreted as indicating that old adults' slowing was not affected by the processing demands of the task. This finding would therefore support the peripheral slowing hypothesis.

3.3. Age differences in decision strategies: Information selectivity

As discussed in Chapter 2, individuals make use of simplified strategies that reduce processing load when the demands placed by a decision-making task are heavy. These strategies may result in optimal decision performance, but may also entail limitations that may result in decision errors. The hypothesis that old adults use simplified decision strategies builds on the robust finding that old people have less efficient working memory, processing speed, and attentional resources (see Chapter 1). It is therefore proposed that old adults use decision strategies that reduce processing load as a means of compensating for limited processing capacity (e.g., Johnson, 1990; Meyer et al., 1995).

In the next section I review studies that have demonstrated the use of simplified strategies in decision-making by old adults. These studies have consistently showed that old adults tend to exhibit selectivity of information; that is, they utilise only a subset of the information available to them. However, age differences in strategy use did not yield age differences in final decisions (e.g., Johnson, 1990, 1993; Meyer et al., 1995; Walsh & Hershey, 1993). Studies on ageing and decision-making have been conducted using decisions under certainty as well as decisions under uncertainty. The former line of research has typically used process methods to examine decision processes and strategies (see section 3.3.1), whereas the latter has used questionnaire-based methods that have focused mainly on medical decisions (see section 3.3.2).

3.3.1. *Age differences in information selectivity: Decision-making under certainty*

Several studies have examined age differences in information search in decisions under certainty. Johnson (1990), for example, examined age differences in the strategies used by young and old adults use during the decision process. Participants were required to make decisions about which car to buy from a choice of six cars. Each car was described in terms of a number of attributes, such as purchase price, riding comfort, fuel economy, etc. Before making a decision, participants could acquire information about each of the attributes for each car. Johnson used the process tracing technique to record the sequence in which participants sought attribute information. The use of a compensatory strategy (i.e., 'inter-attribute' search) was inferred when participants searched for different attributes (e.g., car price, riding comfort, etc.) within the same alternative (i.e., car type). The use of a non-compensatory strategy (i.e., 'intra-attribute' search) was inferred when participants searched for the same attribute information across different alternatives (i.e., car types). This type of information search is considered as non-compensatory because it does not involve the combination of all attribute information for each alternative. Using this strategy only part of the attributes for each alternative is considered. The findings showed that old adults tended to examine information using the non-compensatory strategy, whereas the young adults were more likely to examine information using the compensatory strategy: That is, old adults tended to engage in less averaging and weighting of alternatives' attributes. Although participants in the two age groups did not differ in the overall time it took them to make a decision, the young group used more subsets of information during that time. Despite age differences in the amount of information considered, no age differences were observed in the final decision young and old participants reached. In another study, Johnson (1993) provided a replication of these findings when participants were asked to choose an apartment to rent out of several apartments.

Johnson's findings are consistent with the theory that old adults possess limited processing capacity. The author postulated that the old adults in her study had used the non-compensatory strategy as a means of minimising processing load. However, as the author additionally noted, it was also possible that the greater experience possessed by the old participants may have played a role in their use of fewer subsets of information. That is, the old adults have had more experience in purchasing a car or renting a house: That experience may have served to guide their information search through greater reliance on pre-existing knowledge than on searching for information within the decision-problem. Also possible is that old adults consider some attributes as less relevant than others. For example, for old adults car speed may become less important whereas its comfort ride may become more important.

Use of a subset of information in old adults' decision-making has also been reported by Walsh and Hershey (1993). In this study, participants had to decide whether a hypothetical couple should open an individual retirement account. The decision-problem incorporated three variables of information that the decision-maker might consider: the need for an additional retirement fund, whether the account was a suitable investment, and whether the account was affordable. Participants could ask for information about these variables. To examine which strategies participants employed in searching for information, a verbal protocol procedure was used (see section 2.3.2.1). The study revealed that old adults were less likely to re-consider the same piece of information and that they tended to use a smaller subset of information variables. A similar pattern of results was obtained when the data were analysed using expertise as a variable. Experts were participants who reported of having much experience in financial planning, and novices were participants who reported vast ignorance in financial planning. The findings showed that there were similarities between the old and the expert participants, in that they both considered less information during the decision process than the young and novice participants. The authors proposed that the differences in strategy use observed might stem from differences in experience between young and old adults: That is, the more extensive experience of old adults in making real-life decisions contributed to their developing mental models by which they were able to anticipate which variables were relevant to making these decisions.

3.3.2. *Age differences in information selectivity: Decision-making under uncertainty*

As noted above, several questionnaire-based studies have investigated age differences in decision-making under uncertainty by focusing on decisions regarding medical treatments. Curley, Eraker, and Yates (1984) presented participants of different ages (from 16 to 86) with a medical scenario in which they were required to imagine themselves finding it painful to walk a few blocks at a time. They were told that there exists a treatment for this illness. However, the treatment might either work well or worsen their condition. Participants were not informed about the exact odds that the treatment would work, instead they were told that the odds were somewhere between 30% and 70%. Participants were asked to make a decision regarding whether or not to have the treatment. The results showed that the oldest group (ages 70-86) was most likely to leave the decision to the doctor.

Meyer et al. (1995) presented groups of women aged between 18 and 88 with a hypothetical scenario about breast cancer which described the discovery of a lump in a woman's breast. Additional information (i.e., recommendations relevant to the medical condition from different expert sources) was subsequently presented and participants were asked to make exploratory tests and to choose a treatment option. The age groups did not differ with respect to the final treatment selected; however, the old women (age 65-88) explored less information than the younger women (age 18-39). This article also reported the findings of a follow-up survey that was given to women who were in fact diagnosed with breast cancer in the past. Consistent with the findings of Curley et al. (1984), the findings of that survey revealed that old women tended to avoid making a decision when they discovered that they suffered from breast cancer: Those women preferred their doctor or husband to make the decision.

Zwahr, Park, and Shifren (1999) studied women's decision processes regarding effective treatment for menopause. Participants were asked to think that they were a 56-year-old woman who had to decide whether to take an estrogen replacement treatment or an alternative treatment for menopause. Women of different ages were given a booklet that contained information about the pros and cons of the treatment available, the types of treatments, and other alternative treatments available for this problem. Decision processes were measured based on participants' reports about the number of options they perceived, the number of comparisons they made between the alternatives available, and the quality of the rationale in making a decision. The authors also used cognitive measures such as working memory, perceptual speed, reasoning abilities, and verbal ability to examine their respective role in the decision-making process. The results showed that old women perceived fewer treatment alternatives, made fewer comparisons between alternatives, and provided less sophisticated rationale for their decisions than did the young women. Also, the old women selected immediate treatment, whereas the young group selected delaying treatment - a finding consistent with those of Meyer et al. (1995) and Leventhal et al. (1993). The findings also indicated that cognitive factors predicted the number of options perceived and the number of comparisons made between alternatives. Zwahr et al. (1999) suggested that age-related changes in these cognitive abilities contributed to age differences in the decision process.

Inconsistently with the studies reviewed above, however, Walker et al. (1997) found that old and young adults did not differ in the amount of information they used in making driving-related decisions. These authors asked participants to make route selection decisions based on information provided in real time (e.g., information regarding amount of congestion and alternative route speed limit). The findings showed that old adults made the same decisions as young adults, and used the same information to make their decisions.

To summarise, although studies on age differences in decision-making under certainty and uncertainty have used different research methods, findings have been consistent in demonstrating that young and old adults make comparable decisions even though old adults tend to search for and consider less information. Old adults are also more likely to avoid making decisions.

3.3.3. *Explanations to account for information selectivity in old age: Greater experience or cognitive limitations?*

As mentioned above, two main explanations can account for information selectivity in old age. One is that selectivity results from old adults' information-processing limitations: Old adults employ less demanding strategies as a means of compensating for limited processing resources. Alternatively, however, selectivity may provide an effective strategy as a result of old adults' accumulated experience. Having greater experience, old adults are able to refer to their existing knowledge - enabling them both to draw on this information and to focus on important information. Indeed, a study by Meyer et al. (1995) examining medical decision-making showed that prior knowledge about breast cancer and its treatments (as indicated by prior knowledge statements participants gave before being exposed to the decision situations and the information about it) influenced the treatment alternative selected. Specifically, participants who indicated they were against radiation tended to select removal of the breast. Participants indicating that they favor radiation tended not to select removal of breast as a treatment option. These findings may imply that having more experience with medical issues, old adults already possessed greater knowledge about medical conditions and were therefore able to fill in relevant information from their pre-existing knowledge (see Zwahr, 1999, for a summary of the role of experience and prior knowledge in medical decision-making). [8]

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[8] Meyer et al. (1995) pointed out that selectivity in medical decision-making can also be explained in terms of cohort differences in degree of trust in medical authority as well as by older adults' potentially greater anxiety about health issues. Being more anxious, older adults may be tempted to accept a treatment suggested by a doctor without further inquiry.

In an attempt to determine the role of cognitive facors in decision-making processes, Zwahr et al. (1999) included measures of different cognitive abilities (i.e., perceptual speed, working memory, reasoning, recall of written text, and verbal ability). The authors showed that these cognitive abilities were associated with the number of options perceived, the number of comparisons made between available alternatives, and the quality of the decision rationale given (i.e., the reasoning provided as a basis for the decision made). Specifically, individuals who attained higher scores on the cognitive tests perceived more options for treatment, made more comparisons, and provided better rationales for their decisions. Nevertheless, most of the studies reviewed above have not distinguished between the two accounts of information selectivity. These studies have all made use of decision-problems related to everyday life, and thus could not control for possible effects of experience on decision-making processes (e.g., Johnson, 1990; Meyer et al., 1995). Although the use of ecologically valid decision situations is important in studying cognitive changes in old age, using such decision situations presents the disadvantage of confounding experience with the cognitive factors involved in decision-making.

Although attempts at addressing the latter issue in research area into decision-making are at the initial stages, research in the related area of problem-solving has provided some insights regarding this issue. Like decision-making, problem-solving is a complex task by which an individual attempts to reach a goal or a desired outcome. Whereas decision-making involves a selection of an action from two or more possible actions (Yates & Patalano, 1999), problem-solving consists of a series of actions or thoughts that an individual must take in order to reach the desired goal (Newell & Simon, 1972). These actions have to be identified by the problem-solver. In decision-making, however, the possible actions are often available to the decision-maker.

Problem-solving research has used both traditional abstract tasks (e.g, Denney, 1989) as well as realistic and practical problems to study age differences (e.g, Denney, 1989). When tested on abstract problems, Denney (1989) found that old adults were inferior to young adults in terms of the number of strategies they generated while solving the problem. Performance on these tasks, however, may not have reflected participants' actual skill in solving practical problems, and some researchers have suggested that old adults might show performance superior to young adults on practical problem-solving tasks because of their accumulative experience in similar situations (e.g., Camp, Doherty, Moody-Tomas, & Denney, 1989). Research employing practical problems has indicated that old adults still generate fewer strategies to solve a problem than middle age and young adults (Denney & Pearce, 1989; Denney, Tozier, & Schlotthauer, 1992). Denney et al. (1992) have therefore argued that old adults' greater experience cannot compensate for their cognitive declines.

In an attempt to tease apart the effects of experience from those of cognitive factors, Camp et al. (1989) have used regression analyses to determine which factors predict problem-solving performance. In addition to measures of problem-solving performance (i.e, the number of possible causes of a problem and the number of potential solutions), measures of crystallised and fluid intelligence were also employed. Participants were tested on problems generated by the experimenter as well as on problems generated by the participants themselves. The results indicated that old adults performed at an inferior level to young adults on experimenter-generated problems, but that they performed as well as the young adults at solving problems drawn from their own lives. Problem-solving performance on the experimenter-generated problems was mainly related to measures of fluid intelligence, whereas performance on participant-generated problems did not appear to be related to any intelligence measure. These findings suggest that both cognitive factors and experiential factors contribute to problem-solving performance.

Berg, Meegan, and Klaczynski (1999) have argued that the finding that old adults generate fewer strategies to solve problems may not reflect poorer problem-solving. According to this argument, old adults may use their experience to disregard some solutions because they already know that those solutions are not optimal. To examine whether generation of fewer strategies in old age is related to the greater experience of old adults, Berg et al. used several self-report measures of experience regarding the problem and its domain. They also measured the number of potential solutions to the problems presented and the amount of information participants requested for solving those problems. The results indicated both that the old adults mentioned fewer strategies in dealing with the problems and that they required less additional information than the young adults. Also, reported experience with the problems presented did not differ between the age groups. The authors concluded that experience is not a determining factor in problem-solving performance and that age differences in problem-solving performance can be explained in terms of stylistic differences (i.e., an exhaustive versus a more heuristic approach to problem-solving). One aim of this thesis is to fill in the gap that exists in the ageing and decision-making research area with respect to the role of cognitive factors in decision-making performance in old age. This will be done by firstly examining decision-making performance when experience cannot guide decision-making, and secondly by examining the effects of varying the cognitive demands placed by the decision-making task on the performance of old adults.

3.4. Wisdom and decision-making

In the sections above, a rather negative view of the effects of ageing on decision-making has been discussed, focusing on cognitive deterioration and loss in old age. A more positive view of ageing effects on decision-making has been expressed by Baltes and colleagues (e.g., Baltes & Smith, 1990; Baltes, Staudinger, Maercker, & Smith, 1995) in their work on wisdom. Wisdom is defined by these researchers as "an expert knowledge system about the fundamental pragmatics of life" (Baltes & Smith, 1990, p. 94). This conception of wisdom relates to the two component-model of intellectual development proposed by Baltes and colleagues (e.g., Baltes & Baltes, 1980, 1990). This model is influenced by Horn and Cattell's (1976) theory of fluid and crystallised intelligence (see section 1.2.1.1). The two-component model encompasses the *mechanics of intelligence and pragmatics of intelligence*. Mechanics of intelligence involve basic information processing operations, which are content-free and controlled by biological and genetic influences. In old age decline in these mechanics are observed. Pragmatics of intelligence comprise of factual and procedural knowledge. They are rich in content and dependent on culture and experience.

Everyday activities, such as decision-making and problem-solving, are dependent on this knowledge-based component. According to this perspective of intellectual development, the hallmark of positive ageing lies in the potential growth in the pragmatics of intelligence (Baltes & Smith, 1990). Within the two-component model of intellectual development, wisdom is considered a form of growth in the pragmatics of intelligence.

Baltes and Smith (1990) outlined a framework of five criteria to operationalise wisdom. These criteria include rich factual knowledge (knowledge about the conditions of life and its variation); rich procedural knowledge (knowledge about strategies of judgement and advice on life matters); life span contextualism (understanding that development and life events are embedded in the multiple contexts such as, family, work, age-related and cultural-related); relativism (knowledge about differences in values, goals and priorities of individuals and cultures); and uncertainty (understanding that knowledge is limited and life events cannot be fully predictable).

Wisdom is expected to relate to advanced age. Through the lifespan people accumulate experience and knowledge regarding life matters, therefore old age is likely to be a facilitative factor for the acquisition of wisdom (Baltes & Smith, 1990). This hypothesis was tested by Smith and Baltes (1990) and Staudinger, Smith, and Baltes (1989). In Smith and Baltes's (1990) study young participants (about 30 years of age) and old participants (about 60 years of age) were presented with fictitious decision-problems involving life planning, and were asked to discuss the problem and offer advice for individuals who face these problems. The participants' thought process was collected by the think-aloud method, and was rated based on the five criteria of wisdom. The results suggested that the old participants achieved higher ratings on the wisdom criteria than the young participants. Staudinger, et al. (1989) evaluated wisdom on life review decision-problems presented to young and old participants. The old and the young participants received equivalent ratings on all but the uncertainty awareness criterion. On this criterion the old participants attained higher ratings than the young participants. These data showed that old adults do not show age-related loss in the domain of pragmatic knowledge. Furthermore, they sometimes perform better than the young adults.

The advantage of experience and old age was also shown to facilitate decision-making performance in a study by Walsh and Hershey (1993). The authors examined how expertise and age affect decision-making performance in problems of financial planning. They included in their study three groups of adults: Young, old, and a group of highly trained experts in financial planning. Participants were presented with five problems in which an individual faces a decision of whether to open a retirement saving account. The participants were asked to decide whether each of the five individuals should open the account. Participants were instructed to specify the information they thought was necessary for making the decision. The study also included a measure of financial planning knowledge. Decision accuracy was evaluated against a criteria determined by senior financial planners. The results indicated that the old adults had more knowledge about financial planning than the young adults, but were less knowledgeable than the experts. The experts were more accurate in their decisions than the young and the old participants, and the old adults were more accurate than the young adults but this trend was not significant. The results also showed that the experts considered more subsets of information than the young and the old adults, and the old adults considered more subsets of information than the young adults. The authors concluded that the experts and the old adults were able to produce more accurate decisions than the young adults because of having greater knowledge of financial planning. This greater knowledge led the experts and the old adults to consider relevant information that facilitates performance.

To conclude, studies on wisdom, expertise, and ageing in decision-making indicate that old adults can be superior to young adults when faced with decision-problems from everyday life given their extended experience and knowledge in general life matters.

3.5. Rationale of the thesis

Whereas research into problem-solving performance in old age has attempted to separate effects of experience from those of cognitive factors, there is a dearth of studies examining this issue with regard to decision-making in old age. The research into age differences in decision-making reviewed above has not afforded conclusions regarding the potential role of cognitive limitations as underlying age differences in decision-making. First, as discussed above, the decision-problems used by these studies confounded experience and cognitive factors in decision-making performance. Second, these studies did not include experimental manipulation that would allow the investigation of any effects of cognitive limitations in decision-making performance by old adults.

This thesis aims closely to examine the role of cognitive limitations in old age in the employment of two compensatory mechanisms: the allocation of increased processing time and information selectivity. To attain this aim the investigation is focused on old adults' decision-making using decision-problems, for which experience cannot guide decision-making performance (e.g., information use). In addition, the decision-making tasks used in this thesis are designed to enable the manipulation of cognitive demands of the task. This experimental approach will allow conclusions regarding the effects of cognitive ageing on decision-making to be made. The decision-making tasks employed will be discussed in more detail in section 3.6.2 below.

3.6. General methodology employed in the empirical work

3.6.1. The use of a cross-sectional design

The experiments reported in this thesis employ a *cross-sectional design*. A cross-sectional design refers to a design in which variation in chronological age is introduced as a pseudo independent variable in the experiment (Kausler, 1991). Performance of participants from different age groups is compared. This design differs from the *longitudinal design* in which the same participants are tested at different times during their lives. The cross-sectional design sometimes makes use of two extreme age groups, namely, young and old adults. The definition of age is made with regard to chronological age. Young adults are usually in their 20s and 30s, and old adults are 65 years of age and over. Old age is thus defined in relation to the usual retirement age of 65 (Kausler, 1991). However, these age boundaries are not fixed, and studies often employ participants who are outside these age ranges. In the experiments reported in this thesis the age of the young group ranged from 17 to 42 (mean age 20.8), and the age of the old group ranged from 60 to 86 (mean age 71).

Some researchers have suggested to assign participants to age groups based on their *functional age* (for a review see Salthouse, 1986). Functional age refers to the biomedical status of an individual. Salthouse (1986) noted that functional age could be used to predict the time a person is likely to have until his/her death. Under the functional age definition, an old person is an individual who is likely to live no more than 10 years. Because of difficulties at determining the biomedical functional age of individuals (Salthouse, 1986), cognitive aging research typically employs the chronological age definition.

Having two age groups of participants in cross-sectional design who perform the test at the same time implies that the two age groups differ not only with respect to their age, but also in terms of their cohort (i.e., generation). In experiments reported in this thesis the old participants belong to a generation born during the 1920's and 1930's. Their performance is compared to a generation of young adults who were born during the 1970's and 1980's. Therefore, age in a cross-sectional design in not a true independent variable because it is not manipulated by the experimenter. This implies that the two age groups may vary not only with respect to their age, but also on other variables which may stem from the different cohort to which the participants belong. This characteristic carries problems when interpreting differences in performance between the two age groups, because the differences may reflect cohort differences rather than true age change in cognitive ability. Cognitive performance of people from different cohorts may differ because of the different economic and social conditions under which they grew up (Rice, 2001). For example, old adults may perform less well than young adults in a reasoning task because of differences in the number of years spent in formal education, because of differences in the emphasis that the education system places on reasoning ability during different historical times, or because differences in the amount of practice young and old adults have in such tasks. There is always the problem that some factor cannot be identified and cannot be controlled statistically. In longitudinal designs this problem does not exist because the participants are from the same generation, and they perform the test at different times in their lives.

Despite the problems inherent to the cross-sectional design, this design is commonly employed in cognitive ageing research because data can be easily obtained within a confined period of time (Rice, 2001). Examples for such studies were provided in the reviews in Chapter 1 and Chapter 3. As cross-sectional designs are a common practice in the cognitive ageing research, the experiments reported in this thesis also employ this design. The interpretation of the findings of these experiments will therefore take into account these limitations.

3.6.2. *The decision-making tasks*

The majority of the decision-making tasks (Experiments 2 to 6) used in this thesis are designed to enable the control of external factors that might affect decision-making performance (e.g., experience) as well as the manipulation of the cognitive demands placed by the task. To exclude experience as a factor affecting decision-making performance, the decision-making tasks used in Experiments 2 to 6 (see Chapters 5 to 9) share two main characteristics. First, all the information presented within the decision-problem (e.g., outcome probability, outcome payoff) is important for an effective decision-making performance and should thus be used by participants. Second, this information cannot be supplemented from experience-based knowledge: To make an optimal decision, people must use the information contained within the decision-problem itself, and hence, selectivity of information (i.e., ignoring any dimension of the available information) will result in poorer decision performance. This differs from tasks used in previous research in which information selectivity did not affect the final decision made because additional information could plausibly have been accessed from prior knowledge.

These decision-making tasks involve decisions under uncertainty (see 2.2) and are variations of a task developed by Dror et al. (1998) and Dror et al. (1999). Dror et al.'s (1998) and Dror et al.'s (1999) decision-making task is modeled as a card game, similar to blackjack. As described above, the objective on every trial is to maximise the cards' total value without exceeding a total of 21. On each trial, three cards appear on the computer screen: Two cards are the participant's and one card is the opponent's (i.e., the computer). Participants have to decide whether or not to take an additional card. The risk level of a trial exceeding 21 when taking an additional card is varied with regard to the sum of the participant's two cards: no risk (trials with a sum of 11 or less), low risk (trials with sums 12 and 13), medium risk (trials with sums of 14 and 15), high risk (trials with sums of 16 and 17), very high risk (trials with sums 18 and 19) and infinite risk (trials with sums of 20).

The decision-making tasks used in this thesis are variations of the above task. In Experiments 2, 3, and 5 a card game has been employed which differs from the card game used by Dror et al. (1998) and Dror et al. (1999) in several aspects. First, participants are presented with one card rather than two. Second, nine is the maximum combined sum of cards' values that participants should aim for on each trial. Third, the opponent's card is not presented, and thus the task is reduced to the participant's part in the game. Fourth, participants receive points if they make a correct response and lose points if their response is incorrect. The objective of the game is to gain as many points as possible. Experiments 4 and 6 make further modifications of this task, though the main paradigm remains the same. These tasks were employed because they allow the experimenter to carefully manipulate the demands of the task (i.e., the amount of information available).

3.6.3. *Data analyses*

An important issue when comparing the data of old and young adults is that of the difference in variance between the data of the two age groups. A known characteristic of old adults' data is its high variance (e.g., Rabbitt, 1993). These differences in variance between the two group's data may result in a non-significant *p* value. When analyses of variance (ANOVAs) are conducted on the data of the two age groups this feature violates both the assumptions of normality and homogeneity. Neverthelss, the *F* test is robust with regard to these violations (Keppel, 1982). A common practice, however, is to transform the data in order to reduce its variance. In this thesis analyses on the raw data will be described, as the *F* test is robust. However, further to validate the results, square root transformations were also used when age did not produce a significant effect or interactions. This was done in order to examine the possibility that high variance in the data of the old group was responsible for the absence of age effects.

3.7. Overview of the empirical work in the thesis

The experiments reported in this thesis investigate the effects of cognitive limitations on the employment of two compensatory mechanisms used by old adults in decision-making: One mechanism is the allocation of increased processing time, and the second mechanism is selectivity of information. This thesis is concerned with decision-making under uncertainty. The decision-problems used in the research presented involve two dimensions of information that a decision-maker may consider in making an optimal decision (i.e., in maximising gain or producing a desirable outcome). The two dimensions are outcome probability (i.e., probability of a desired or undesired outcome to occur) and outcome payoff (i.e., the amount of gain or loss associated with each decision's outcome). Normative models assume that a decision-maker considers both types of information to evaluate decision alternatives (see section 2.3.1).

Experiment 1 explored whether old adults make use of these dimensions when faced with decision-problems taken from real-life situations. Experiments 2 to 6 used a more controlled decision-making task to examine the use of these dimensions by old adults. Using such a controlled decision-making task, Dror et al. (1998) have shown that both young and old adults are making use of outcome probability information in their decisions when this is the only information provided within a decision-problem. It was of interest to examine, first, whether old adults make use of other dimensions of information, such as, information about prior decision outcomes or information about outcome payoffs, and second, how variations in cognitive demands affects the processing and the use of these dimensions. Experiment 2 examined the hypothesis that old adults allocate more time to making decisions under high task demands that tax their processing capacity. Task demands were varied by the existence or absence of decision outcomes. The specific question addressed was whether old adults allocate more time to make decisions when provided with outcomes of prior decisions. Experiment 3 examined whether allocation of more time was accompanied by utilising outcome bias. Outcome bias was manipulated by varying the probability of prior decision outcomes.

Experiments 4, 5, and 6 examined the hypothesis that old adults are more selective in the information they use in decision-making. Experiment 4 examined whether old adults make use of payoff information during decision-making when only payoff information is varied. Experiment 5 examined how increase in the processing demands of the task (i.e., varying two dimensions of information, probability and payoff) affected the use of these dimensions of information by old adults. The hypothesis was that with increased demands, old adults would exhibit information selectivity ignoring one dimension of information - either that concerning probability or payoff. This hypothesis was also examined in Experiment 6 employing a similar decision-making task to that of Experiment 5 but which encourages the incorporation of payoff information (i.e., by making payoff information more salient).

Table 1 summarises the variables employed in each experiment.

Table 1: The variables that were manipulated in each experiment

Experiment	Within-subject variables	Between-subject variables[a]
1	probability	---
(real-life decisions)	payoff	
Using a more controlled decision-making task		
2	probability	task demands (outcome information)
3	probability	outcome bias
4	---	payoff
5	probability	payoff
6	probability	payoff

[a] Age was a between-subject variable in all experiments

4. EXPERIMENT 1: The utilisation of probability and payoff in decision-problems taken from real-life

4.1. Introduction

Previous research on age differences in decision-making has commonly employed decision-problems taken from real-life situations to examine how old adults process and use various subsets of information during decision-making (e.g., Johnson, 1990; Meyer et al., 1995; Zwahr et al., 1999). These subsets of information included attributes of decision alternatives (e.g., cost of a car, its size, and its riding comfort) in decision-making under certainty (see review Chapter 3). Research investigating decision-making under uncertainty (e.g., Meyer, 1995; Zwahr, 1999) has provided participants with information about the decision-problem domain in general (e.g., information about breast cancer, possible treatments, different doctors' opinions). No study, however, has examined the use of specific information regarding outcome probability and outcome payoff by old adults in such decision-problems taken from real-life. Outcome probability refers to the likelihood that a certain outcome will happen following a decision, and outcome payoff refers to the amount of gain or loss associated with possible decision outcomes. These two dimensions of information are important for optimal decision-making according to normative models of decision-making (see section 2.3.1).

Because the focus of this thesis is on the processing and use of these two dimensions of information, Experiment 1 aims to explore their use by old adults in decision-problems from real-life. The experiment is exploratory in nature and, therefore there were no a-priori hypotheses regarding possible age effects. The question addressed by Experiment 1 is whether old adults make use of probability and payoff information when making decisions for decision-problems taken from real-life.

In Experiment 1 participants were presented with various decision-problems from real-life situations and asked to decide whether or not to take a specific action - such as whether or not to take a medication for treating a specific medical condition. The decision-problems differed with regard to the relative amount of gain or loss (i.e., payoff) associated with an outcome following a decision to take an action (e.g., to undergo an operation). Approach decision-problems were those possessing larger potential gain than loss, and avoidance decision-problems were those possessing larger potential loss than gain. The problems also differed with respect to the likelihood (i.e., probability) of a successful outcome occurring (e.g., the operation will be successful). The use of payoff information was inferred when participants exhibited greater willingness to take a positive action (e.g., take the medication) under the approach condition than under the avoidance condition. If outcome probability information was also incorporated, then the willingness to take an action should increase as a function of the probability of a successful outcome.

4.2. Method

4.2.1. Design

The experiment employed a mixed design in which age (old and young) was the between-subject factor and payoff (approach and avoidance) and probability (low, moderate, and high) were the within-subject factors. The approach condition was defined as a decision-problem for which the potential gain was larger then the potential loss (e.g., taking a medication would result in a complete recovery from a medical condition versus the potential minor side effects). The avoidance condition was defined as a decision-problem for which a potential loss was larger than the potential gain (e.g., taking a medication for flu could result in a major medical condition, such as stroke). The probability manipulation had three levels of probability of success, low, moderate, and high, following a positive action (e.g., the probability that taking a medication would result in recovery from a medical condition). The number of "yes" responses (i.e., the decision to take an action) served as a measure of the willingness to take an action.

4.2.2. *Participants*

Seventy-four participants volunteered to take part in this experiment. Thirty-eight participants (23 females, 15 males) were old adults who were recruited from various senior citizen clubs and church groups in Southampton. Based on the participants' self-reports, all were in good health, were not institutionalised, and were physically and socially active. Their age range was between 60 and 80 (mean age 70.2). The young participants were 36 Psychology undergraduate students at the University of Southampton (24 females, 12 males) who volunteered to take part in the experiment in exchange for experimental credits. Their age range was between 18 and 28 (mean age 20.1).

The two age groups were matched for educational background. The young group had a mean of 13.7 years of formal education (SD = 0.63), and the old group had a mean of 13.3 years of formal education (SD = 2.7). A two-sample t-test not assuming equal variances[9] showed no significant differences between the young and the old group, $t(41.2) = 0.83$, $p > .05$.

4.2.3. *Materials*

The materials consisted of a decision questionnaire with 12 decision-problems composed of pairs of six decision-problems. Each pair presented a similar decision situation with a similar cover story, but one problem was designed as an approach decision-problem and the other was designed as an avoidance decision-problem (see Appendix A). Below is an

[9] Degrees of freedom were corrected for a test not assuming equal variance.

example of a pair of decision-problems, presenting similar situations but different payoffs (approach and avoidance).

Approach version:

> Suppose you are very ill. You were prescribed a drug that is known to cure this illness. The drug is known to have side effects, such as drowsiness and headaches. Will you take the drug?

Avoidance version:

> Suppose you have flu. You were prescribed a drug that is known to remove flu symptoms. The drug is known to have side effects and in rare cases can cause a stroke. Will you take the drug?

The decision questionnaire had two parts, each containing three approach and three avoidance decision-problems. Each of the three approach decision-problems in the first part had its paired avoidance decision-problem in the second part and vice versa. The decision-problems were also designed so that the probability of a positive outcome (e.g., that an operation would be successful) occurring following a decision to take an action (e.g., the decision to undergo the operation) was varied between three levels of probability (low, moderate, and high). Probability variation was performed by varying the contextual information from which the probability of a successful outcome could be inferred. For each payoff condition, there were two problems with low probability, two problems with moderate probability, and two problems with high probability (see Appendix A). Below are examples of decision-problems of the three levels of outcome probability.

Low probability:

Suppose you took an exam and failed. You are considering asking for your exam to be remarked. You are told that it is possible that remarking will result in a higher mark, the same mark, or a lower mark. It is known that remarking in most cases does not result in a higher mark. Will you ask for remarking?

Moderate probability:

Suppose you work in the army monitoring incoming aircraft on radar. Your task is to identify enemy aircraft in order to ensure that they are not crossing the border. You spot an aircraft on the radar screen but visibility of the aircraft is obscured. Will you inform your boss about the aircraft?

High probability:

You were severely injured in an accident. You are about to undergo a complex operation, which may save your life. The doctor who is about to operate on you has a record of high success in operating on this condition. Will you decide to undergo the operation?

The twelve decision-problems included were based on a pilot assessment of the payoff quality (approach or avoidance) and the outcome probability they possessed (for the pilot questionnaires see Appendices B and C; for the pilot results see Appendix D and Appendix E). Participants in the old group were also required to fill in a self-reported health and life-style questionnaire (see Appendix F).[10]

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[10] The health and life-style questionnaire was a modified version of a questionnaire that was kindly provided by Naftali Raz, University of Memphis.

4.2.4. Procedure

Participants came into the laboratory for testing. Each participant completed the questionnaire individually in a quite room. The questionnaire included the following instructions.

> Below are decision-problems that people may face in every day life. Please read carefully each decision-problem and make a decision. For example,
>
> Suppose you suffer from a serious illness. You are offered a new experimental treatment. This new treatment has been proved to be effective for most patients who have already received it.
>
> Will you try the new treatment? YES NO
>
> (please circle)
>
> If you decide to try the new treatment please circle "YES" and if you decide not to try it, please circle "NO".
>
> Below are number of decision-problems. For each problem please make a decision as demonstrated in the example above.

Participants were instructed to read each decision-problem and to decide whether or not they wished to take a specific action based on the question presented in each decision-problem. If they wished to take an action they circled the "yes" option, and if they did not wish to take an action they circled the "no" option. The order of the two parts of the questionnaire was counterbalanced between participants. In each part the order of the questions was the same for all participants. It should be noted that the participants involved also took part in another experiment reported later in this thesis (Experiment 6). The two experiments were performed on the same visit to the laboratory. Half of the participants performed the task of Experiment 1 first and half of them performed that of Experiment 6 first. Participants completed both tasks in approximately 45 minutes. After completion of the two tasks, the old participants were asked to fill in a self-reported health and life-style questionnaire.

4.3. Results

For each participant the number of decision-problems for which a "yes" response was given was calculated. Figure 4 shows the mean number of "yes" responses[11] as a function of probability of success, age, and payoff condition.

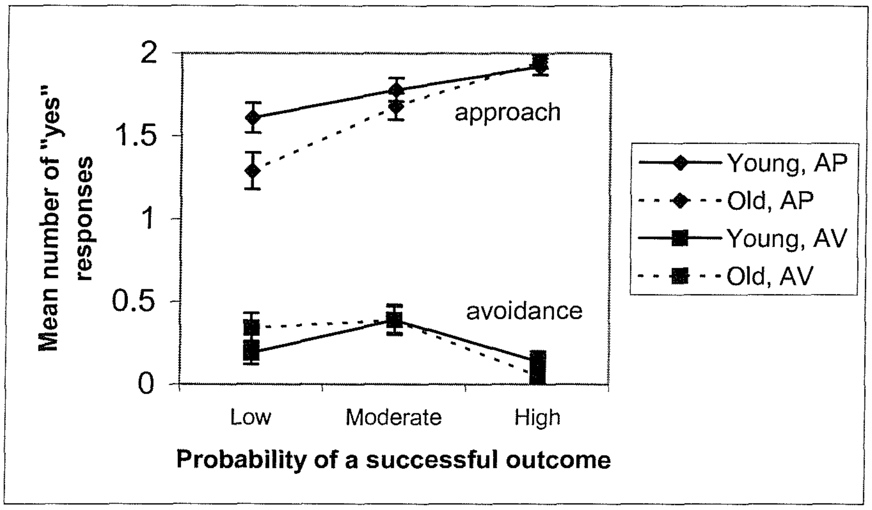

Figure 4: Mean number of "yes" responses as a function of probability, age, and payoff (AP = approach; AV = avoidance)[12]

Mixed design ANOVA[13], with age as the between-subject factor and payoff and probability as the within-subject factors, indicated a significant main effect of payoff, $F(1, 72) = 1311.30, p < .01$. For the approach condition the mean number of "yes" responses was 1.7

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[11] The number of "yes" responses served as a measure of willingness to take an action (rather than percentage of "yes" responses) because each probability level in each payoff condition included only two decision-problems. It did not seem appropriate to calculate percentage of "yes" responses based on two responses.

[12] Error bars on the figures represent one standard error above and below the mean.

(SD = 0.27), and for the avoidance condition it was 0.25 (SD = 0.27). There was also a significant main effect of probability, $F(1.87, 134.83) = 7.08, p < .01$, and a significant interaction between payoff and probability, $F(1.79, 128.56) = 23.38, p < .001$. The analysis also showed a significant interaction between payoff, probability, and age, $F(1.79, 128.56) = 4.40, p < .05$. There was a marginal interaction between payoff and age, $F(1, 72) = 3.52, p = .065$. There was no main effect of age, $F(1, 72) = 1.21, p > .05$, and no interaction between probability and age, $F(1.87, 134.83) = 0.15, p > .05$.

Further to examine the interaction between payoff and probability and the interaction between payoff, probability, and age, in each age group nine dependent-sample t-tests (using Bonferroni corrections, $p < .005$) were performed. To examine what effect payoff had at each probability level, the t-tests compared the payoff conditions in each probability level. To examine what effect probability had in each payoff condition, probability levels were compared in the approach and in the avoidance conditions. Table 2 summarises the results of the t-tests.

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[13] Degrees of freedom were adjusted using Greenhouse-Geisser because of Sphericity violation.

Table 2: The results of t-tests comparing the number of "yes" responses between the payoff conditions in each probability and between the probability levels in each payoff condition in the young and old groups

	Young	Old
	Effect of payoff at each probability level	
AP[a] low – AV[a] low	$t(35) = 13.09, p < .005$	$t(37) = 7.59, p < .005$
AP mod – AV mod	$t(35) = 11.45, p < .005$	$t(37) = 13.01, p < .005$
AP high – AV high	$t(35) = 25.3, p < .005$	$t(37) = 35.56, p < .005$
	Effect of probability on approach	
AP low – AP mod	$t(35) = -1.36$, n/s	$t(37) = -2.96, p = .005$
AP mod – AP high	$t(35) = -1.54$, n/s	$t(37) = -3.22, p < .005$
AP low – AP high	$t(35) = -2.94, p = .006$	$t(37) = -5.73, p < .005$
	Effect of probability on avoidance	
AV low – AV mod	$t(35) = -1.75$, n/s	$t(37) = 0.50$, n/s
AV mod – AV high	$t(35) = 2.31$, n/s	$t(37) = 3.62, p < .005$
AV low – AV high	$t(35) = 0.63$, n/s	$t(37) = 2.73$, n/s

[a] AP refers to approach condition and AV refers to avoidance condition

The results of the t-tests indicate that participants in both age groups were affected by payoff on each of the probability levels. Specifically, participants were more willing to take an action (i.e., "yes" response) in the approach than in the avoidance condition. In the approach condition, participants in both age groups became more willing to take an action as probability of a successful outcome increased from low to high probability. Participants in the old group appeared to be affected by probability to a greater extent than the young group, showing a significant increase in the number of "yes" responses from low to moderate probability and from moderate probability to high probability. The young participants showed an increase in "yes" responses from low to high probability only. The stronger probability effect in the data of the old adults might have resulted from their reduced willingness to taken an action on the low probability in the approach condition than the young adults (see Figure 4). In the avoidance condition, participants in the old group reduced their willingness to respond "yes" from moderate to high probability. Participants in the young group were not affected by probability in the avoidance condition. Thus, whereas in the approach condition the willingness to take an action increased from low to high probability of success in both age groups, this trend appeared to decrease from moderate to high success probability in the avoidance condition for the old group only.

4.4. Discussion

The aim of Experiment 1 was to explore the use of payoff and probability information by old adults for decision-problems pertaining to real-life situations. Both age groups were affected by payoff showing more willingness to take an action under the approach condition than under the avoidance condition. Under the approach condition both age groups increased their willingness to take an action as probability of a successful outcome increased from low to high probability. However, the old participants demonstrated a stronger increase than the young adults. The old participants showed an increase in the number of "yes" responses from low to moderate probability and from moderate to high probability. The young participants demonstrated such an increase from low to high probability only. The stronger effect of probability in the data of the old group originated from them being less inclined than the young adults to take an action under low probability of success. These differences between the two age groups may reflect differences in risk perception. A possible loss may seem higher for older adults than for young adults because being at the end of their life-span, older adults may have more difficulties and less time to recover from a loss (Dror et al., 1998; Yates & Patalano, 1999). When a successful outcome is unlikely to occur (i.e., has low probability), the possible loss is likely to materialise and hence, becomes salient. Under these conditions age differences in risk perception may be exhibited.

Under the avoidance condition, however, participants in the old group became less willing to take an action as probability of success increased from moderate to high probability. The young group did not change their willingness to take an action across probability. The absence of probability effect in the avoidance condition in the young group and the reduction in willingness to take an action in this condition from moderate to high probability of success in the old group is inconsistent with the expectation that participants would increase their willingness to take an action as probability of successful outcome increases. Examining the decision-problems under the high probability condition reveals that they hold an immense loss (i.e., losing one's life; refer to decision-problems 'operation' and 'a drug', Appendix A). No other decision-problems involve life loss. Thus, this disparity between expected and observed patterns of willingness to take an action might have resulted from the use of decision-problems that produced a bias towards greater potential loss on decisions-problems with high probability of success than on decision-problems with low or moderate probabilities of success. The old adults but not the young adults were affected by these decision-problems. This difference between the age groups may reflect differences in the perception of risk for those decision-problems. Old adults who are more prone to suffering medical conditions and who are at the end of the life-span may perceive the possible loss of life as being more likely to occur than young adults. Thus, undergoing an operation, for instance, may be perceived in old age as holding great danger for their lives. This interpretation is consistent with Hermand, Mullet, and Rompteaux (1999) who found that older adults associated more risk with health related issues, as surgery, than did young adults.

The results of Experiment 1 demonstrated that on decision-problems from real-life situations both young and old adults indeed made use of both probability and payoff information. However, the interaction between payoff, probability, and age, suggest that they used the information differently. These differences between the two age groups may reflect differences in experience or in risk perception. Because the decision-making task used in the present experiment does not control for these factors it is of limited utility for investigating the effects of cognitive factors on decision-making performance in old age.

To attain this goal, the experiments presented in Chapters 5 to 9 take a more experimental approach that affords the following advantages. Firstly, it allows greater control of factors that are uncontrolled in a more naturalistic environment (e.g., experience, subjective judgement of risk, cognitive demands of a task). Secondly, it allows the use of tasks that place greater demands on the cognitive system. These would allow greater access to cognitive effects of ageing. Thirdly, RTs could be recorded as a measure of decision processes, in addition to examining the actual decisions made by young and old individuals. Fourthly, the two dimensions of information that provide the focus of this thesis (i.e., probability and payoff) can be manipulated in a more subtle way. In decision-problems taken from real-life, as used in Experiment 1, payoff and probability information was not provided in a precise form. As proposed above, age differences in the perception of risk may affect the way young and old adults utilise this information. Increased control over such subjective judgements of risk could be achieved by representing payoff and probability information by a precise number.

Therefore, in the following experiments, I use decision-making problems for which experience cannot contribute to decision-making performance. Additionally, those experiments provide a precise value for probability and payoff information allowing the control of differences in risk perception and the manipulation of the processing demands of the task.

5. EXPERIMENT 2: Allocation of increased processing time in old age: The effect of decision outcomes

5.1. Introduction

Previous research has demonstrated that old adults make the same decisions as young adults. For example, old and young adults have been shown to choose the same decision alternatives when making a decision about which retirement account to open (Walsh & Hershey, 1993), which car to buy (Johnson, 1990), or which apartment to rent (Johnson, 1997). Similarly, when decisions under uncertainty are involved, young and old adults make the same decisions when playing a card game (Dror et al., 1998), when choosing a treatment for a medical condition (Meyer, et al., 1995), and when driving a car (Walker, et al., 1997).

Given the well-documented declines in the efficiency of information-processing in old age and the findings that young and old adults reach the same decisions, a question that arises is that of how old adults are able to preserve competent decision-making despite those declines. Several mechanisms by which old adults are thought to compensate for cognitive declined have been identified (for a review see Backman & Dixon, 1992; Dixon & Backman, 1995). One such mechanism is the allocation of more time in performing a given task (see section 1.4.2). In the research area of decision-making, studies have demonstrated that old adults take more time to reach a decision than young adults (e.g., Dror et al., 1998; Johnson, 1997). Johnson (1997) examined young and old adults' performance on a decision task that involved choosing an apartment to rent from among eight alternatives. Participants could ask for information about various features of each apartment (e.g., cost, appliances, square footage). The results showed that, relative to the young participants, the old participants spent more time viewing each piece of information. This finding could be accounted for in terms of peripheral slowing (for example, slowing of motor speed or stimulus encoding). A demonstration of an increase in processing time would be provided when the slowing of old adults becomes more profound on high levels of task demands. To infer that the increase in processing time served as a compensatory mechanism, preserved level of performance as measured by other measure of performance (e.g., accuracy) should be apparent.

Therefore, to examine the effects of ageing on the allocation of time during the decision process, there is a need for a decision-making task that allows the manipulation of task demands. Task demands can be manipulated by varying the amount of information available in the decision-problem (Abelson & Levi, 1985; Jacoby et al., 1974; Navon & Gopher's, 1980; Payne, 1976; Svenson, 1979). One factor that determines the amount of information processed during the decision process is the uncertainty of a decision outcome. Uncertainty is determined by the predictability of an outcome occurring subsequent to a decision. When outcomes possess either high or low probability of occurrence, uncertainty is low because one outcome is more likely to occur than the other(s). However, when the probability of an outcome's occurrence is at chance level uncertainty is infinite because all possible outcomes are equally likely to occur. Decisions under high uncertainty require that a greater amount of information has to be evaluated, because several outcomes carry equal levels of predictability and therefore all have to be considered and compared. Under low uncertainty, by contrast, the predictability of one outcome overweighs the predictability of the other(s), and therefore the consequences of the less likely outcome(s) can be ignored. Only the consequences of a single outcome (the one with high predictability) need to be considered.

Dror et al. (1998) varied the demands of a decision-making task by varying uncertainty. In their study, participants were asked to play a card game similar to blackjack. Risk levels of exceeding a total of 21 (i.e., of going bust) were varied. The different risk levels hold different levels of uncertainty regarding the occurrence of bust outcome. Participants made decisions but were not told the outcomes of those decisions. The findings showed that young and old participants made comparable decisions across risk levels, as measured by the proportion of trials in which participants accepted an additional card. In addition, RT data showed that the decisions of both young and old adults slowed as uncertainty increased (i.e., it took more time to reach a decision on the medium risk level compared to the no risk and high risk levels). However, although the old participants tended to be slower than the young participants, slowing was constant across all risk levels. The authors therefore concluded that the old participants processed information as efficiently as the young participants did, and that the findings did not support the compensation hypothesis according to which age-related slowing should increase as a function of increased uncertainty.

It is possible however, that the task employed by Dror et al. (1998) did not fully load old adults' processing capacity, and that therefore compensation did not occur. It is of interest to examine whether additional variations in the cognitive demands of the task would affect old adults' allocation of processing time. To attain this goal, Experiment 2 uses an additional variation in the demands of the decision-making task used by Dror et al. (1998). In addition to uncertainty, the experiment varies the amount of information regarding decision outcomes. In everyday decision-making a decision's outcome may serve as a reference for future decisions. When decision outcomes are provided, a decision-maker may recall them and take them into account when faced with a new decision (e.g., Garling & Romanus, 1997; Garling, Romanus, & Selart, 1994; Laughhunn & Payne, 1984; Staw, 1981; Thaler & Johnson, 1990; Tversky & Kahneman, 1981). For example, Garling and Romanus (1997) asked undergraduate students to imagine they were on a betting day at a horse-race track. Participants were asked to imagine that on a previous race they had won, lost or had not gambled. The results showed that participants' willingness to gamble on a current race increased after prior win and decreased after prior loss, relative to when no prior gamble had been made.

Reference to prior outcomes implies that additional information is processed during the decision process, as compared to conditions under which there is no reference to prior outcomes (Diehl & Stearman, 1995; Kahneman & Tversky, 1979). As old adults are limited in their information-processing capacity, when faced with additional information (such as, outcomes of prior decisions), they may require more time than young adults to make present decisions. Hines (1979) examined RTs and error rates among young and old adults performing a RT choice task. Participants were required to indicate whether two letters were the same or different. The existence of outcome feedback was manipulated between subjects; half of the participants were given information regarding the accuracy and the speed of their responses, and half of the participants were not provided with any feedback. The results showed that, overall, the old participants were slower on the task than the young participants, but that feedback had a differential effect on the two age groups: feedback speeded the RTs of young participants but slowed the RTs of the old participants. Based on the assumption that the existence of outcomes entails more information to process (Kahneman & Tversky, 1979), and on the findings of Hines (1979), old adults were predicted to be slowed down in their decisions to a greater extent than young adults when decision outcomes are available.

Experiment 2 examined the allocation of time by old adults under two demand conditions: when experiencing decision outcomes (i.e., high demands) and when decision outcomes are not experienced (i.e., low demands). A decision-making task similar to the one developed by Dror et al. (1998) was used. Uncertainty was determined by the card values, each of which has a different probability of a bust outcome to occur. For example, trials with very low uncertainty were trials with either low or high probability of a bust outcome, whereas trials with infinite uncertainty were trials carrying a moderate probability of a bust outcome.[14] It was predicted that when decision outcomes were presented to participants, the processing capacity of old adults would be overloaded, and thus relative to young adults, old adults' RTs would be slowed down to a greater extent when outcomes were provided. It was also predicted that in the outcome condition, the old adults would show a greater rate of

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[14] In Experiment 2 payoff (i.e., the amount to win or lose) was not varied. Payoff variation was included, however, in later experiments (Experiments 4 to 6).

slowing as the level of uncertainty increased. This would produce an interaction between uncertainty and age in the outcome condition. No such interaction was predicted in the no-outcome condition (Dror et al., 1998). Based on the research reviewed above (e.g., Dror et al., 1998; Johnson, 1990, 1993; Meyer et al., 1995) it was also predicted that the two age groups would not differ in their final decisions (i.e., in their willingness to accept an additional card).

5.2. Method

5.2.1. Design

The experiment employed a mixed design, with age (old and young) and outcome (outcome and no-outcome) as the between-subject factors and uncertainty (6 levels, from no uncertainty to infinite uncertainty) as the within-subject factor. Uncertainty was manipulated with respect to the probability of the occurrence of either bust or no-bust outcome. Low or high probability of bust outcome meant that uncertainty was towards the lower end level, whereas moderate probability of bust meant that uncertainty was towards the higher end level. Table 3 shows the uncertainty levels for the card values and the corresponding outcome probability.

Table 3: The cards corresponding to each uncertainty level

Card value	**0**	**1**, 9	**2**, 8	**3**, 7	**4**, 6	5
P(b)[a] or P(nb)[a]	0	.1	.2	.3	.4	.5
Uncertainty level	No	Very low	Low	High	Very high	Infinite

[a] P(b) refers to the probability of a bust outcome for the card values written in bold font and P(nb) refers to the probability of a no-bust outcome for the card values in normal font.

For the purpose of examining the final decisions (i.e., willingness to accept an additional card), the experiment employed a mixed design with age (old and young) and outcome (outcome and no-outcome) as the between-subject factors and card value (10 levels, from zero to nine) as the within-subject factor. Final decisions were measured in the form of the percentage of the trials for which a participant accepted an additional card (Dror et al., 1998). RT was measured from the beginning of a trial (i.e., card presentation) to the participants' response.

5.2.2. Participants

Sixty-nine participants volunteered to take part in the experiment. Thirty-five were old participants (23 females and 12 males), recruited from various senior citizen clubs and church groups in Southampton. Based on the participants' self-reports, all the participants were in good health, not institutionalised, and were both physically and socially active. Their ages ranged between 62 to 86 (mean age 71.3). The young participants were 34 undergraduate Psychology students at the University of Southampton (22 females, 12 males) who volunteered to take part in the experiment in exchange to experimental credits. Their ages ranged between 17 to 42 (mean age 21.1). Participants in both age groups shared similar educational backgrounds, in that they all completed at least secondary school or had an equivalent level of education.[15]

After excluding one old participant (see section 5.3), the number of participants was equal across age groups and outcome conditions, with the same male to female ratio across

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[15] In this experiment as well as in Experiments 3 and 5 the exact number of years spent in formal education were not recorded. This information was, however, recorded in Experiments 1, 4, and 6 which, in practice, were conducted after Experiments 2, 3, and 5. It was at that stage of the research process that the potential influence of education on decision-making performance was recognised (see also footnote 26).

groups. In each outcome condition there were 34 participants (17 young and 17 old) with 12 males (6 young and 6 old) and 22 females (11 young and 11 old).

5.2.3. *Materials*

The materials consisted of pictures of cards (3.8 x 4.9 cm each) presented on a computer screen. A number was displayed at the centre of the card. The numbers on the cards varied between zero and nine. The experiment was programmed using a commercial application for psychological experiments (Cerdrus Corporation, 1991). Participants in the old group were also required to fill in a self-reported health and life-style questionnaire (Appendix F). Both the young and the old participants were also asked to fill in an introspective report about the experiment (Appendix G).

5.2.4. *Procedure*

Participants came into the laboratory for testing. Participants in each age group were randomly assigned to one of the two outcome conditions, and were tested individually in a quiet room. All participants completed the experiment within a single testing session that lasted approximately 20 minutes. Prior to the experiment the participants received the following instructions[16] presented on the computer screen.

> Hello, welcome to the experiment. Thank you very much for your participation. In this experiment you will play a simple card game. The object in each hand is to have the maximum sum of card values but not to exceed 9. If your total is 10 or over then you go bust, and you lose the hand. In each hand you will see one card on the computer screen. The card will have a value between zero to nine. You need to decide whether or not you want another card. The value of the additional card will also be a number between zero to nine. If you think you should take another card, then press the "yes" key. If you think you should not take another card, then press the "no" key. Please think carefully about your

[16] These were the instructions for the first phase of the experiment.

decision. Press the spacebar to continue. [participants were shown an example of an initial card they receive]

You need to decide whether or not you want another card. Remember, you want to have the maximum sum of card values but not to go over 9. If you make a correct decision you will get 10 points, however, if you make an incorrect decision 10 points will be reduced.

[no-outcome condition] Press the spacebar to see an example. [participants were shown two examples of decision outcomes that could follow a "yes" response]

[outcome condition only] Following your response the value of the additional card will be revealed, and whether or not you won or could have won. If you make a correct decision you will get 10 points, however, if you make an incorrect decision 10 points will be reduced. Press the spacebar to see an example. [participants were shown two examples of decision outcomes that could follow a "no" response]

However, if you DON'T choose another card you may still win or lose a hand: If you decide not to take a card and choosing a card would have made you go bust, that means you made a correct decision and you win the hand and get 10 points; if you decide not to take a card and choosing a card would have made you maximise your sum without going bust, that means you lose the hand and 10 points are reduced from your points total. Thus, you can win or lose a hand if you decide to take a card; and you win or lose a hand if you decide not to take a card. [participants were shown two examples of outcome feedback]

[outcome condition] After receiving the additional card, when you are ready you initiate the next hand by pressing the spacebar.

[no-outcome condition] However, in the experiment you will not be told whether you win or lose, and the value of the additional card will not be revealed. Although you are not told the result of your decision in each trial, the computer calculates your points during the experiment.

[both outcome conditions] Your goal is to gain as many points as possible.

[no-outcome condition only] Once you make a decision, an exclamation mark will appear on the screen to signal you that the computer recorded your decision and is ready for the next trial. When you are ready to initiate a trial, press the spacebar.

> Please use your non-dominant hand to press the spacebar, and with your dominant hand use two fingers for the yes/no response. Before beginning the actual experiment there will be ten practice trials. If you have any questions, please ask them during the practice.
> Press the spacebar to begin practice trials.

The instructions were followed by a block of ten practice trials. The experimenter was present during that time to answer any questions participant might wish to ask. Following the practice trials, the experiment was initiated, and the experimenter left the room.

5.2.4.1. The task

The decision-making task employed was modeled as a card game. On every trial, participants were presented with one card that appeared on a computer screen. The object of each trial was to maximise the sum of the cards' values without going over a total of nine. The participants' task was to decide whether or not to take an additional card.[17] If the participant decided to take an additional card, he/she responded by pressing the "yes" key on the keyboard (the "b" key which was labeled "yes"). If he/she decided not to take an additional card he/she pressed the "no" key (the "n" key which was labeled "no"). Participants responded "yes" or "no" using one of two fingers of their dominant hand and used their non-dominant hand to press the spacebar to continue to the next trial. Participants

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[17] The decision-making task was a version of blackjack, and of a task employed by Dror et al. (1998) and Dror et al. (1999). In the experiments presented in this and subsequent chapters the task was simplified, however, so that participants were presented with only one card (excluding the opponent's card). In blackjack, winning or losing is dependent not only on one's own cards, but also on the opponent's cards. For example, a player can maximise the sum of his/her cards without going bust, but would lose the hand if his/her partner had cards of a higher total value; on the other hand, a player could win if his/her partner were to go bust. Dror et al. (1999) showed that the opponent's card affected decisions of young adults. This variable was not of interest and therefore was excluded.

in both outcome conditions were told that they could win or lose points depending on the correctness of their decision. Participants could win or lose an equal number of points, that is, payoff was not varied, rather, it was held constant. If the participant accepted an additional card and the total of the cards' values was below nine, the participant won 10 points; if it exceeded nine he/she lost 10 points. If the participant rejected an additional card and this card could have made the total greater than nine, the participant won 10 points for correctly rejecting a card; if the additional card could have made a total less than nine, 10 points were lost for incorrectly rejecting it. This information was provided in a textual descriptive form as described above, and participants were told that the main goal of the game is to earn as many points as possible. However, they were not told whether the outcomes (i.e., the additional cards they could receive) were determined by chance or by a specific pattern.

5.2.4.2. The structure of the experimental session

Both outcome conditions consisted of two phases. The first phase of the outcome and the no-outcome conditions differed, however, with respect to the existence of outcome feedback. Participants in the outcome condition received outcome feedback following their decision, whereas participants in the no-outcome condition did not received any feedback. The outcome feedback informed participants as to whether or not their decision was correct and whether they had won or lost 10 points, showing the initial card and the additional card they received, or could have received (in case they decided not to take an additional card). The second phase of the outcome and the no-outcome conditions was identical. In the second phase, participants performed the same task but did not receive outcome feedback. Figure 5 shows the structure of the experimental session in the outcome condition and in the no-outcome condition.

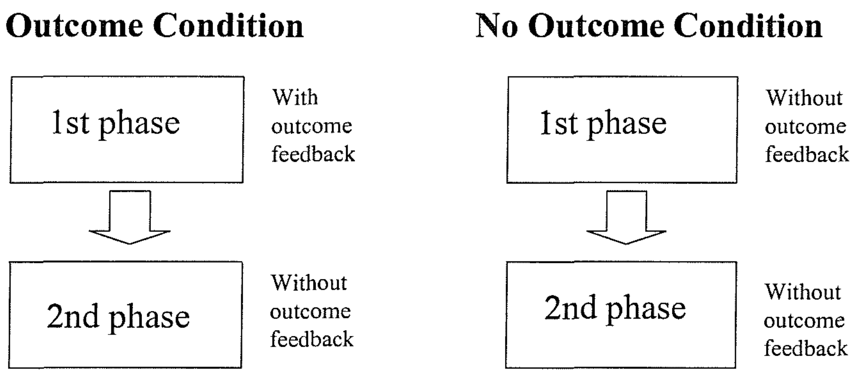

Figure 5: The structure of the experimental session in each outcome condition

In each phase there were 10 blocks of 10 trials each (in total 200 trials), with a random order of trials within each block. Each card value appeared once in each block. The purpose of including the two phases was twofold: One goal was to examine the decision time of old adults when current outcomes were experienced. A second goal was to examine old adults' decision time when they had been provided with outcomes for a previous set of decisions. That each outcome condition consisted of two phases made the number of trials presented in the two outcome conditions equal, and thus controlling for practice effect. The two conditions thus differed only with respect to the provision of outcome feedback during the first phase of the experiment.

5.2.4.3. *First phase: A trial sequence*

Figure 6 presents the sequence of events within a trial during the first phase of the outcome condition. As shown in Figure 6, on every trial a card was displayed until a response was made ("yes" or "no"), following which an outcome feedback is presented. The next trial was initiated by pressing the spacebar.

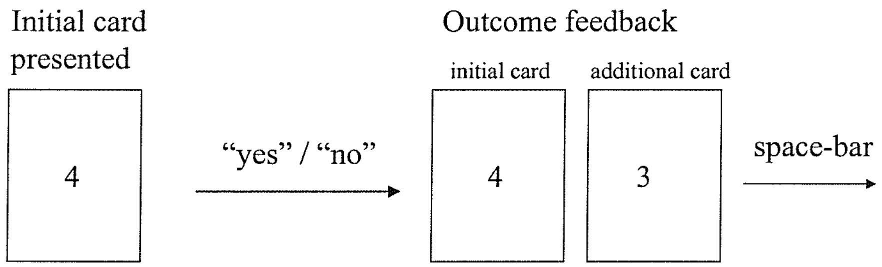

Figure 6: A trial sequence in the first phase of the outcome condition

Figure 7 shows the sequence of events in a trial in the first phase of the no-outcome condition.

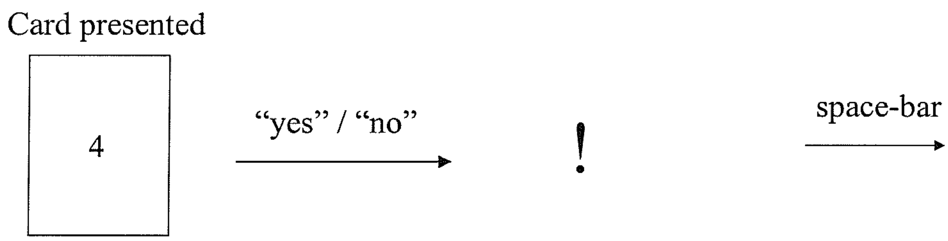

Figure 7: A trial sequence in the first phase of the no-outcome condition

In the first phase of the no-outcome condition participants performed the same task as those in the outcome condition. They were not provided with outcomes following their response, however. Instead, an exclamation mark appeared on the screen and, when ready, participants initiated the next trial by pressing the spacebar. In the first phase of both outcome conditions participants were instructed to think carefully about their decisions and respond in their own time. Participants completed 10 practice trials before beginning the first phase.

- Outcome feedback

As noted above, participants in the outcome condition received outcome feedback following their response. Figure 8 shows the four possible outcomes. [18]

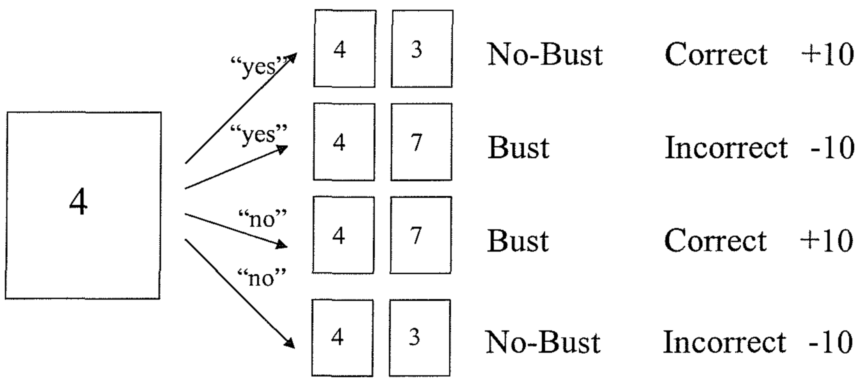

Figure 8: The four possible decision outcomes and the payoff for each outcome

Participants' decisions could be correct or incorrect whether they accepted or rejected an additional card. The correctness of their decision was dependent both on their decision and on whether or not the cards' total value was higher than nine. Specifically, when accepting another card the decision was correct if the total was nine or below (no-bust). If the total was higher than nine (bust), then the decision was incorrect. The decision to reject another card was correct if the potential cards' total could have been bust and incorrect when the cards' total could have been no-bust.

Outcomes were pre-determined in the experimental program in accordance with the actual probability of each card value being paired with a second card that would make a bust total.

[18] Participants in both outcome conditions were informed (in the instructions) about these four possible outcomes.

Table 4 shows the probability of each card's value being paired with an additional card that could produce a bust outcome.

Table 4: Pre-determined probability of bust outcomes for each card value

Card value	0	1	2	3	4	5	6	7	8	9
P(b)[a]	0	.1	.2	.3	.4	.5	.6	.7	.8	.9

[a] P(b) refers to probability of a bust outcome.

The presentation of the initial and additional cards in the outcome feedback was counterbalanced so that each initial card value and additional card value appeared only once in each block. In addition, across blocks, each initial card was paired with all the 10 card values as additional cards. Table 5 shows the initial and the additional cards included in the first phase of the outcome condition.

Table 5: The initial and additional cards included in each trial in the first phase of the outcome condition

Block									
1	2	3	4	5	6	7	8	9	10
0.5.NB	0.4.NB	0.1.NB	0.7.NB	0.2.NB	0.0.NB	0.3.NB	0.8.NB	0.9.NB	0.6.NB
1.7.NB	1.9.B	1.2.NB	1.1.NB	1.6.NB	1.8.NB	1.5.NB	1.0.NB	1.4.NB	1.3.NB
2.3.NB	2.7.NB	2.6.NB	2.0.NB	2.5.NB	2.2.NB	2.9.B	2.4.NB	2.8.B	2.1.NB
3.4.NB	3.1.NB	3.9.B	3.3.NB	3.7.B	3.5.NB	3.6.NB	3.2.NB	3.0.NB	3.8.B
4.0.NB	4.6.B	4.3.NB	4.2.NB	4.9.B	4.1.NB	4.8.B	4.7.B	4.5.NB	4.4.NB
5.1.NB	5.8.B	5.4.NB	5.5.B	5.0.NB	5.6.B	5.2.NB	5.3.NB	5.7.B	5.9.B
6.6.B	6.2.NB	6.8.B	6.9.B	6.3.NB	6.4.B	6.0.NB	6.5.B	6.1.NB	6.7.B
7.9.B	7.0.NB	7.7.B	7.8.B	7.1.NB	7.3.B	7.4.B	7.6.B	7.2.NB	7.5.B
8.8.B	8.5.B	8.0.NB	8.6.B	8.4.B	8.9.B	8.7.B	8.1.NB	8.3.B	8.2.B
9.2.B	9.3.B	9.5.B	9.4.B	9.8.B	9.7.B	9.1.B	9.9.B	9.6.B	9.0.NB

Note. The first number represents the initial card participants receive; the second number represents the additional card they received or could have received in this trial, and which was presented in the outcome feedback. The letters 'NB' represent no-bust trails and 'B' stands for bust trials.

As noted above, there were 100 trails in each phase of the experiment. Fifty-five trials were no-bust trials (including trials with a sum equal nine) and 45 trails were bust trials. Half of the blocks included five no-bust and five bust trials and half of the blocks included six no-bust and four bust trials.

5.2.4.4. *Second phase*

On completion of the first phase, participants in both outcome conditions proceeded to the second phase, which was identical for both conditions. The trial sequence in the second phase was identical to the trial sequence in the first phase of the no-outcome condition (see Figure 7 above). That is, following a response, participants were not informed about the outcomes of their decision. Rather, an exclamation mark appeared on the screen. When participants were ready they pressed the spacebar to initiate the next trial. Different from the first phase of the experiment, in the second phase participants (in both outcome conditions) were instructed to respond as quickly and accurately as possible after the card appeared on the screen. [19] Participants were given three practice trials before the beginning of the second phase.

When participants had completed the session they were asked to fill in an introspective report about the experiment (Appendix G). The old participants were also required to fill in a questionnaire regarding their health status, and their social and physical activities (Appendix F).

5.3. Results

Analyses were performed separately on percentage of "yes" responses and RTs data from each phase of the experiment. The percentage of "yes" responses was analysed using mixed

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[19] There was no reason for applying time pressure in the second phase of the experiment. Time pressure in this phase was later recognised as a confounding variable, though this variable was of use in post hoc analysis (see discussion).

design ANOVA in which the between-subject factors were age and outcome and the within-subject factor was card value. The RT data were analysed using mixed design ANOVA in which the between-subject factors were age and outcome and the within-subject factor was uncertainty. The data of one participant from the old group was excluded because she did not follow the instructions during the second phase of the experiment; the participant did not respond either "yes" or "no" in 26% of the trials in the second phase.

5.3.1. *First phase*

The aim of the first phase was to examine whether the existence of current outcomes affects decision-making by old adults. Analyses excluded trials on which participants did not press either "yes" or "no" key, or on which responses had been made in less than 175 milliseconds (ms) from the beginning of a trial. In the old group 0.35% of trials were excluded and in the young group 0.09% of trials were excluded.

5.3.1.1. *Percentage of "yes" responses*

To examine whether final decisions were affected by the presentation of outcomes, the percentage of trials in which an additional card was accepted for each card value was examined. Mixed design ANOVA showed a significant main effect of card value, $F(3.33, 212.91) = 574.46, p < .001$, reflecting the finding that participants were more reluctant to accept an additional card as card value increased. Figure 9 shows the mean percentage of "yes" responses as a function of card value collapsed across age and outcome conditions. Age and outcome were collapsed because they did not affect performance.

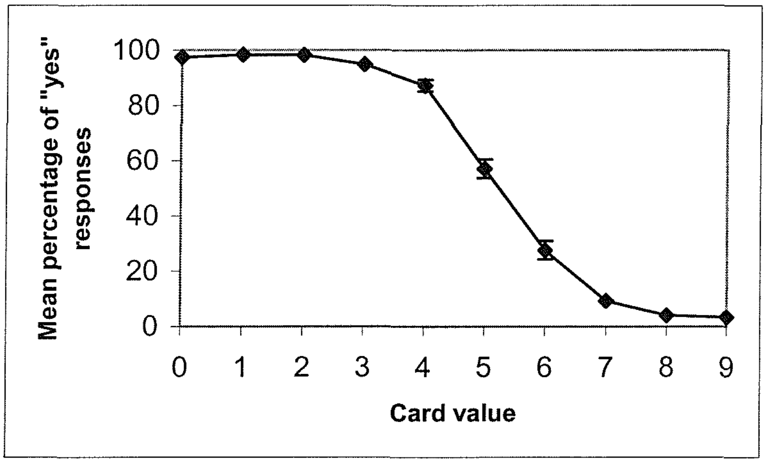

Figure 9: Mean percentage of "yes" response as a function of card value collapsed across age and outcome conditions (first phase)

There was no main effect of age, $F(1, 64) = 0.27, p > .05$ and no main effect of outcome, $F(1, 64) = 1.45, p > .05$. The interactions between card value and age, $F(3.33, 212.91) = 0.57, p > .05$, card value and outcome, $F(3.33, 212.91) = 0.43, p > .05$, and card value, age, and outcome, $F(3.33, 212.91) = 0.53, p > .05$, were not significant.

A possible reason for the absence of a significant interaction involving age, however, is a higher variance in the data of old adults (e.g., Rabbitt, 1993). The old group had slightly higher variance (SD = 7.3) compared to the young group (SD = 6.02). To examine the possibility that higher variance in the data of the old group eliminates a significant interaction involving age, the data of the two age groups was transformed using square root transformation (Howell, 1987). The square root transformation[20] was performed on the mean percentage of "yes" responses for each card value of each participant in both age groups. ANOVA on the transformed data showed the same findings as the analyses on the

[20] Since some of the values on which the transformation was performed were small (less than 10), the value 0.5 was added to the mean choice probability values before the transformation was performed (Howell, 1987).

raw data. There was a significant main effect of card value, $F(3.53, 225.83) = 444.75$, $p < .001$. No other main effects or interactions were significant. There was no main effect of age, $F(1, 64) = 0.27$, $p > .05$ and no main effect of outcome, $F(1, 64) = 0.03$, $p > .05$. The interactions between card value and age, $F(3.53, 225.83) = 0.50$, $p > .05$, card value and outcome, $F(3.53, 225.83) = 1.08$, $p > .05$, and card value, age, and outcome, $F(3.53, 225.83) = 0.78$, $p > .05$, were not significant.

5.3.1.2. RTs

Outliers in RT data were checked for each participant. Outliers were defined as RT scores greater than 2.5 standard deviations (SD) above the mean of the remaining scores for each card value. In the old group 0.02% of the trials were excluded. No outliers were found in the young group. Outliers were also checked across participants. Participants who produced RTs which were 2.5 SD above the mean of the rest of the participants in their age group in each outcome condition were excluded from the analyses. Overall, six old (out of 34) and six (out of 34) young participants were excluded.

In the first phase of the experiment the effect of current outcomes on the old group's RTs was examined. Figure 10 shows the mean RTs as a function of outcome and age, and Figure 11 shows mean RTs as a function of uncertainty and age in each outcome condition.

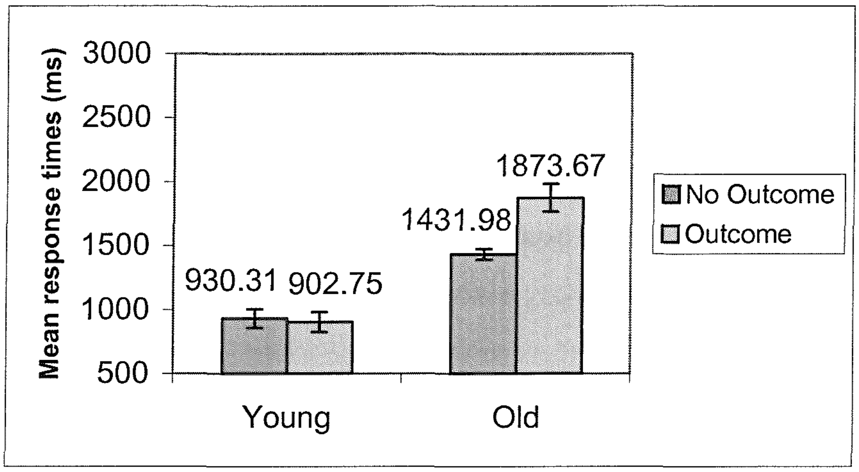

Figure 10: Mean RTs as a function of outcome condition and age (first phase)

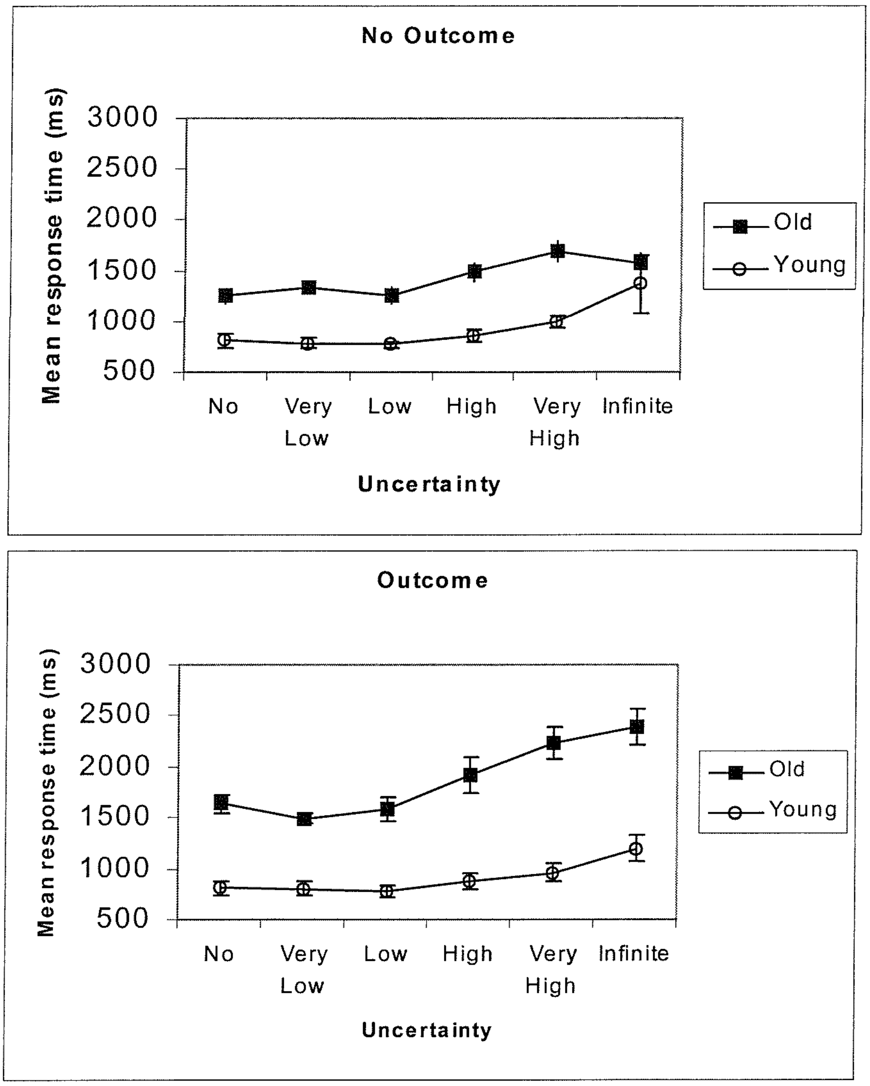

Figure 11: Mean RTs as a function of uncertainty and age in each outcome condition (first phase)

Mixed design ANOVA showed a significant main effect of uncertainty, $F(2.53, 131.31) = 30.31$, $p < .001$. This trend was significantly linear, $F(1, 52) = 69.2, p < .001$, suggesting that participants became slower as uncertainty increased. There was a significant main effect of age, $F(1, 52) = 85.61$, $p < .001$. Overall, the old adults were slower than the young adults. The old adults' mean RTs was 1653 ms (SD = 377) and the young adults' mean RTs was 916 ms (SD = 281). The main effect of outcome was significant, $F(1, 52) = 6.77, p < .05$.

There was a significant interaction between uncertainty and age, $F(2.53, 131.31) = 3.14$, $p > .05$, and a significant interaction between outcome and age, $F(1,52) = 8.69$, $p < .01$. Further to examine the interaction between outcome and age, independent-sample t-tests (using Bonferroni correction, $p < .025$) were performed on the data of each age group comparing between the two outcome conditions. There was a significant difference between the two outcome conditions in the old group, $t(26) = -.79$, $p < .01$, suggesting the old adults were slower under the outcome condition. The difference was not significant in the data of the young group, $t(26) = 0.26$, $p > .025$.

The analyses also showed a significant interaction between outcome, uncertainty, and age, $F(2.53, 131.31) = 3.21$, $p < .05$. To examine the quality of the magnitude of the age differences in RT, tests of within-subjects contrasts were performed. The tests confirmed a significant linear interaction between age, uncertainty, and outcome, $F(1, 52) = 5.69$, $p < .05$, suggesting that outcome differentially affected the two age groups' rate of slowing across uncertainty. Further to examine the three-way interaction (that is, to find out in which outcome condition the interaction between age and uncertainty was present), mixed design ANOVA with uncertainty as the within-subject factor and age as the between-subject factor was performed on the data of each outcome condition. There was a significant interaction between uncertainty and age in the outcome condition, $F(2.79, 75.19) = 5.75$, $p < .01$. This interaction was significantly linear, $F(1, 27) = 9.80$, $p < .01$, suggesting that the differences between the two age groups' RTs across uncertainty increased as uncertainty increased under the outcome condition. The interaction between uncertainty and age was not significant in the no-outcome condition, $F(1.89, 47.28) = 1.67$, $p > .05$.

5.3.2. Second phase

The aim of the second phase was to examine how outcomes, which were already experienced in the first phase, affected later decisions. Analyses again excluded trials on which participants did not press either "yes" or "no" key as well as responses which were made in less than 175 ms. In the old group 0.09% of trials were excluded and in the young group 0.18% of trials were excluded.

5.3.2.1. Percentage of "yes" responses

Mixed design ANOVA showed a significant main effect of card value, $F(3.12, 199.59) = 599.11$, $p < .001$, suggesting that as the card value increased, participants were more reluctant to accept another card. Figure 12 shows the mean percentage of "yes" responses as a function of card value collapsed across age and outcome conditions. Age and outcome were collapsed because these variables did not affect performance.

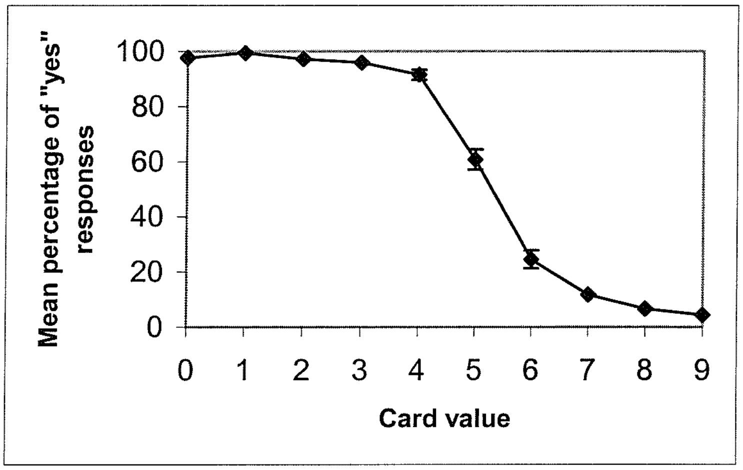

Figure 12: Mean percentage of "yes" response as a function of card value collapsed across age and outcome conditions (second phase)

There was niether a main effect of age, $F(1, 64) = 0.07, p > .05$, nor a main effect of outcome, $F(1, 64) = 0.05, p > .05$. The inetarctions between outcome and age, $F(1, 64) = 0.07, p > .05$, card value and age, $F(3.12, 199.59) = 0.66, p > .05$, card value and outcome, $F(3.12, 199.59) = 0.89, p > .05$, and card value, outcome, and age, $F(3.12, 199.59) = 1.11, p > .05$, were not significant. ANOVA on the square root transformed data showed the same results. There was a significant main effect of card value, $F(3.71, 237.53) = 421.63, p <$

.001, but no other significant main effects or interactions. There was niether a main effect of age, $F(1, 64) = 0.02$, $p > .05$, nor a main effect of outcome, $F(1, 64) = 0.20$, $p > .05$. The inetarctions between outcome and age, $F(1, 64) = 0.11$, $p > .05$, card value and age, $F(3.71, 237.53) = 1.14$, $p > .05$, card value and outcome, $F(3.71, 237.53) = 0.74$, $p > .05$, and card value, outcome, and age, $F(3.71, 237.53) = 0.94$, $p > .05$, were not significant.

5.3.2.2. RTs

In the old group 0.01% of the responses were identified as outliers. No outliers were identified in the young group. Five old participants (out of 17) and two young participants (out of 17) were excluded from the analyses because of producing RTs which were 2.5 SD above the mean of the rest of the participants in their age group in each outcome condition.

In the second phase the effect of outcomes which were presented in a previous set of decisions on RTs of old adults was examined. Figure 13 shows mean RTs as a function of uncertainty for the young and the old participants in both outcome conditions.

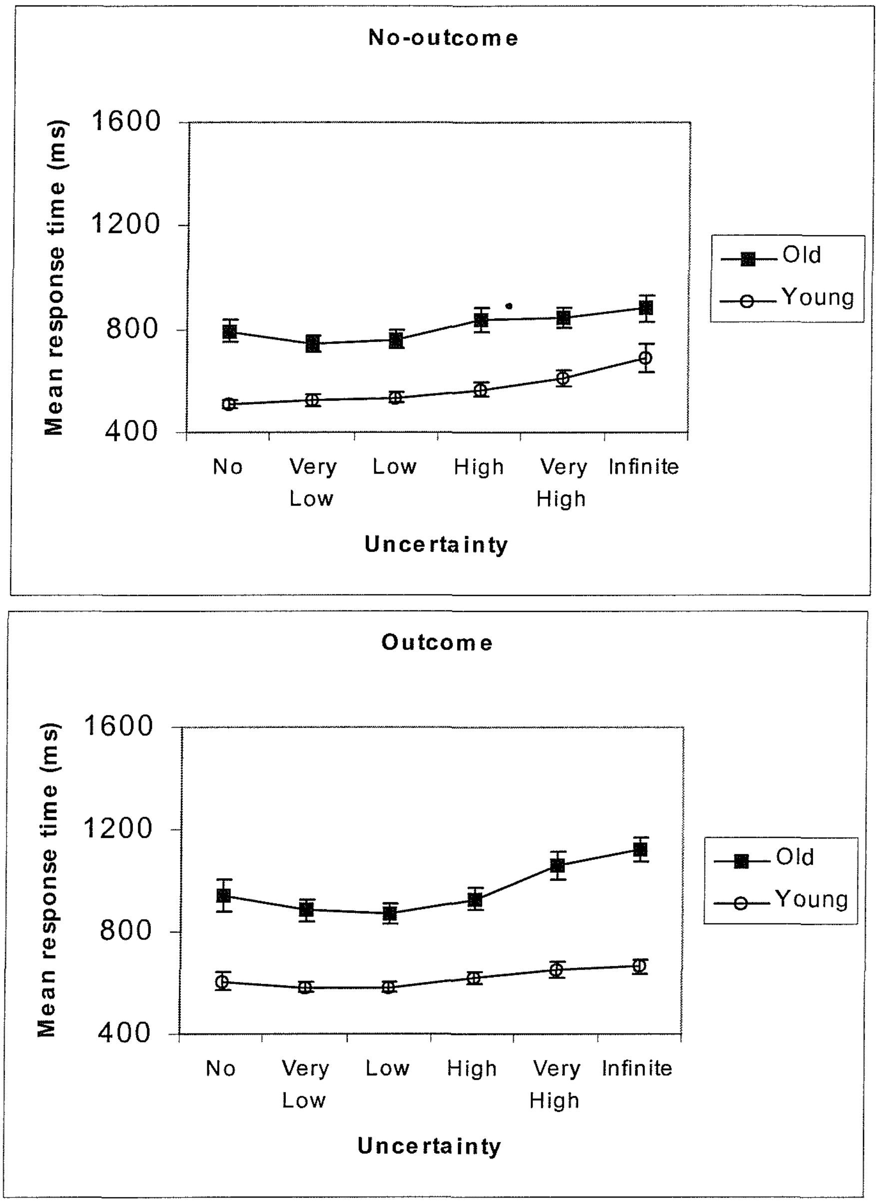

Figure 13: Mean RTs as a function of uncertainty and age in each outcome condition (second phase)

Mixed design ANOVA showed a significant main effect of age, $F(1, 57) = 91.44$, $p < .001$. The old adults' mean RT was 886 ms (SD = 158) and the mean young adults' RT was 596 ms (SD = 100). The main effect of outcome was significant, $F(1, 57) = 10.90$, $p < .001$. There was a main effect of uncertainty, $F(3.44, 196.33) = 28.31$, $p < .01$, and a significant interaction between outcome, uncertainty, and age, $F(3.44, 196.33) = 3.60$, $p = .011$, which was significantly linear, $F(1, 57) = 7.01, p = .01$. The interaction between outcome and age was marginally significant, $F(1, 57) = 3.39, p = .071$. The interactions between outcome and uncertainty, $F(3.44, 196.33) = 0.86, p > .05$, and uncertainty and age, $F(3.44, 196.33) = 1.56, p > .05$, were not significant.

Further to examine the three-way interaction, a mixed design ANOVA, in which age as the between-subject factor and uncertainty as the within-subject factor, was performed on the data of each outcome condition. In the outcome condition there was a significant interaction between age and uncertainty, $F(3.43, 95.9) = 4.43, p < .01$, which was significantly linear, $F(1, 28) = 16.24, p < .001$, and quadratic, $F(1, 28) = 5.28, p < .05$. In the no-outcome condition the interaction between age and uncertainty was not significant, $F(2.23, 64.66) = 0.9, p > .05$. These data indicate that compared to participants in the young group, those in the old group showed a greater increase in RTs with increased uncertainty in the outcome condition, but not in the no-outcome condition.

5.4. Discussion

The aim of Experiment 2 was to examine whether the demands placed by a decision-making task (determined by the presence of decision outcomes) affect the RTs of old adults. This question was examined both when current outcomes were provided (i.e., during the first phase of the experiment) and when outcomes were experienced in a previous set of trials provided (i.e., examining RTs in the second phase). The patterns of results in both phases of the experiment were similar. As expected, the participants in the old group made the same final decisions as did those in the young group (as measured by the percentage of trials for which an additional card was accepted). The analyses on the transformed data showed the same results, suggesting that high variance in the data of the old group did not underlie the absence of significant interactions involving age. These findings are consistent with those of Dror et al. (1998) who used a similar decision-making task, and with previous research (e.g., Johnson, 1993, 1997; Meyer et al., 1995; Walsh & Hershey, 1993) that has reported no age differences in everyday decisions. Consistent with Dror et al., (1998), the RT data showed that the old adults took longer to make a decision than the young adults did. The results also showed that current outcome information provided during the first phase of the experiment had differentially affected the RTs of young and old adults: Young adults were not affected by the provision of outcomes, but old adults became slower. This finding is consistent with that of Hines (1979) who found that outcome feedback slowed down old adults on a choice RT task, but did not slow down the young adults.

The main finding of Experiment 2 is that the existence of outcomes, whether current or previously experienced, had a differential effect on the old group's rate of slowing across uncertainty. Consistent with the findings of Dror et al. (1998), when participants were not provided with outcomes, the old participants did not show a greater slowing under increased uncertainty as compared to the young participants. However, when outcomes were experienced, either in current trials or in previous ones, relative to the young group, the old group showed a greater increase in RT as uncertainty increased.

These findings extend those of Dror et al. (1998) by showing that in a more demanding decision task (i.e., when participants get to know their decision outcomes), old adults took more time to make a decision. The data also show that the cognitive demands of a decision-making task can be a factor mediating age differences in decision-making performance. However, one may argue that the decision task employed in this experiment was actually simpler than that employed by Dror et al. (1998). In Dror et al.'s (1998) study, participants were presented with two cards and had to sum up their values before making a decision. In the present experiment, however, participants received only one card and no summing up was required. The question then arises as to why the existence of decision outcomes places greater processing demands than the necessity of making out the sum of two numbers. The question may be accounted for by the robust finding that simple mental arithmetic ability does not degrade with age, and may even improve (e.g., Pesta et al., 1996). For old adults, the process of summing-up may be less demanding than reference to decision outcomes, because the former draws on a practised skill. Moreover, reference to decision outcomes requires retrieval from episodic memory, which old adults find difficult, in particular when concurrent processing is required (i.e., responding under different uncertainty levels). This interpretation is consistent with the findings of Riby et al. (2000) who showed that old adults were slower than young adults in an episodic memory retrieval task and that this slowing was stronger under conditions of increased processing load (i.e., dual-task).

The findings that the old adults reached the same decisions as the young adults in both outcome conditions but were slowed down to a greater extent in the outcome condition[21] support the compensatory hypothesis. According to the compensatory hypothesis, when information-processing demands exceed old adults' processing capacity, they are able to reach the same decisions as young adults by utilising more time to process information. This account of the findings is consistent with the proposal that old adults have a limited working memory capacity as well as less efficient episodic memory retrieval processes.

The findings can also be accounted for by a different explanation. Old adults may become slower when they are informed of their decision outcomes because they have set a more cautious decision criterion (Ratcliff et al., 2000; Smith & Brewer, 1995). Knowing the outcomes of their decisions may have led the old participants to be concerned about their performance, taking more time to try to ensure making correct decisions. This explanation is consistent with studies showing that old adults (but not young adults) tend to value accuracy over speed (Salthouse, 1979; Salthouse & Somberg, 1982; Strayer et al., 1987).

[21] These findings carry an important methodological implication; namely that the existence of outcome feedback is a factor contributing to age differences in RTs. This factor should be taken into account when experiments aim to examine age differences in cognitive performance are designed.

Although the above explanation seems plausible, the data from the second phase of Experiment 2, in which time pressure on decision-making was imposed (see footnote 19), supports the explanation that old adults have a less efficient decision process. According to the SSM (see section 2.3.2.2), when time pressure is imposed, the decision threshold is reduced, and less information is accumulated. The explanation was supported by Dror et al. (1999) who showed that time pressure had the effect of reducing slowing rate across uncertainty increased in young adults. In the present experiment, the data from the second phase showed that even under conditions of time pressure under which the decision threshold is reduced[22], the old adults in the outcome condition still showed a greater increase in RT as a function of uncertainty relative to the young group. These data support the hypothesis that the increase in RTs under high uncertainty in the old group was a result of a slower decision process, and thus, cannot be accounted for merely by age differences in decision threshold. This interpretation is consistent with studies that have demonstrated that response criterion is not the only factor contributing to age differences in various cognitive tasks (Hertzog et al., 1993; Salthouse, 1979; Strayer et al., 1987). Together with the finding that the final decisions were comparable between the two age groups, the results of Experiment 2 support the notion of compensation via allocation of more processing time in old age.

The findings of Experiment 2 showed that the old adults processed outcomes of prior decisions when making present decisions. Decision outcomes were determined by the card value probability (i.e., the probability that this value would be paired with an additional card

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[22]To check whether time pressure had the effect of reducing the decision threshold, RTs in the first phase (no time pressure) and the second phase (with time pressure) of the experiment were compared in each age group in the outcome condition (where the interaction between age and uncertainty exists). It was found that time pressure indeed flattened the RT curve of both age groups (i.e., had the effect of reducing the threshold). For details on the analyses used see Appendix H.

resulting in a bust total). Participants could therefore make use of the probability expressed by the card value without referring to the outcomes they have experienced. The outcome information might, nevertheless, have been processed during the decision-making process of the present decision-problem. Introspective reports completed by both age groups suggested that both the young and the old participants assumed outcomes to carry information that needed to be attended to and were trying to find a probabilistic pattern in the occurring outcomes. Nevertheless, it is not clear to what extent this information has been processed. Because the probability of decision outcomes experienced by participants in the outcome condition was the same as the probability expressed by the card values, reference to outcome information indeed did not lead to different decisions from those that were made with no reference to prior outcomes (i.e., no-outcome condition). It will therefore be interesting to examine how decisions themselves are affected when prior outcomes do not follow the same bust probability that is expressed by the card value; rather, when they are determined by a different probability (i.e., biased) from which participants could estimate the likelihood of winning and loosing. This question will be addressed in Experiment 3. Experiment 3 will therefore provide an opportunity to examine the allocation of more time by old adults when outcomes of decisions carry information that can affect later decisions.

6. EXPERIMENT 3: Allocating increased processing time in old age: The effect of biased outcomes

6.1. Introduction

Experiment 2 demonstrated that during decision-making old adults process outcomes of prior decisions. This conclusion was based on the findings that the presence of decision outcomes increased the time it took the old adults to make a decision, and that relative to the young adults, they showed a more profound slowing as uncertainty increased under this condition. As participants in the old group reached the same decisions as those in the young group, their allocation of more processing time under increased task demands (outcome condition) can be taken to support the compensation hypothesis. However, the outcomes participants experienced in Experiment 2 had no effect on later decisions (of participants from both age groups) because these outcomes followed the outcome probability (i.e., bust probability) expressed by the cards' values (see Table 4). That is, the outcome probability that participants in the outcome condition experienced was identical to the outcome probability that could be estimated from the card values in the no-outcome condition.

Experiment 3 had two aims. Firstly, to examine whether old adults are affected by decision outcomes that indicate outcome probability different from the one conveyed by the card values (i.e., biased outcomes), and secondly, to examine whether old adults allocate more processing time than young adults when processing these biased outcomes. On the basis of studies showing that old adults are as capable as young adults at inferring frequency of events (e.g., Hasher & Zacks, 1979; Kausler et al., 1981; Sanford & Maule, 1973), it was predicted that old adults would be able to extract the probabilistic information conveyed by biased outcomes. Based on the findings of Experiment 2, it was also predicted that old adults would allocate more time than young adults to process biased outcomes.

To achieve the above aims, this experiment included two between-subject outcome bias conditions that conveyed a bust probability that was different from the bust probability conveyed by the card values (see Table 4): The positive condition had a higher probability of no-bust outcomes and the negative condition had a higher probability of bust outcomes. Prior experience of positive bias and negative bias outcomes was predicted to affect later decisions: prior experience of positive biased outcomes was predicted to result in a higher percentage of trials on which participants would accept another card as compared to prior experience with negative biased outcomes.

RTs were also measured in order to examine whether processing of biased outcomes was accompanied by an increase in processing time on the part of the old adults. Compared to young adults, old adults were expected to be slowed down to a greater extent as uncertainty increased when they processed biased outcome information. The finding that old adults are able to utilise the biased probability information conveyed by decision outcomes while at the same time demonstrating an increase in RT could provide further support for the proposal that the allocation of more time to processing outcome information allows old adults to reach the same decisions as young adults, thus supporting the compensation hypothesis.

6.2. Method

6.2.1. Design

Experiment 3 employed a mixed design. For the purpose of examining final decisions (i.e., the percentage of "yes" responses), age (young and old) and outcome bias (positive and negative) were the between-subject factors and card value (ten level from card value zero to card value nine) was the within-subject factor. When RTs were examined, the ten card values were collapsed to six uncertainty levels as in Experiment 2, producing a mixed design with age (young and old) and outcome bias (positive, and negative) as the between-subject factors and uncertainty (six levels from no uncertainty to infinite uncertainty) as the within-subject factor.

The outcome bias manipulation consisted of varying the probability of a bust outcome between two conditions: Positive and negative. The manipulation was done in relation to the outcome probability of bust outcome as expressed by the card values. Relative to the probability expressed by the card values, the positive condition had a higher probability of no-bust outcomes and the negative condition had a higher probability of bust outcomes. This manipulation was applied only to card values between 3 and 7.[23] The bust probabilities for the positive and negative conditions were equally changed. For the positive condition, the probability of bust was reduced (relative to bust probability expressed by the card value) by 0.1 for cards 3 and 7, and by 0.2 for the cards 4, 5, and 6. For the negative condition, the probability of bust was increased (relative to bust probability expressed by the card value) by 0.1 for cards 3 and 7 and by 0.2 for the cards 4, 5, and 6. Table 6 presents the probabilities of a bust outcome for each card value in the outcome bias conditions in relation to the bust probabilities expressed by the card values.

[23] The probability manipulation was applied to these card values because uncertainty regarding the outcome of a decision is maximised at these values.

Table 6: Probabilities of bust outcome for each card value in each outcome bias condition as compared to the bust probability expressed by the card value

Card value	0	1	2	3	4	5	6	7	8	9
P(b) card value	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
P(b) positive bias	.0	.1	.2	.2	.2	.3	.4	.6	.8	.9
P(b) negative bias	.0	.1	.2	.4	.6	.7	.8	.8	.8	.9

Note: P(b) refers to the probability of a bust outcome.

To produce the negative condition, eight out of 100 trials from the outcome condition in Experiment 2 were modified to bust outcomes trials (see Table 7 below) and to produce the positive condition, the same number of trials were modified to no-bust outcomes trials (see Table 8 below). These changes had a number of restrictions to ensure that the positive and negative manipulations were equal and symmetrical (see Appendix I for details). The percentage of "yes" responses as well as RTs were measured.

6.2.2. Participants

Participants consisted of 52 volunteers. Twenty-six participants (16 females, 10 males) were old adults who were recruited from various senior citizen clubs and church groups in Southampton. Based on the participants' self-reports, all the participants were in good health, were not institutionalised, and were physically and socially active. Their ages ranged between 61 to 84 (mean age 72.1). The young participants were 26 Psychology undergraduate students at the University of Southampton (16 females, 10 males) who volunteered to take part in the experiment in exchange for experimental credits. Their ages ranged between 18 to 42 (mean age 21.4). The young and the old participants had a similar educational background in that they had all completed at least secondary school or equivalent.

6.2.3. Materials

The materials were the same as in Experiment 2.

6.2.4. Procedure

Participants came into the laboratory for testing. In each age group, thirteen participants (eight females and five males) were randomly assigned to one of two outcome bias conditions, either positive or negative. Participants were tested individually in a single testing session that lasted approximately 10 to 15 minutes. Unlike Experiment 2, Experiment 3 was composed of only one phase. Participants were required to perform a decision-making task, identical to the task performed in the outcome condition of Experiment 2 (see section 5.2.4). As before, participants were told in the instructions that they could win 10 points or lose 10 points depending on the correctness of their decision, and the outcome feedback also included the number of points won or lost following the decision that participants made.

Prior to beginning the task, participants received the same instructions as in the outcome condition in Experiment 2 (see section 4.2.4). The instructions were presented on the screen followed by ten practice trials. The practice trials of the two outcome bias conditions differed in the number of bust to no-bust trials. In the positive condition the practice trials included six no-bust trials and four bust trials, and in the negative condition there were four no-bust practice trials and six bust practice trials. Participants were not told whether outcomes were determined by chance or by a deterministic (i.e., biased) pattern. Throughout presentation of the instructions and practice trials the experimenter stayed in the room with the participant to answer any questions the participant might have regarding the task. Following the practice trials, the task was continued and the participant was left to complete the task. Participants were instructed to perform the task in their own time. Table 7 shows the initial and additional cards for trials included within each block in the biased negative condition (for the restrictions that guided the presentation of initial and additional cards see Appendix I).

Table 7: The trials included in each block in the negative condition

Block									
1	2	3	4	5	6	7	8	9	10
0.5.NB	0.4.NB	0.1.NB	0.7.NB	0.2.NB	0.0.NB	0.3.NB	1.0.NB	0.9.NB	0.6.NB
1.7.NB	1.9.B	1.2.NB	1.1.NB	1.6.NB	1.8.NB	1.5.NB	0.8.NB	1.4.NB	1.3.NB
2.3.NB	2.7.NB	2.6.NB	2.0.NB	2.5.NB	2.2.NB	2.9.B	2.4.NB	2.8.B	2.1.NB
3.9.B	3.1.NB	3.9.B	3.3.NB	3.7.B	3.5.NB	3.6.NB	3.2.NB	3.0.NB	3.8.B
4.0.NB	4.6.B	**4.9.B**	4.2.NB	4.9.B	4.1.NB	4.8.B	4.7.B	4.5.NB	**4.8.B**
5.1.NB	5.8.B	5.4.NB	5.5.B	5.0.NB	5.6.B	**5.7.B**	**5.8.B**	5.7.B	5.9.B
6.6.B	**6.6.B**	6.8.B	6.9.B	6.3.NB	6.4.B	6.0.NB	6.5.B	**6.7.B**	6.7.B
7.9.B	7.0.NB	7.7.B	7.8.B	**7.6.B**	7.3.B	7.4.B	7.6.B	7.2.NB	7.5.B
8.8.B	8.5.B	8.0.NB	8.6.B	8.4.B	8.9.B	8.7.B	8.1.NB	8.3.B	8.2.B
9.2.B	9.3.B	9.5.B	9.4.B	9.8.B	9.7.B	9.1.B	9.9.B	9.6.B	9.0.NB

Note. The first number represents the initial card participants received, and the second number represents the additional card they chose or could have chosen in this trial. The letters 'NB' represent no-bust trails and 'B' stands for bust trials. The trials in bold are the trials that were modified to bust trials.

Table 8 shows the initial and additional cards for trials included within each block in the biased positive condition.

Table 8: The trials included in each block in the positive condition

Block									
1	2	3	4	5	6	7	8	9	10
0.5.NB	0.4.NB	0.1.NB	0.7.NB	0.2.NB	0.0.NB	0.3.NB	1.0.NB	0.9.NB	0.6.NB
1.7.NB	1.9.B	1.2.NB	1.1.NB	1.6.NB	1.8.NB	1.5.NB	0.8.NB	1.4.NB	1.3.NB
2.3.NB	2.7.NB	2.6.NB	2.0.NB	2.5.NB	2.2.NB	2.9.B	2.4.NB	2.8.B	2.1.NB
3.4.NB	3.1.NB	**3.4.NB**	3.3.NB	3.7.B	3.5.NB	3.6.NB	3.2.NB	3.0.NB	3.8.B
4.0.NB	4.6.B	4.3.NB	4.2.NB	**4.4.NB**	4.1.NB	**4.3.NB**	4.7.B	4.5.NB	4.4.NB
5.1.NB	**5.2.NB**	5.4.NB	5.5.B	5.0.NB	5.6.B	5.2.NB	5.3.NB	**5.3.NB**	5.9.B
6.2.NB	6.2.NB	6.8.B	6.9.B	6.3.NB	6.4.B	6.0.NB	6.5.B	6.1.NB	**6.1.NB**
7.9.B	7.0.NB	7.7.B	7.8.B	7.1.NB	7.3.B	7.4.B	**7.1.NB**	7.2.NB	7.5.B
8.8.B	8.5.B	8.0.NB	8.6.B	8.4.B	8.9.B	8.7.B	8.1.NB	8.3.B	8.2.B
9.2.B	9.3.B	9.5.B	9.4.B	9.8.B	9.7.B	9.1.B	9.9.B	9.6.B	9.0.NB

Note. The first number represents the initial card participants received, and the second number represents the additional card they chose or could have chosen in this trial. The letters 'NB' represent no-bust trails and 'B' stands for bust trials. The trials in bold are the trials that were modified to no-bust trials.

As in Experiment 2, participants completed an introspective report about the experiment at the end of the session. The old participants were also required to fill in a questionnaire regarding their health status, and their social and physical activities (Appendix F).

6.3. Results

Analyses were performed separately on percentage of "yes" responses and RTs. The percentage of "yes" responses data were analysed using a mixed design ANOVA in which the between-subject factors were age and outcome bias and the within-subject factor was card value. The RT data were analysed using a mixed design ANOVA in which the between-subject factors were age and outcome bias and the within-subject factor was uncertainty. Trials on which participants had not pressed either the "yes" or "no" key, or on which they had responded in less than 175 ms were excluded from the analyses. In the old group 0.44% of the trials were excluded and in the young group 0.07% of the trials were excluded.

6.3.1. Percentage of "yes" responses

To examine how final decisions were affected by positive and negative biased outcomes, the percentage of trials in which an additional card was accepted was examined as a function of card value. Figure 14 shows the mean percentage of "yes" responses as a function of card value and outcome bias collapsed across age groups. Age was collapsed because it did not affect performance (see p. 119 for analyses of age main effect and interactions involving age).

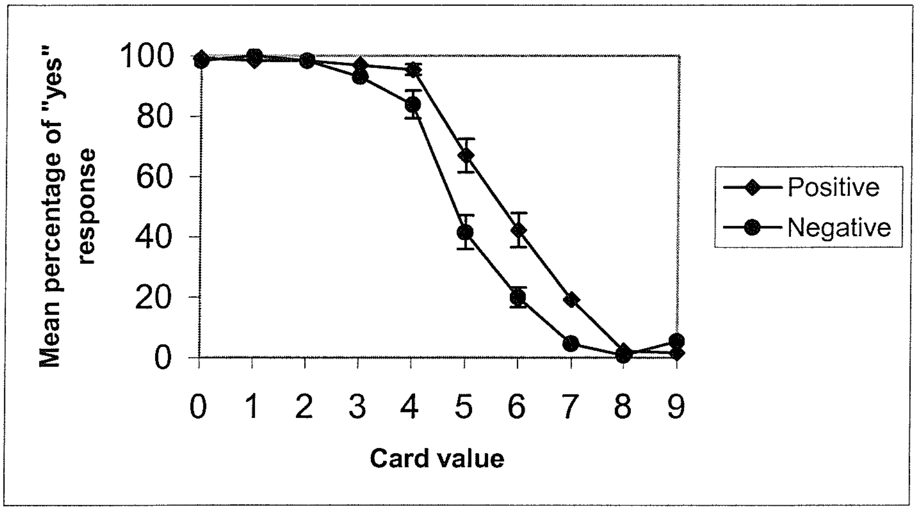

Figure 14: Mean percentage of "yes" responses as a function of card value and outcome bias collapsed across age groups

ANOVA showed a significant main effect of card value, $F(3.2, 153.67) = 525.66, p < .001$, reflecting the finding that participants were more reluctant to take an additional card as the card value increases. There was also a significant main effect of outcome bias, $F(1, 48) = 15.67, p < .001$. Participants in the negative condition were less willing to accept an additional card than those in the positive condition. In the negative condition the mean percentage of "yes" responses was 53.46 (SD = 6.34) and in the positive condition it was 61.00 (SD = 7.27). There was a significant interaction between card value and outcome bias, $F(3.2, 153.67) = 5.63, p < .01$. This interaction suggests that the effect of outcome differed across card values. As Figure 14 shows, the curves (i.e., mean percentage of "yes" responses) in the positive and the negative conditions differed on the moderate card values (i.e., card values 4 to 7). Relative to the positive condition, participants in the negative condition showed a decrease in the percentage of trials in which an additional card was accepted on the moderate card values.

Further to examine the interaction between outcome bias and card value, independent sample t-tests (using Bonferroni correction, $p < .025$) comparing the two outcome bias conditions, were performed on the percentage of "yes" responses for card values that their outcome probabilities were manipulated (i.e, percentage of "yes" responses averaged across card values 3, 4, 5, 6, and 7) and on the percentage of "yes" responses for the card values that their probabilities were not manipulated (i.e., percentage of "yes" responses averaged across card values 0, 1, 2, 8, and 9). T-test (not assuming equal variances) on the data of the card values for which outcome probabilities were manipulated showed a significant difference in the mean percentage of "yes" responses between the positive and the negative conditions, $t(49.76) = 4.29, p < .001$. The negative condition had a mean of 46.46% (SD = 11.9) and the positive condition had a mean of 61.13% (SD = 12.75). The t-test on the data of card values for which outcome probabilities were not manipulated showed no significant difference in the mean percentage of "yes" responses between positive and negative, $t(50) = 0.55, p > .025$.

The analyses showed no main effect of age, $F(1, 48) = 1.38, p > .05$, and no significant interactions involving age. There was no interaction between outcome bias and age, $F(1, 48) = 0.002, p > .05$, and no interaction between card value and age, $F(3.20, 153.67) = 1.62, p > .05$. The absence of an interaction involving age and outcome bias suggests that the outcome manipulation had the same effect on the decisions of both age groups. However, the old group had greater variance in response to card values 3 to 7 (SD = 15.17) on which the outcome manipulation was employed compared to the young group (SD = 13.11). Mixed design ANOVA on the square root transformed data showed similar findings to the analyses on the raw data. The main effect of card value was significant, $F(3.45, 165.39) = 384.90, p < .001$, as well as the main effect of outcome bias, $F(1, 48) = 9.58, p < .01$. There was a significant interaction between card value and outcome bias, $F(3.45, 165.39) = 4.37, p < .001$. The main effect of age was not significant, $F(1, 48) = 2.81, p > .05$. There was no interaction between outcome bias and age, $F(1, 48) = 0.007, p > .05$. However, the interaction between card value and age was significant, $F(3.45, 165.39) = 2.66, p < .05$.

To summarise, the results suggest that both age groups made the same decisions, and were affected by biased outcomes. Another question of interest, however, was whether in making the same decisions as the young adults, the old adults had allocated more time than the young adults. To examine this question RTs were examined.

6.3.2. RTs

In the old group 0.02% of the data were identified as outliers and were excluded from the analyses. No outliers were identified in the young group. Participants who had RTs which were 2.5 SD above the mean of the rest of the participants in their age group in each outcome bias condition were excluded. In the young group the data of four participants (out of 26) were excluded, and in the old group the data of five participants (out of 26) were excluded.

To examine whether old adults allocated more time to processing biased outcome information, the rate of slowing across uncertainty was examined. Mixed ANOVA indicated a significant main effect of age, $F(1,44) = 42.48, p < .001$, and a significant main effect of uncertainty, $F(2.59, 114.21) = 20.12, p < .001$, suggesting that the old group took longer to make a decision, and that both young and old groups were slowed down as uncertainty increased. There was a significant interaction between uncertainty and age, $F(2.59, 114.21) = 2.87, p < .05$. This interaction was significantly linear, $F(1, 44) = 8.00, p < .01$, suggesting that the rate of slowing with increased uncertainty appeared to be greater for participants in the old group than for those in the young group. There was also a significant interaction between uncertainty and outcome bias, $F(2.59, 114.21) = 2.99, p < .05$. This interaction was significantly quadratic, $F(1, 44) = 4.89, p < .05$. Figure 15 shows the mean RTs as a function of uncertainty and age collapsed across the outcome bias conditions, and Figure 16 shows the mean RTs as a function of uncertainty and outcome bias collapsed across age. Age and outcome were collapsed because these variables did not interact.

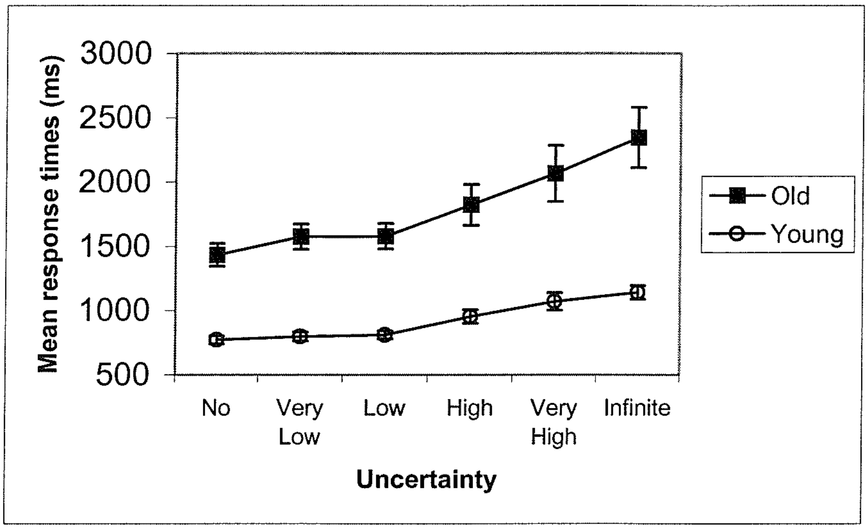

Figure 15: Mean RTs as a function of uncertainty and age collapsed across outcome bias

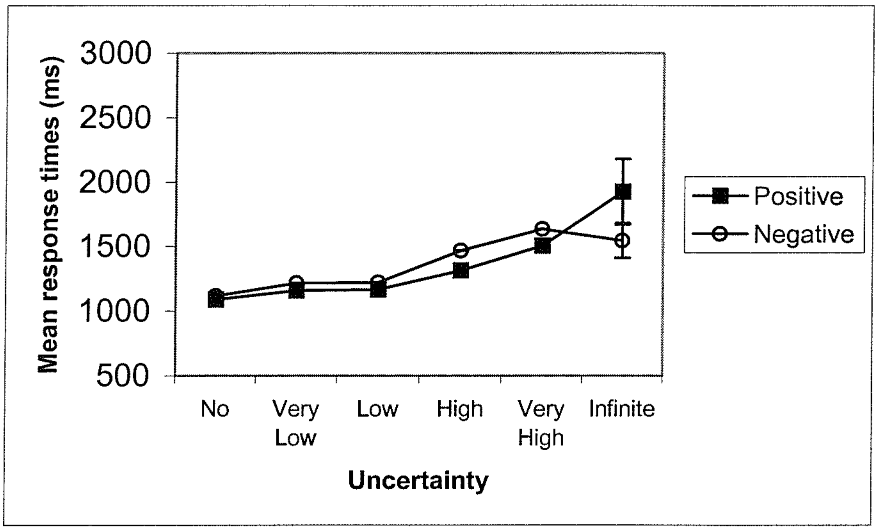

Figure 16: Mean RTs as a function of uncertainty and outcome bias collapsed across age

There was niether an interaction between outcome bias and age, $F(1, 44) = 0.09, p > .05$, nor between uncertainty, outcome bias, and age, $F(2.59, 144.21) = 1.22, p > .05$. Further to examine the interaction between uncertainty and outcome bias independent-sample t-tests were performed on each level of uncertainty to compare between the two outcome bias conditions (using Bonferroni correction, $p < .008$). These comparisons, however, showed no significant difference between the positive and the negative conditions in any of the uncertainty levels. T values for comparisions for no uncertainty, very low, low, high, very high, and infinite uncertainty are $t(46) = -0.19$, $t(46) = -0.36$, $t(46) = -0.36$, $t(46) = -0.74$, $t(46) = -0.48$, and $t(36.25)$[24] $= 1.32$, respectively.

6.4. Discussion

The results of Experiment 3 showed that old adults had made the same decisions as the young adults, and that participants in both age groups were affected by outcomes bias. Specifically, both the young and the old adults were less willing to take another card in the negative condition as compared to the positive condition. The results were the same when analyses were performed on the square root transformed data, suggesting that the absence of a significant interaction involving age was not a result of high variance in the data of the old group. These findings are consistent with studies showing that inference of event frequency does not degrade with age (e.g., Sanford & Maule, 1973; Hasher & Zacks, 1979).

The RT data confirmed that, compared to participants in the young group, those in the old group showed a more profound slowing as uncertainty increased for biased outcomes (both positive and negative) as indicated by an interaction between uncertainty and age. There was no indication for a three-way interaction between uncertainty, age, and biased outcome, however, suggesting that in both the positive and the negative conditions the old adults tended to slow down to a greater extent as a function of uncertainty than did the young adults. Because participants were not told whether or not outcomes were biased (i.e., carrying bust probability different from that expressed by the card values), allocation of more time on part of the old adults may have reflected an attempt to find a probabilistic

[24] Degrees of freedom were corrected for a test not assuming equal variance.

pattern in the decision outcomes. Post-experimental introspective reports further suggested that both the young and the old participants were looking for a pattern in the outcomes they experienced.

The results of Experiment 2 demonstrated that old adults take longer to process unbiased outcome information. The data of Experiment 3 extend these findings by showing that this compensatory mechanism (i.e., allocation of more time) is employed when old adults process biased outcomes. The findings of Experiments 2 and 3 therefore provide further support for the hypothesis that old adults may utilise more processing time as a compensatory mechanism, allowing them to process decisions outcome information and make the same decisions as young adults. These finding are in accord with past research that has demonstrated that old adults utilise more time to perform a memory task (e.g., Brebion et al., 1997; Strayer et al., 1987), which allows them to reach an equivalent (or even higher) level of performance as young adults.

In Experiments 2 and 3, allocation of more time allowed old adults to process outcome information (unbiased and biased, respectively) and to make the same decisions as young adults. However, it is also of interest to examine whether old adults utilise other types of information such as payoff information. Experiment 4 examines this question.

7. EXPERIMENT 4: Information selectivity: The utilisation of payoff information

7.1. Introduction

Previous research has shown that old adults both tend to search for and require fewer subsets of information than do young adults during the decision process, demonstrating information selectivity (e.g., Curley et al., 1984; Johnson, 1990, 1993; Meyer et al., 1995; Walsh & Hershey, 1993; Zwahr et al., 1999; see also review in Chapter 3). Nevertheless, such studies have demonstrated that decisions produced by old adults are not different from decisions made by young adults.

Although information selectivity in decision-making by old adults is commonly reported, most studies have confounded factors relating to cognitive limitations with expertise in making decisions. As the studies cited above have all required participants to make decisions on familiar everyday decision-problems (e.g., which car to buy, which medical treatment to choose), the findings that old adults are more selective during the decision process may be accounted for by two explanations. One is that information selectivity in old age is a compensatory mechanism by which old adults cope with limited processing capacity (e.g., Johnson, 1990; Meyer et al., 1995; Zwahr et al., 1999). An alternative interpretation to selectivity, however, is that the greater experience and existing knowledge possessed by old adults guides their information search (e.g., Johnson, 1990; Walsh & Hershey, 1993). Based on the findings of past research, therefore, it is not clear whether cognitive limitations or greater experience underlie information selectivity in decision-making by old adults, because experience with the decision-problems employed has been a confounding variable.

The aim of Experiment 4 was to test the hypothesis that selectivity serves as a mechanism by which old adults compensate for decline in cognitive capacity. To test this hypothesis, it was attempted to control for experiential factors involved in decision-making. The question addressed was whether old adults exhibit selectivity when prior experience with a decision-problem cannot be useful in making an optimal decision (i.e., a decision that produces a desirable outcome). To address this question a decision-problem was used on which participants could not rely on their experience to produce an optimal decision. In order to make an optimal decision, decision-makers had to make use of the information available within the decision-problem. Selectivity of information would therefore result in impaired decisions (i.e., non-optimal decisions). If selectivity were to be exhibited by old adults in response to this decision-problem, it can be argued that cognitive factors, rather than experience, contribute to information selectivity in old age.

Experiment 2 demonstrated that old adults make use of probability information when making decisions (and see Dror et al., 1998). Experiment 4 examines whether old adults make use of another dimension of information, namely, outcome payoff (i.e., the possible gains or losses associated with a decision alternative). To examine this question, the decision task used in the present experiment varied payoff information only, while the information about outcome probability was held constant (.5 on all trials). Thus, on every trial, participants did not need to compute probability information because they were asked to assume equal probability for the two possible outcomes. Possible payoffs for each decision alternative were varied between subjects.

Participants were asked to play a card game which presented them with two cards facing down (so they could not see the values on the cards). The object of the game was to attain a sum of card values, without exceeding nine. Participants had to decide whether or not to reveal the cards. Because a high level of uncertainty exists in making such decisions under an outcome probability of .5, payoff information was the only information that could be used by participants to guide their decisions. Payoff was varied between subjects, producing three payoff conditions: approach, avoidance, and control (i.e., neutral payoff). Payoff was provided in terms of the number of points participants could win or lose following their decisions, depending on the decision taken (i.e., whether to reveal or not to reveal the cards) and its accuracy (i.e., whether or not the decision was in accordance with the outcome). When revealing the cards the control condition could win 10 points if the total was no-bust (i.e., nine or less) or lose 10 points if the total was bust (i.e., greater than nine). When not revealing the cards, the control condition could win 10 points if the total was bust, or lose 10 points if the total was no-bust. The approach and the avoidance conditions had asymmetrical payoffs: When revealing the cards, the approach condition had more points to win if the total was no-bust (16) than to lose if the total was bust (4), and the avoidance condition had less points to win if the total was no-bust (4) than to lose if the total was bust (16). When not revealing the cards, the approach condition had more points to lose if the total was no-bust (16) than to win if the total was bust (4), and the avoidance condition had less points to lose if the total was no-bust (4) than to win if the total was bust (16).

To calculate the EV for each decision alternative (i.e., "yes" for revealing the cards versus "no" for not revealing them), normative model's equation was used as follows (see also 2.3.1):

$$EV = [(P(B) \times \text{payoff}) + (P(NB) \times \text{payoff})]$$

where P(B) is the probability of a bust outcome and P(NB) is the probability of a no-bust outcome.

In the approach condition the EV is higher for the decision to reveal the cards (winning 6 points) than for the decision not to reveal them (losing 6 points). Below is the calculation of the EV for each decision alternative in the approach condition:

EV (approach, "yes") = $[(0.5 \times -4) + (0.5 \times 16)] = +6$

EV (approach, "no") = $[(0.5 \times 4) + (0.5 \times -16)] = -6$

In the avoidance condition the EV is higher for the decision not to reveal the cards (winning 6 points) than for the decision to reveal them (losing 6 points). Below is the calculation for the EV for each decision alternative in the avoidance condition:

EV (avoidance, "yes") = $[(0.5 \times -16) + (0.5 \times 4)] = -6$

EV (avoidance, "no") = $[(0.5 \times 16) + (0.5 \times -4)] = +6$

In the control condition the EV is the same for the decision to reveal the cards (winning zero points) and for the decision not to reveal them (losing zero points). Below is the calculation for the EV in the control condition:

EV (control, "yes") = $[(0.5 \times -10) + (0.5 \times 10)] = 0$

EV (control, "no") = $[(0.5 \times 10) + (0.5 \times -10)] = 0$

Based on normative models of decision-making, an optimal strategy is defined as the decision strategy (i.e., percentage of "yes" responses) that chooses the decision alternative (i.e., to reveal or not to reveal the cards) with the highest EV. Therefore, the optimal strategy in the approach condition would be to reveal the cards across all trials. In the avoidance condition the optimal strategy would be not to reveal the cards across all trials. In the control condition the optimal strategy would be to either respond randomly (i.e., on some trials responding "yes" and on other responding "no") or to choose either decision at random (i.e., responding only "yes" or only "no" across all trial).[25] Figure 17 represents the optimal strategy (percentage of "yes" responses) that would be effective in each payoff condition.

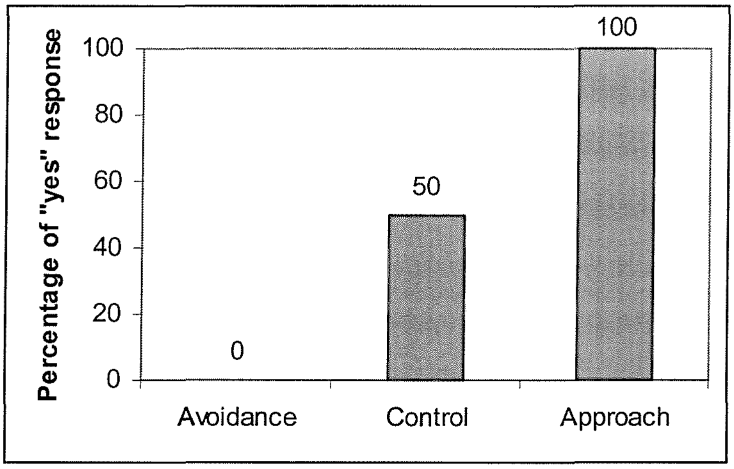

Figure 17: The optimal strategy (i.e., percentage of "yes" responses) in each payoff condition

Use of payoff information would be reflected in a higher percentage of "yes" responses in the approach condition (i.e., more likely to reveal the cards) and a lower percentage of "yes" responses in the avoidance condition (i.e., more likely not to reveal the cards) compared to the control condition. Not utilising payoff (i.e., selectivity) would result in random responses in the approach and avoidance conditions, producing no effect of payoff.

To examine whether potential age differences in the use of payoff could be accounted for in terms of differences in remembering the payoff matrix, recall of the payoff matrix was measured. RT was also measured to examine whether the old adults processed payoff

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[25] Responding randomly (i.e., "yes" and "no" alternately) as well as choosing at random to respond with a single response across all trials is expected to result in 50% of "yes" responses when the responses are averaged across participants.

information. According to the SSM, asymmetrical payoff (e.g., approach) reduces the decision threshold, resulting in a faster decision (e.g., "yes") compared with a decision (e.g., "no") corresponding to the opposite decision threshold (e.g., avoidance). Thus, the SSM predicts that RTs for "yes" and "no" responses will be affected differently by payoff: In the approach condition "yes" responses will be faster than "no" responses, in the avoidance condition "no" responses will be faster than "yes" responses, and in the control condition "yes" and "no" responses will produce the same RTs.

7.2. Method

7.2.1. Design

The experiment employed a between-subject design with age (old and young) and payoff (control, approach, and avoidance) as the between-subject factors. The payoff manipulation employed varied the number of points participants could win or lose following their decision between three payoff conditions (approach, avoidance, and control). The payoff was determined by the decision made and the accuracy of the decision. Table 9 presents the number of points associated with each response ("yes" for revealing the cards and "no" for not revealing the cards) and each outcome (bust / no-bust).

Table 9: The payoff structure (numbers of points gained and lost) for each payoff condition

	No-bust outcome			Bust outcome		
Response	Approach	Avoidance	Control	Approach	Avoidance	Control
"yes"	+16	+4	+10	-4	-16	-10
"no"	-16	-4	-10	+4	+16	+10

The percentage of "yes" responses as well as RTs were measured. For analysing RT data, a mixed design was employed with age and payoff as the between-subject factors and response type ("yes" or "no") as the within-subject factor.

Recall of the payoff structure was scored on the basis of correct recall of the payoff rule (i.e., whether a given situation would produce a gain or a loss) and of the number of points that could be won or lost under each of the four possible situations: (1) a "yes" response resulting in a no-bust outcome; (2) a "yes" response resulting in a bust outcome; (3) a "no" response resulting in a no-bust outcome; and (4) a "no" response resulting in a bust outcome. The maximum score for each situation was two points, attainable as follows: one point for recalling the rule (i.e., whether winning or losing) and one point for recalling the number of points that could be won or lost. Thus, maximum score for correctly recalling the payoff matrix was eight.

7.2.2. Participants

The participants were 87 young and old volunteers. Forty-five old adults (23 females, 22 males) were recruited from senior citizen clubs and church groups in Southampton. Their age range was between 61 and 85 (mean age 70.6). Based on the participants' reports, all were in good health, were not institutionalised, and were physically and socially active. The young participants were 42 Psychology undergraduate students at the University of Southampton (21 females, 21 males) who volunteered to take part in the experiment in exchange for experimental credits. Their age range was between 18 and 33 (mean age 20.8). After excluding three old participants (see section 7.3), the number of participants in the payoff conditions was equal (28 participants in each condition, 14 in each age group). The number of females and males was equal in each payoff condition for both age groups (seven females and seven males).

It was attempted to match the two age groups for educational background.[26] The mean number of years in formal education for the old group was 13.31 (SD = 2.51) and for the young group the mean was 14.55 (SD = 1.44). Two-sample t-test (two-tail) assuming unequal variance showed a significant difference in education level between the two age groups, $t(65.16) = 2.77, p < .01$.

7.2.3. *Materials*

The materials consisted of two cards, facing down, and which were presented at the beginning of each trial. The outcome feedback cards were identical to those presented in Experiment 2 in the outcome condition (see section 5.2.4.3).

7.2.4. *Procedure*

Participants came into the laboratory to take part in the experiment. In each age group, participants were randomly assigned to one of three payoff conditions: approach, avoidance, or control. As in the experiments presented earlier, participants were tested individually within a single testing session that lasted approximately 15 minutes. Prior to the beginning

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[26] In Experiments 2 and 3 participants were included who had completed at least secondary education, but the exact number of years in formal education was not recorded. Some studies have suggested that education is an important factor in decision-making performance (Bush, Barrett-Connor, Cowan, Criqui, Wallace, Suchindran, Tyroler, & Rifkind, 1987; Schmitt, Gogate, Rothert, Rovner, Holmes, Talarcyzak, Given, & Kroll, 1991; Zwahr et al., 1999) and may therefore contribute to age differences in decision-making. It was, therefore, decided to record the number of years participants had spent in formal education.

of the experiment participants received the following instructions[27] which were presented on the computer screen.

> Hello, welcome to the experiment. Thank you very much for your participation. In this experiment you will play a simple card game. The object in each hand is to have a sum of card values which does not exceed 9. If your total is 10 or over then you go bust, and you lose the hand. Press the spacebar to continue.
>
> In each hand you will see two cards facing down. Each card will have a value between zero to nine. However, as the cards are facing down you do not know what their values are. You need to decide whether or not you want to reveal the cards. If you think you should reveal the cards, then press the "yes" key. If you think you should not reveal the cards, then press the "no" key. Please think carefully about your decision. Press the spacebar to continue. [participants see an example of two cards facing down presented at the beginning of each trial]
>
> You need to decide whether or not you want to reveal the cards. Remember, you want to have a sum of cards' values which does not exceed 9. Following your response the values of the two cards will be revealed, and whether or not you won or could have won. If you reveal the cards and the sum does not exceed 9 you win 10 points. If you reveal the cards and the sum exceeds 9 you lose 10 points. Press the spacebar to see an example. [participants were presented with examples of two decision outcomes that could follow a "yes" response]
>
> However, if you DON'T reveal the cards you may still win or lose a hand: If you decide not to reveal the cards and the cards have a total of more than 9, that means you made a correct decision and you win the hand and get 10 points; if you decide not to reveal the cards and the cards have a total of 9 or less, that means you lose the hand and 10 points are reduced from your points total. Thus, you can win or lose a hand if you decide to reveal the cards; and you win or lose a hand if you decide not to reveal the cards.

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[27] The instructions presented here include the points participants could win or lose in the control condition. The approach and avoidance conditions were instructed about different number of points as specified in Table 9.

[participants were presented with examples of two decision outcomes that could follow a "no" response]

After the cards' values are shown to you, when you are ready you initiate the next hand by pressing the space bar. Please note that there is an equal chance that the cards' total will be below or above 9. Your goal is to gain as many points as possible. Please use your non-dominant hand to press the spacebar, and with your dominant hand use two fingers for the yes/no response. Before beginning the actual experiment there will be ten practice trials. If you have any questions, please ask them during the practice. Press the spacebar to begin practice trials.

The card game employed in this experiment was a modified version of that used in Experiments 2 and 3. On every trial the participants were shown two cards facing down, so that they could not view the cards' values. The objective on every trial was to attain a sum of cards' values which did not exceed nine. Participants had to decide whether or not to turn the cards over to reveal the numbers on those cards. They were instructed to press the "yes" key if they wished to reveal the cards, and to press the "no" key if they wished not to reveal them. Participants were told that the objective of the game was to earn as many points as possible. As in Experiments 2 and 3, the instructions included explicit information about the payoff structure, but in the present experiment the payoff structure differed between the payoff conditions as specified above. Specifically, participants in the control condition were told that if they revealed the cards they could win 10 points if the total value of the cards was no-bust, and that they would lose 10 points if the total value of the cards was bust. If they did not reveal the cards they could win 10 points if the total value was bust and lose 10 points if the total value was no-bust. In the approach condition participants were told that if they revealed the cards they could win 16 points if the total was no-bust, and lose 4 points if the total was bust. If they did not reveal the cards, they could win 4 points if the total was bust and lose 16 points if the total was no-bust. In the avoidance condition, participants were told that if they revealed the cards they could win 4 points if the total was no-bust, and lose 16 points if the total was bust. If they did not reveal the cards they could win 16 points if the total was bust and lose 4 points if the total was no-bust. This information was provided as a textual description (see the instructions presented above).

Before the beginning of the task the experimenter made sure that participants understood the payoff structure. Participants were also informed that the chance of the total value of the cards being bust was equal to the chance of the cards having a no-bust total. Following each response, participants were provided with outcome feedback, showing them the values of two cards (regardless of whether or not they decided to reveal them), whether or not their decision was correct, and the number of points they had won or lost by that decision. Participants were instructed to respond in their own time. The experiment included 10 blocks of 10 trials each presented in random order. The two cards which were presented in the outcome feedback of each trial were the same as those presented in the outcome condition in Experiment 2 (see Table 5).

Following completion of the experiment the old participants were asked to fill in a questionnaire regarding their general health and life-style (Appendix F). Also, both the young and the old participants were asked to recall the payoff structure on which they had been tested (see Appendix J). To measure recall, the participants were asked about four outcome situations (i.e., what happens when responding "yes" and the total of cards' values is no-bust? What happens when responding "yes" and the total is bust? What happens when responding "no" and the total is no-bust? And what happens when responding "no" and the total is bust?). For each situation, participants were asked to say whether they could win or lose, and how many points were associated with winning and losing.

7.3. Results

The data of three old adults were excluded from the analyses, because they failed to respond with either "yes" or "no" response keys on a high percentage of trials (participant n°. 9 did not respond in 23% of the trials, participant n°. 11 did not respond in 87% of the trials, and participant n°. 13 did not respond in 89% of the trials). The analyses also excluded trials on which participants did not respond using one of the two response keys (either "yes" or "no"). In the young group 0.45% of the data were excluded and, in the old group, 1.38% of the data were excluded. Because the young and the old groups differed in education, this measure was entered as a covariate in the analyses. However, because it was not significant, $F = 0.7, p > .05$, it is not discussed further.

In the former experiments responses that were made in less than 175 ms were excluded from the analyses because of the assumption that such rapid responses had probably been executed before the stimulus could be processed. However, in Experiment 4, because the stimuli presented were cards facing down, the stimuli did not carry information that could be processed on each trial - that is, information-processing need not be trial-dependent, but rather participants could adopt or develop a decision strategy (i.e., press "yes" and "no" alternately, or press "yes" on all trials, etc.) and use it with no other information needing to be processed within each trial. Therefore, it was decided to examine the data including those rapid responses.

7.3.1. Percentage of "yes" responses

Figure 18 shows the mean percentage of "yes" responses as a function of payoff and age.

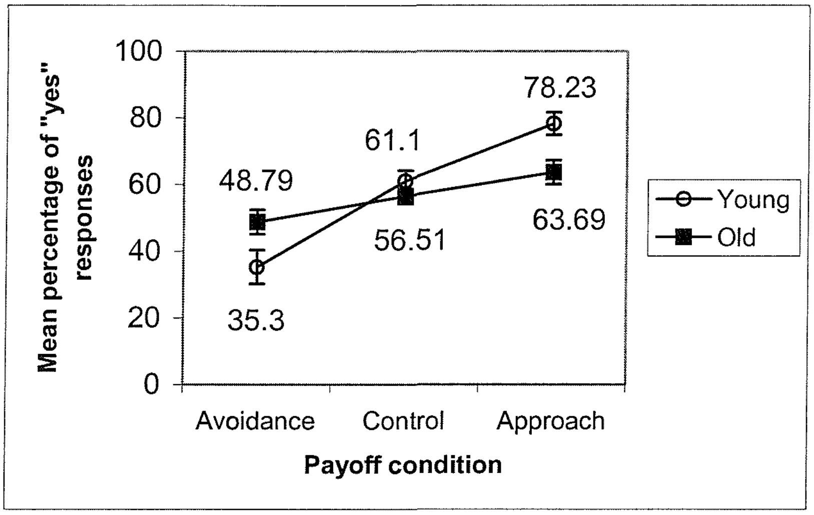

Figure 18: Mean percentage of "yes" responses as a function of payoff and age

Two-way ANOVA with age and payoff as the between-subject factors revealed a significant main effect of payoff, $F(2, 78) = 32.09, p < .001$. As compared to the control condition, participants in the approach condition showed increased willingness to reveal the cards, and participants in the avoidance condition showed decreased willingness to do so. The mean percentage of "yes" responses in the control condition was 58.08 (SD = 10.41), in the approach condition the mean was 70.96 (SD = 14.81), and in the avoidance condition the mean was 42.04 (SD = 17.64). The interaction between payoff and age was significant, $F(2, 78) = 7.69, p < .01$. There was no main effect of age, $F(1, 72) = 0.40, p > .05$.

Further to examine the interaction between payoff and age planned comparisons (independent-sample t-tests) were performed on the data of each age group. The analyses of the young group showed significant differences between approach and avoidance, $t(26) = 7.05, p < .001$, between approach and control, $t(26) = -3.69, p < .01$, and between avoidance and control, $t(26) = 4.31, p < .001$. In the old group there was a significant difference between approach and avoidance, $t(26) = 2.9, p < .01$, but there was no significant difference between approach and control, $t(26) = -1.69, p > .05$, or between avoidance and control, $t(26) = 1.79, p > .05$. To examine whether the hypothetical trend (i.e., approach >

control > avoidance) was significant in each age group, polynomial (linear) contrasts were performed on the data of each age group. The analyses showed a significant trend in the old group ($F(1, 39) = 10.55, p < .01$) as well as in the young group ($F(1, 39) = 58.48, p < .001$). These findings suggest that the young group made use of avoidance and approach payoff, and that the old group also made some use of payoff. Although the young group did not show optimal strategy, they were closer to the optimal strategy than the old group (cf. Figure 17).

7.3.2. *The number of participants in each age group using approach and avoidance payoff*

To examine the possibility that the young group had showed a stronger payoff effect because more young than old participants had used approach and avoidance payoff, the number of young and old participants using payoff in each payoff condition was computed. Using payoff was defined as responding "yes" on 65% or more of the trials in the approach condition or responding "yes" on 35% or less of the trials in the avoidance condition. Table 10 shows the number of young and old participants using payoff in the each payoff condition.

Table 10: The number of young and old participants using approach and avoidance payoff

	Young[a]		Old[a]		Total	
	Use	No Use	Use	No Use	Use	No Use
Approach	12	2	4	10	16	12
Avoidance	5	9	2	12	7	21
Total	17	11	6	22	23	33

[a] n = 28 in each group

Pearson's Chi Square test confirmed a significant association between age and use of payoff in the approach condition, $\chi^2_1 = 9.33, p < .01$, but not in the avoidance condition, $\chi^2_1 = 1.71$, $p > .05$. This suggests that the two age groups were differentially affected by approach but not by avoidance payoff. Specifically, more young participants (12) than old participants (four) tended to use approach payoff.

Most of the participants did not exhibit the optimal strategy. Use of optimal strategy was defined as responding "yes" on 95% or more of the trials in the approach condition and responding "no" on 5% or less of the trials in the avoidance condition. Only three participants in the young group and one participant in the old group used the optimal strategy.

7.3.3. RTs

No outliers were identified within the data of each participant. The analyses included responses, which were made under 175 ms (see above). The data of two participants were excluded from the RT analyses because they had responded either "yes" or "no" throughout the experiment, hence, having empty cells in one of the responses. In addition, the data of four old participants and two young participants were excluded because they had produced RTs that were 2.5 SD above the mean RTs of the rest of the participants in their age group.

Figure 19 shows the mean RTs as a function of response, payoff, and age.

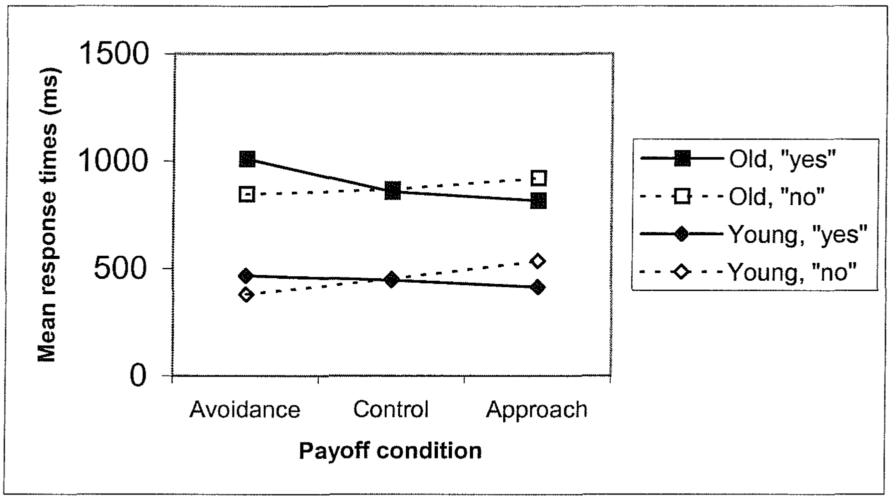

Figure 19: Mean RTs as a function of response, payoff, and age

Mixed design ANOVA with age and payoff as the between-subject factors and response as the within-subject factor revealed a significant main effect of age, $F(1, 70) = 34.24, p < .001$, suggesting that participants in the old group took more time to respond than participants in the young group. The old group's mean RT was 1046 ms (SD = 662) and the young group's mean RT was 495 ms (SD = 273). There was also a significant interaction between response and payoff, $F(2, 70) = 13.84, p < .001$.

Further to examine the interaction between response and payoff (i.e., to examine in which payoff condition there was a significant difference between "yes" and "no" responses), multiple paired-sample t-tests (using Bonferroni correction, $p < .016$) were performed on the data of each payoff condition. There was a significant difference between "yes" responses and "no" responses in the approach condition, $t(26) = -3.89, p < .016$. "Yes" responses were faster than "no" responses. Mean "yes" response was 607 ms (SD = 367) and mean "no" response was 721 ms (SD = 390). The difference between the responses was also significant in the avoidance condition, $t(23) = 3.6, p < .016$. "No" responses were faster than "yes" responses. Mean "yes" response was 739 ms (SD = 415) and mean "no" response was 612 ms (SD = 366). In the control condition there was no significant difference in RTs between the two responses, $t(24) = -0.27, p > .016$. Mean "yes" response was 660 ms (SD = 421) and mean "no" response was 669 ms (SD = 421). No other main effects or interactions were significant. There was neither a main effect of response, $F(1, 70) = 0.006, p > .05$, nor payoff, $F(2, 70) = 0.03, p > .05$. The inetarctions between response and age, $F(1, 70) = 0.61, p > .05$, payoff and age, $F(2, 70) = 0.21, p > .05$, and payoff, response, and age, $F(2, 70) = 0.40, p > .05$, were all not significant. The absence of the three-way interaction suggests that payoff and response affected the two age groups similarly, as illustrated in Figure 19.

7.3.4. Recall of payoff structure

Overall, the young group had a better recall score than the old group. The mean recall score for the young group was 7.36 (SD = 1.41) and, for the old group, it was 5.31 (SD = 2.4). This difference was significant as indicated by a two-sample t-test assuming unequal variance, $t(66.25) = 4.76, p < .001$. To examine whether recall of the payoff matrix was a predictor of the employment of payoff, regression analyses were performed. Recall of the payoff matrix appeared to account for 65% of the variance in payoff employment[28], $r^2=0.65$, $F(1, 83) = 5.69, p < .05$.

7.4. Discussion

The question addressed by Experiment 4 was whether old adults use payoff information. The RT data showed that both the young and the old participants processed payoff information. Both age groups appeared to be faster in choosing the decision alternative that produced the higher EV ("yes" in the approach condition and "no" in the avoidance condition) than in choosing the decision alternative that produced the lower EV ("no" in the

[28] Payoff employment was defined as responding "yes" on 65% or more of the trials in the approach condition and responding "no" on 35% or less of the trials in the avoidance condition. Thus, employment of payoff was coded in the regression analysis as a binary measure (i.e., either employing or not employing payoff).

approach condition and "yes" in the avoidance condition). This pattern of RTs is consistent with the predictions of the SSM.[29]

The data (i.e., percentage of "yes" responses) also showed that the young participants made use of approach and avoidance payoff. That is, compared to the control condition, they were more reluctant to reveal the cards in the avoidance condition, and more willing to do so in the approach condition. However, the old group showed differences in willingness to reveal the cards between the approach and the avoidance conditions, although these two conditions did not significantly differ from control. These findings suggest that the old participants did make use of payoff, but to a lesser extent than the young participants. This pattern of results was further confirmed by examining the number of young and old participants using payoff in each payoff condition. The data showed that more young adults than old adults were making use of approach payoff, although there was no difference between the two age groups in the number of participants who used avoidance payoff.

In general, the findings demonstrate that both age groups responded to payoff, although the young group responded to it to a greater degree. The question therefore arises as to why the old adults responded less to payoff information. A plausible explanation is that the old participants might have had difficulties in remembering the payoff matrix. Indeed, they were less able than the young adults to recall the payoff matrix at the end of the experiment, and recall of payoff appeared to predict payoff employment.

[29] However, the faster response for "yes" in the approach condition and for "no" in the avoidance condition may be an artefact of a greater motor speed resulting from repeatedly pressing the same key across trials, rather than reflecting decision processes.

The importance of recalling the payoff matrix in employment of payoff is consistent with the findings of Meyer et al. (1995), who showed that recall ability has a role in decision-making performance. These authors investigated women's decisions about breast cancer treatment. Participants were asked to make treatment decisions after reading an informative text about breast cancer and an authentic health scenario about breast cancer. The authors found that the type of information recalled by participants influenced the treatment chosen by them. Furthermore, relative to young women, old women exhibited poorer recall of the information presented about possible treatments.

Failure to recall the payoff matrix in Experiment 4 may have resulted from difficulties in creating a simple representation of the payoff matrix (such as that presented in Table 9). It should be noted that the payoff matrix was presented to participants during the instruction stage in a textual descriptive form and not in explicit tabular form. The latter may be a simpler representation of the payoff matrix, allowing the relations between a decision and an outcome to be more easily remembered. The possibility that difficulties in remembering the payoff matrix contributed to failures in payoff recall and its employment is in line with evidence showing that old adults demonstrate deficient reading comprehension and poorer recall of recently presented material (Hartley, 1988; and see Kemper & Kemtes, 1999, for a review). Further research might test this explanation by examining whether increased cognitive support could help old adults to make optimal use of payoff information. For example, cognitive support could be provided by including a simple representation of the payoff structure in the instructions. Alternatively, cognitive support could be provided by instructional guidance for the creation of an optimal strategy (e.g., "based on the number of points you can earn, which decision will allow you to earn more points?"). This line of research would bear practical implications for the development of decision aids for old adults.

The most important finding, however, is that the old group showed some use of payoff information. It will be of interest therefore to examine whether selectivity by old adults is affected by the demands placed by the task. Demonstrating that old adults become more selective as the cognitive demands placed by the task increase would provide support for the hypothesis that cognitive factors contribute to selectivity in old age.

8. EXPERIMENT 5: Information selectivity in old age under increased task demands

8.1. Introduction

In Experiments 2, 3, and 4 old adults were required to make decisions based on one dimension of information, either outcome probability or outcome payoff. In general, the findings revealed that the old adults were able to base their decisions on probability information and, to an extent were able to make decisions based on payoff information. Experiment 5 aims to test the hypothesis that information selectivity in old age can result from cognitive limitations. In order to test this hypothesis, Experiment 5 examines whether increased cognitive demands induce selectivity in old adults by including two, rather than one, dimensions of information on which decisions could be based (i.e., probability and payoff). Both of these dimensions are important for optimal decision-making as posited by normative models of decision-making (e.g., von Neumann & Morgenstern, 1947; and see section 2.3.1). The specific question addressed by Experiment 5 is therefore as follows: Do old adults utilise both probability and payoff information in their decisions or do they ignore one of those dimensions?

Experiment 1 demonstrated that old adults are able to make use of both probability and payoff information when faced with decisions from everyday life. As noted in Chapter 4, the decision-problems used in that experiment did not control for external factors (i.e., experience and risk perception) which may have a role in decision-making performance. Different from Experiment 1, the decision-problem used in Experiment 5 (as well as in Experiments 2 to 4) allows the investigation of the effect of cognitive factors on decision-making by controlling for those external factors. The finding that old adults are more selective than young adults in the information they make use of in their decisions in

Experiment 5 would therefore suggest that cognitive limitations contribute to their decision-making performance.

•

In the present experiment, participants were required to make decisions when playing the same card game used in Experiments 2 and 3. The card game employed different probabilities of a bust outcome based on the value of the initial card with which participants were presented. In addition to outcome probability, the task also included information about outcome payoff. In Experiment 5, as in Experiment 4, outcome payoff was varied between subjects, producing three payoff conditions (approach, avoidance, and control). Payoff was provided in terms of the number of points participants could win or lose following their decisions, depending on the decision taken (i.e., whether to accept or to reject another card) and its accuracy (i.e., whether or not the decision was in accordance with the outcome). When accepting or rejecting an additional card, the control condition had an equal number of points to win when correct or lose when incorrect (10 points). The approach and the avoidance conditions had asymmetrical payoffs when accepting an additional card: The approach condition had more points to win (16) than to lose (4), and the avoidance condition had fewer points to win (4) than to lose (16). When rejecting another card the approach condition had more points to lose (16) than to win (4), and the avoidance condition had fewer points to lose (4) than to win (16).

According to normative models of decision-making, to produce an optimal decision, an individual should multiply probability by payoff to produce an EV (i.e., expected value) for each decision alternative (see section 2.3.1). The alternative with the highest EV should be chosen. Based on this account the EV of each decision alternative in this decision-making task can be calculated as follows:

$$EV = [(P(B) \times \text{payoff}) + (P(NB) \times \text{payoff})]$$

where P(B) is probability of a bust outcome, P(NB) is probability of a no-bust outcome.

As before, an optimal strategy is thus defined here as the decision strategy (i.e., as measured by the percentage of trials on which a participant accepted an additional card) that results in a choice of the decision alternative (i.e., to take an additional card or not) which produces the highest EV. Figure 20 shows the optimal strategy for each card value based on the EV calculated for each card value in each payoff condition (see Appendix K for details on calculating EV for each card value in each payoff condition).

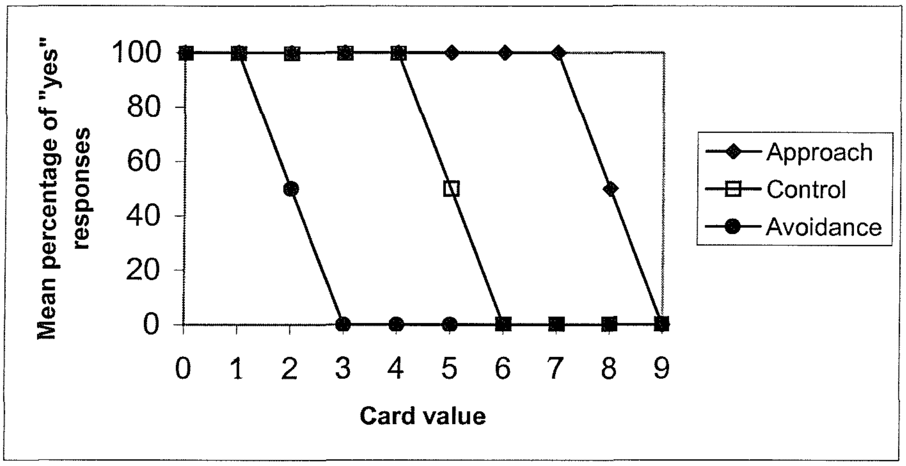

Figure 20: The optimal strategy (i.e., mean percentage of "yes" responses) across card values in each payoff condition

As Figure 20 shows, the asymmetrical payoffs (i.e., approach and avoidance) should produce different patterns of choosing another card across card values as compared to control. For the approach condition it would be more beneficial to increase the percentage of trials on which an additional card was accepted for card values 5 to 7, and for the avoidance condition it would be more beneficial to reduce the percentage of those trials for card values 3 to 5. The incorporation of probability and payoff information should result in main effects of card value and payoff, and also an interaction between the two. If only probabilistic information is used by participants, it would be demonstrated by a main effect of card value only. If only payoff information is used, only a main effect of payoff would be expected.

Given that old adults are limited in processing capacity, the incorporation of both probability and payoff information may exceed their limited resources, leading them to disregard one dimension of information. Old adults may therefore ignore payoff information, and base their decisions on probability. Alternatively, probabilistic information may be ignored and decisions will be made based on payoff information only. A finding that participants use only probabilistic or only payoff information would provide a demonstration of information selectivity. A demonstration of selectivity on the part of the old adults on this task would provide support to the hypothesis that cognitive factors contribute to selectivity in old age.

8.2. Method

8.2.1. Design

The experiment employed a mixed design in which age (old and young) and payoff (control, approach, and avoidance) were the between-subject factors and probability (i.e., card value with 10 levels, from zero to nine) was the within-subject factor. The data of the outcome condition in Experiment 2 was used as a control condition, in order to compare final decisions under asymmetrical payoff (i.e., approach and avoidance) to decisions under symmetrical payoff (i.e., control). [30]

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[30] Because the control condition consisted of the data of the outcome condition in Experiment 2, participants were not randomly assigned across payoff conditions. However, given that the same recruitment methods were used for recruiting the participants for Experiments 2 and 5, it has seemed acceptable to use the data from Experiment 2 as a control condition in the latter experiment (see Hertzog et al., 1993 for that reasoning).

The probability factor consisted of 10 levels of bust outcome probability, which could be estimated from the card value, as in Experiment 2 (see Table 4). The payoff manipulation was achieved by varying the number of points associated with the accuracy of the decision depending upon the decision-maker's response and the final outcome (i.e., bust or no-bust) between three payoff conditions (approach, avoidance, and control -symmetrical payoff). Table 11 presents the number of points associated with each response ("yes" / "no") and each outcome (bust / no-bust) for each payoff condition.

Table 11: The payoff structure (numbers of points gained and lost) for each payoff condition

	No-bust outcome			Bust outcome		
Response	Approach	Avoidance	Control	Approach	Avoidance	Control
"yes"	+16	+4	+10	-4	-16	-10
"no"	-16	-4	-10	+4	+16	+10

The dependent measure was the percentage of "yes" responses as a measure of final outcomes.[31]

[31] RTs for "yes" and "no" responses were not analysed here because for each card value participants tended to adopt either the "yes" or the "no" response (e.g., responding only "yes" for card value 4 and only "no" for card value 5 throughout the experiment). Therefore, it was not possible to make comparisons between "yes" and "no" responses for the same card value.

8.2.2. *Participants*

Participants were 70 young and old adults who volunteered to take part in the experiment. None had taken part in any of the experiments reported above. The old adults were 36 participants (24 females, 12 males) recruited from senior citizen clubs and church groups in Southampton. Their ages ranged between 65 and 85 (mean age 70.7). Based on their own reports, all participants were in good health, were not institutionalised, and were physically and socially active. The young participants were 34 Psychology undergraduate students at the University of Southampton (22 females, 12 males) who received experimental credits for participation. Their ages ranged between 18 and 39 (mean age 20.5). The young and the old participants had similar educational backgrounds, in that they had all completed at least secondary school or had an equivalent level of education (see footnotes 15 and 26). After excluding two old participants (see section 8.3), the number of participants was equal across payoff conditions (17 participants in each), with an equal number of females and males (11 and six, respectively).

8.2.3. *Materials*

The materials were identical to those used in Experiments 2 and 3, except that the number of points participants won or lost (shown by the outcome feedback) was varied between the three payoff conditions.

8.2.4. *Procedure*

Participants visited the laboratory to take part in the experiment. Participants from each age group were randomly assigned to one of two payoff conditions (approach or avoidance). The experiment consisted of one phase that lasted approximately 15 minutes. The decision-making task was the same as that presented during the first phase of the outcome condition in Experiment 2 (see section 5.2.4.1). Prior to the experiment the participants received the following instructions[32] presented on the computer screen.

> Hello, welcome to the experiment. Thank you very much for your participation. In this experiment you will play a simple card game. The object in each hand is to have the maximum sum of card values but not to exceed 9. If your total is 10 or over then you go bust, and you lose the hand. In each hand you will see one card on the computer screen. The card will have a value between zero to nine. You need to decide whether or not you want another card. The value of the additional card will also be a number between zero to nine. If you think you should take another card, then press the "yes" key. If you think you should not take another card, then press the "no" key. Please think carefully about your decision. Press the spacebar to continue. [participants were shown an example of an initial card they receive]
>
> You need to decide whether or not you want another card. Remember, you want to have the maximum sum of card values but not to go over 9. If you make a correct decision you will get 10 points, however, if you make an incorrect decision 10 points will be reduced.
>
> Following your response the value of the additional card will be revealed, and whether or not you won or could have won. If you make a correct decision you will get 10 points, however, if you make an incorrect decision 10 points will be reduced. Press the spacebar to see an example. [participants were shown two examples of decision outcomes which could follow a "yes" response]
>
> However, if you DON'T choose another card you may still win or lose a hand: If you decide not to take a card and choosing a card would have made you go bust, that means you made a correct decision and you win the hand and get 10 points; if you decide not to take a card and choosing a card would have made you maximise your sum without going bust, that means you lose the hand and 10 points are reduced from your points total. Thus, you can win or lose a hand if you decide to take a card; and you can win or lose a hand if you decide not to take a card. [participants were shown two examples of decision outcomes which could follow a "no" response]

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[32] The instructions presented here include the points participants could win or lose in the control condition. The approach and avoidance conditions were instructed about different numbers of points as specified below.

> After receiving the additional card, when you are ready you initiate the next hand by pressing the spacebar. Your goal is to gain as many points as possible.
>
> Please use your non-dominant hand to press the spacebar, and with your dominant hand use two fingers for the yes/no response. Before beginning the actual experiment there will be ten practice trials. If you have any questions, please ask them during the practice. Press the spacebar to begin practice trials.

The instructions were followed by a block of ten practice trials. The experimenter was present during that time to answer any questions participant might wish to ask. Following the practice trials, the experiment was initiated, and the experimenter left the room.

On every trial, participants were presented with a card with a value between zero to nine, and had to decide whether or not to take an additional card, aiming to maximise the total of cards' values without going over nine. Participants used the "yes" and "no" keys on the keyboard to respond. As before, only one additional card could be requested.

Following their response, participants were informed about their decision's outcome by the feedback. Outcomes were pre-determined in the experimental program in accordance with the actual probability of each card value being paired with a second card that would make a bust total (see Table 4). The outcome feedback that participants received in this experiment was similar to that received in the outcome condition in Experiment 2. That is, the feedback informed participants on the correctness of their decision, the additional card they received or could have received, whether they had gone or could have gone bust, and the number of points they had won or lost by that decision. The number of points that participants could win or lose following a decision varied across the payoff conditions (see Table 11).

As in Experiments 2, 3, and 4, the instructions, which were presented on the computer screen, included explicit information about the payoff structure (see the instructions presented above). Participants in the control condition (i.e., the outcome condition, Experiment 2) were told that if they took another card they could win 10 points if the total value of the cards was no-bust, and lose 10 points if the total value of the cards was bust. They were also told that if they did not take another card they could win 10 points if the cards' value total was bust and lose 10 points if the cards' value total was no-bust. In the approach condition, participants were told that if they took another card they could win 16 points if the total was no-bust, and lose 4 points if the total was bust. They were also told that if they did not take another card they could win 4 points if the total was bust and lose 16 points if the total was no-bust. In the avoidance condition, participants were told that if they took another card they could win 4 points if the total was no-bust, and lose 16 points if the total was bust. If they did not take another card they could win 16 points if the total was bust and lose 4 points if the total was no-bust. As before, this information was provided in a textual descriptive form, and participants were told that the main goal of the game was to earn as many points as possible.

Before the commencement of the task the experimenter made sure that participants understood the payoff structure. There were 10 blocks of 10 trials each (overall, 100 trials), and the initial and additional cards were fully counterbalanced as in the outcome condition in Experiment 2 (see Table 5). Following the completion of the experiment the old participants completed a questionnaire regarding their general health and their social and physical activities (see Appendix F). All the participants were asked to fill in an introspective report about the experiment (see Appendix L).

8.3. Results

The data of two participants from the old group were excluded. One participant did not complete the experiment and the other participant failed to follow the instructions, failing to respond either "yes" or "no" on 29% of the trials. Trials on which participants did not respond using the response keys (i.e., either "yes" or "no"), as well as responses made in under 175 ms, were excluded. In the young group 0.2% of the data were excluded and in the old group 0.24% of the data were excluded.

Mixed design ANOVA with age and payoff as the between-subject factors and card value as the within-subject factor confirmed a significant main effect of card value, $F(3.19, 306.52) = 1081.88, p < .001$, indicating that participants were less willing to take an additional card as the card value increased. Figure 21 presents the mean percentage of trials on which participants accepted an additional card (i.e., "yes" response) as a function of card value collapsed across payoff conditions and age. The latter variables were collapsed because they did not affect performance.

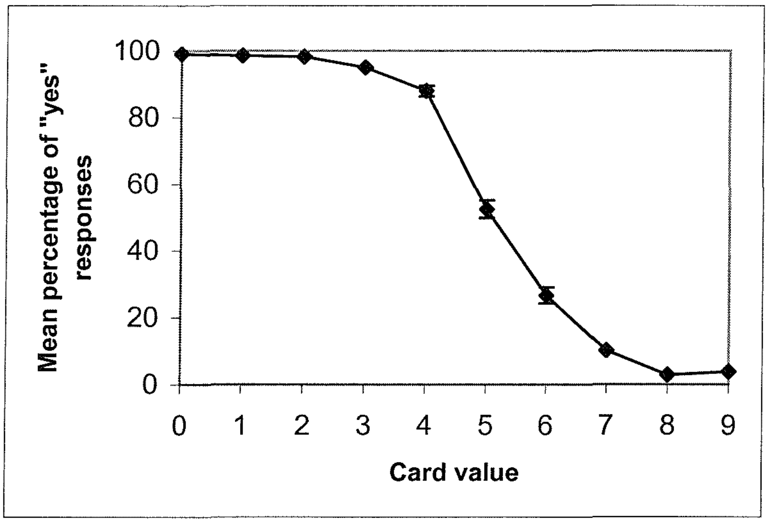

Figure 21: Mean percentage of "yes" responses as a function of card value collapsed across payoff conditions and age

There was niether a main effect of age, $F(1, 96) = 0.87, p > .05$, nor payoff, $F(2, 96) = 0.98$, $p > .05$. There were no interactions between card value and age, $F(3.19, 306.52) = 0.97, p >$ .05, between payoff and age, $F(2, 96) = 0.1, p > .05$, between card value and payoff, F(6.39, 306.52) = 1.01, $p > .05$, and between card value, payoff, and age, $F(6.39, 306.52) = 1.04$, $p > .05$. Because the old group had a higher variance (SD = 13.25) than the young group (SD = 11.54) in response to moderate card values (card values 3 to 7 on which payoff was expected to affect the percentage of "yes" responses), mixed design ANOVA on the square root transformed data were performed. These confirmed the results of the analyses on the raw data: There was a significant main effect of card value, $F(3.49, 335.43) = 761.97$, $p < .001$. No other main effects or interactions were significant. There was niether a main effect of age, $F(1, 96) = 0.87$, $p > .05$, nor payoff, $F(2, 96) = 0.73$, $p > .05$. There were no interactions between card value and age, $F(3.49, 335.43) = 1.25$, $p > .05$, between payoff and age, $F(2, 96) = 0.13$, $p > .05$, between card value and payoff, $F(6.99, 335.43) = 0.78$, $p > .05$, and between card value, payoff, and age, $F(6.99, 335.43) = 1.40$, $p > .05$.

Figure 22 presents the observed mean percentage of "yes" responses produced by all participants in comparison to the optimal response pattern. The data of participants in the young and the old groups were combined because no significant differences were found between the two age groups.

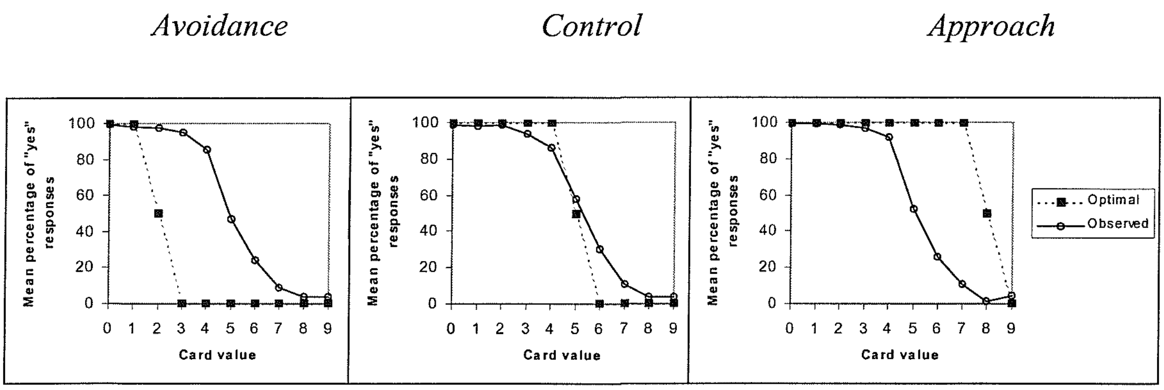

Figure 22: Optimal decisions and decisions observed of all participants in each payoff condition

As Figure 22 shows, the decision pattern exhibited by all participants was close to the optimal pattern in the control condition. However, in both the approach and avoidance conditions participants did not exhibit decision patterns close to optimal.

8.4. Discussion

The question addressed in Experiment 5 was whether old adults use both probability and payoff information in making decisions. It was hypothesised that old adults would use only one dimension of information, thus demonstrating selectivity. The findings showed that both young and old adults used probability information. Specifically, both age groups became less willing to accept an additional card as the card value (i.e., bust probability) increased. These findings replicate those of Experiment 2 and 3 and Dror et al., (1998). The findings also showed that neither the young nor the old participants made use of payoff information: Participants in both age groups accepted an additional card on the same percentage of trials across all payoff conditions. Analyses on the transformed data showed the same results, ruling out the possibility that the absence of significant interactions involving age was a result of the high level of variance observed in the data of the old participants. Participants from both age groups thus showed information selectivity, in that they ignored payoff information and did not conform to the optimal decision pattern. These findings differ from those of Experiment 4 in which both the young and the old adults were observed to have made use of payoff information.

The present findings suggest, therefore, that increased task demands (i.e., increasing the amount of available information) affected both age groups. These findings are consistent with the concept of 'bounded rationality' (Simon, 1955) in that processing both dimensions of information places demands on processing resources, and by attending to only one dimension of information (i.e., probability) these demands can be avoided. It is possible that the increased demands placed by the task discouraged both age groups from employing payoff. The findings of the present experiment are in line with studies reporting a reduction in the amount of information young adults consider when faced with high task demands (e.g., Ben-Zur & Breznitz, 1981; Jacoby et al., 1974; Payne, 1976; Payne et al., 1988). Payne (1976), for example, showed that when faced with two alternatives young participants consider both alternatives by taking into account all the attributes characterising each of them; however, when faced with several alternatives, participants tend to disregard some of them, and process attributes information only for a reduced set of alternatives. In a similar decision-making task to the one employed in the present experiment, Dror et al., (1999) demonstrated that task demands (i.e., time pressure) affected the amount of information young participants made use of when playing a card game. In their study, participants were presented with three cards. Two cards belonged to the participant and one card belonged to the opponent (i.e., the computer). Participants were required to decide whether or not to take an additional card. Under the no time pressure condition, the computer's card affected the participants' decisions on trials in which the participants' cards carried low levels of risk to go bust. On these trials participants tended to avoid accepting another card when the computer's card carried a low risk level and tended to take another card when the computer's card carried a high level of risk. However, under time pressure, the computer's card had no effect on the willingness of participants to take another card. This finding showed that under time pressure participants considered less information by ignoring the computer's card.

Because both age groups ignored the payoff information presented, Experiment 5 did not fulfill its primary aim of testing the hypothesis that old adults are more selective than young adults. A further experiment was therefore proposed as a more satisfactory test of the selectivity hypothesis. In Experiment 6 a decision-making task would be employed in which the reason for utilising the payoff information would be more explicit. It was hoped that this would encourage participants to make use of payoff information in addition to probability information.

9. EXPERIMENT 6: Information selectivity in old age under increased task demands: Making the payoff information more explicit

9.1. Introduction

In Experiment 5, both the young and the old adults demonstrated information selectivity. Specifically, participants in both age groups ignored approach and avoidance payoff and based their decisions on probabilistic information only. As the young adults did not use the payoff information, the decision-making task used in Experiment 5 was not optimal for testing the hypothesis that old adults are more selective than young adults under increased task demands. It was proposed that the decision-making task placed such high demands, leading both age groups to process only part of the information (i.e., probability) while ignoring payoff. To make the task less demanding one could provide a supporting cue to facilitate employment of payoff. This support is often referred to as *environmental support* referring to the provision of external mediators that support processing for successful completion of a task (Craik and Jacoby, 1996). These mediators can be provided in the form of instructional cues provided by the experimenter to prompt the use of certain performance strategies that enhance performance. For example, participants may be guided to make use of organisational strategies to organise the to-be-remembered items in order to improve memory performance (e.g., Hultsch, 1971).

Using such an instructional support, Experiment 6 provided participants with a more explicit instructions for using the payoff information. It was hoped that such instructions would encourage participants to make use of payoff and facilitate observation of performance differences between the two age groups. Experiment 6 therefore employed a different decision-making task. In the former experiments participants were required to make decisions while playing a card game. However, in the present experiment, the decision-making task required participants to imagine that they were managers in a company selling perfumes. Participants had to decide whether or not to sell different perfumes, based on the estimated probability of individual perfumes to be successful products in the marketplace, and on the salary bonuses or financial penalties they would receive for making correct or incorrect decisions, respectively.

Experiment 6 aimed to test the hypothesis that old adults would be more selective than young adults, and the question addressed was whether old adults incorporate both probability and payoff information under increased task demands (i.e., being presented with two dimensions of information rather than one). It was hypothesised that when faced with increased task demands, the old adults would exhibit information selectivity. If old adults were demonstrated to make use of one dimension of information only (probability or payoff), whereas young adults were demonstrated to make use of both, then information selectivity by the old adults would be demonstrated. Such findings would be taken to support the hypothesis that cognitive factors have a role in information selectivity in old age.

9.2. Method

9.2.1. Design

Experiment 6 employed the same design as Experiment 5, which consisted of a mixed design with age (old and young) and payoff (control, approach, and avoidance) as the between-subject factors and probability as the within-subject factor. The probability factor consisted of 10 levels, as in Experiments 2, 3, and 5. However, in Experiment 6, probability was represented in the form of percentage likelihood of a successful outcome (from 10% to 100%). The payoff manipulation (see Table 12) was the same as in Experiments 4 and 5, and was of three conditions (approach, avoidance, and control). Participants' decisions were measured as the percentage of "yes" responses.

Table 12: The payoff structure (numbers of points gained and lost) for each payoff condition

	Perfume is successful			Perfume is unsuccessful		
Response	Approach	Avoidance	Control	Approach	Avoidance	Control
"yes"	+16	+4	+10	-4	-16	-10
"no"	-16	-4	-10	+4	+16	+10

9.2.2. *Participants*

The participants were the same participants who took part in Experiment 1 (see section 4.2.2). In the approach and avoidance conditions, there were 13 old participants (eight females and five males) and 12 young participants (eight females and four males) in each. In the control condition there were 12 old participants (seven females and five males) and 12 young participants (seven females and five males).

9.2.3. *Materials*

The materials consisted of black and white drawings of ten perfume bottles presented on a computer screen. In the middle of every bottle appeared the likelihood (as a percentage) of the product being successful in the marketplace. Above the bottle appeared the question "sell this perfume?" (see Figure 23).

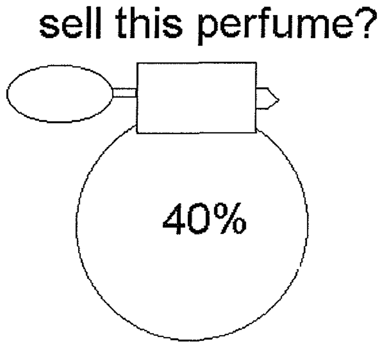

Figure 23: An example of a perfume bottle presented to participants at the beginning of each trial

The outcome feedback participants received following a response showed the same perfume bottle that was presented at the beginning of the trial, whether it was (or could have been) successful, whether the decision (i.e., to sell or not to sell it) was correct, and the number of points the participants had won or lost by that decision (see Figure 24 below).

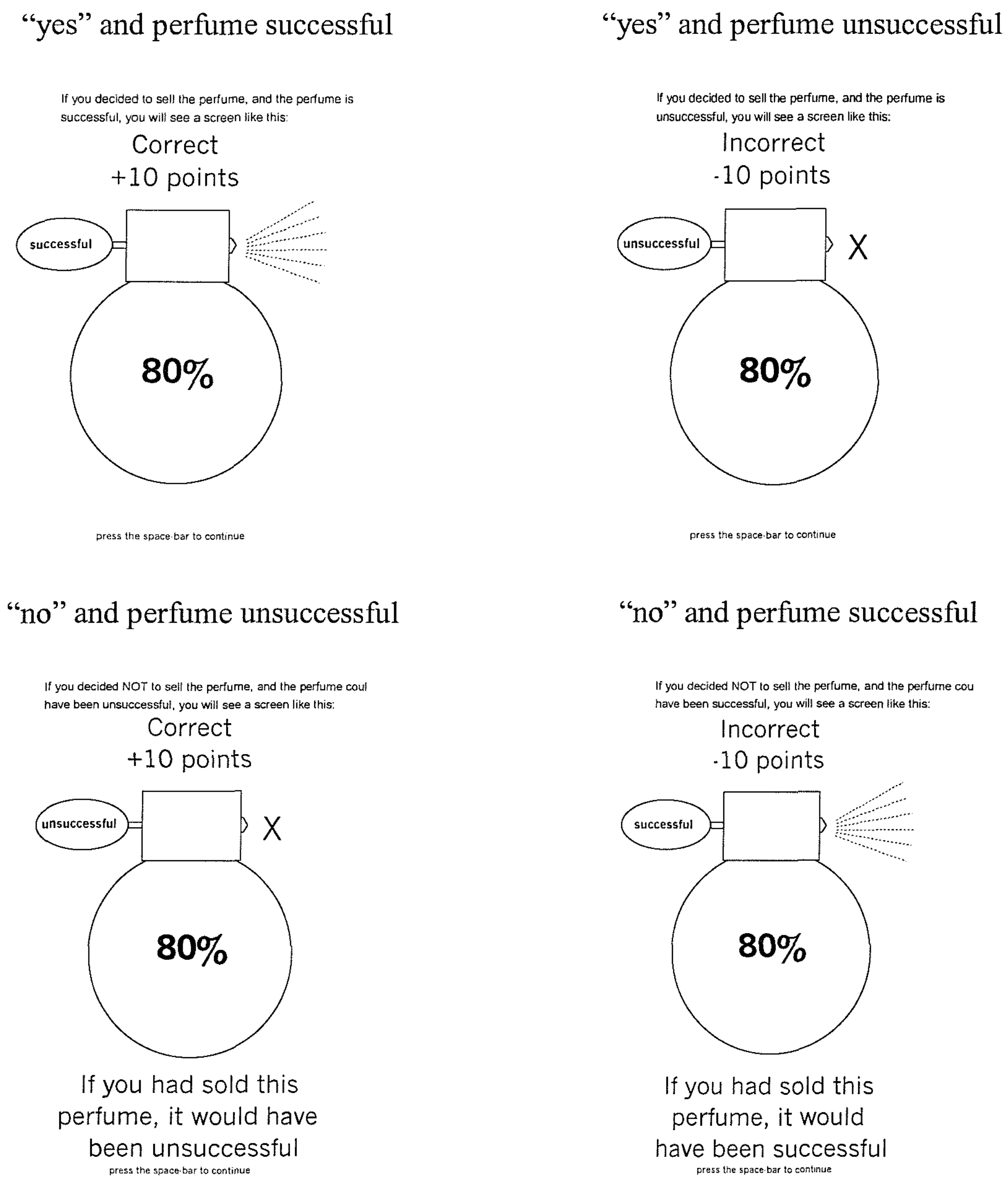

Figure 24: Four possible outcome feedbacks (control condition)

9.2.4. Procedure

Participants came into the laboratory to take part in the experiment.[33] In each age group participants were randomly assigned to one of three payoff conditions (approach, avoidance, or control). Prior to beginning of the decision-making task participants completed 10 practice trials to familiarise them with the response keys ("yes" and "no"). On every trial, participants were shown one of two words (either "yes" or "no") that appeared on the computer screen. They were instructed to press the "yes" key (the key "b" was labeled as "yes") when the word "yes" appeared on the screen and to press the "no" key (the key "n" was labeled as "no") when the word "no" appeared on it. A tone was heard only if they made a mistake. Subsequent to a response, the next trial was then initiated.

Following the "yes" / "no" practice, the decision-making task was initiated, and participants read the following instructions that were presented on the computer screen.

> Hello, welcome to the experiment. In this experiment you are asked to act as a manager in a perfume company. Your task is to decide which perfumes the company will sell. You should aim to sell perfumes that will be successful in the market. To help you to make decisions, a survey is conducted for every new perfume to estimate its chances of success in the market. Press the spacebar to continue.
>
> In each trial you will be presented with a perfume and an estimation of the likelihood that this perfume will be successful in the market. You then have to decide whether or not to sell this perfume. If you decide to sell the perfume, then press the "yes" key. If you decide not to sell the perfume, then press the "no" key. Please think carefully about your decision. Press the spacebar to continue. [participants were presented with an example of a perfume bottle presented at the beginning of a trial]

[33] Participants performed Experiments 1 and 6 during the same testing session. Half of the participants performed the task of Experiment 1 first, whereas half of them performed the task of Experiment 6 first.

Your performance in this task is evaluated by the company management. The company will reward you with points (which affect your salary) according to your success in making accurate decisions. Your goal is to gain as many points as possible in order to increase your salary.

[Control instructions]

If you had decided to sell a perfume that later proved to be successful, you get 10 points. For deciding to sell a perfume that appeared to be unsuccessful, you lose 10 points.

[Avoidance instructions]

The company does not have much money, and tends not to risk money in order to avoid loss of money. Therefore, if you had decided to sell a perfume that later proved to be unsuccessful, you lose 16 points. For deciding to sell a perfume that was successful, you win 4 points.

[Approach instructions]

The company is rich and is prepared to risk money in order to increase its profits. Therefore, if you had decided to sell a perfume that later proved to be successful, you get 16 points. For deciding to sell a perfume that appeared to be unsuccessful, you lose 4 points.

Press the spacebar to see an example. [participants were presented with examples of two possible decision outcomes that could follow a "yes" response]

However, if you decide NOT to sell the perfume, you may still gain or lose points.

[Control instructions]

If you decide NOT to sell a perfume which could have been unsuccessful, you win 10 points. If, however, you decide NOT to sell a perfume which could have been successful, you lose 10 points.

[Avoidance instructions]

Because the company tends to avoid spending money after unsuccessful developments, if you decide NOT to sell a perfume which could have been unsuccessful, you win 16 points. If, however, you decide NOT to sell a perfume which could have been successful, you lose 4 points.

[Approach instructions]

Because the company does not want to miss good opportunities for successful perfumes, if you decide NOT to sell a perfume which could have been successful, you lose 16 points. If, however, you decided NOT to sell a perfume which could have been unsuccessful, you win 4 points.

Press the spacebar to see an example.

[participants were presented with examples of two possible decision outcomes that could follow a "no" response]

After seeing the outcome of your decision, when you are ready you initiate the next trial by pressing the space bar. Please use two fingers of the hand you write with to press "yes" or "no", and use the other hand to press the spacebar. Before the beginning the actual experiment there will be ten practice trials. If you have any questions, please ask them during the practice. Press the spacebar to begin practice trials.

Participants were instructed to imagine that they worked as managers in a company selling perfumes. On every trial, participants were presented with a perfume bottle with a written estimation regarding the likelihood that that perfume would be successful in the marketplace. This estimation was always expressed as a percentage. Participants had to decide whether or not to sell each perfume. If they wished to sell the perfume they pressed the "yes" key, and if they did not wish to sell it, they pressed the "no" key.

Participants were told that the company management would evaluate their decision-making performance, and that they would score points depending on their decisions and their accuracy. If they made a correct decision (i.e., to sell a successful perfume or not to sell an unsuccessful perfume) they would gain points. If they made an incorrect decision (i.e., to sell an unsuccessful perfume, or not to sell a successful perfume) they would lose points. The participants were told that the number of points they would gain or lose would determine the salary they would earn as managers in the company. The number of points was varied across the payoff conditions as in Experiments 4 and 5. In the control condition, participants won 10 points if the perfume they had decided to sell was successful, and lost 10 points if it was not successful. If the perfume was successful but they decided not to sell, they lost 10 points. If the perfume was unsuccessful, however, and they had decided not to sell, they won 10 points. In the avoidance condition, participants won 4 points if they had decided to sell a successful perfume, and lost 16 points if the perfume they had decided to sell was unsuccessful. If they had decided not to sell the perfume they lost 4 points if the perfume was successful and won 16 points if it was unsuccessful. In the approach condition, participants won 16 points if they correctly sold a successful perfume, and lost 4 points if the perfume they had decided to sell was unsuccessful. If they had decided not to sell the perfume they lost 16 points if the perfume was successful and won 4 points if it was unsuccessful. This information was provided in a textual descriptive form, and participants were told that the main goal of the task was to earn as many points as possible. The outcome feedback of each decision also presented the number of points won or lost following that decision (see Figure 24 above for examples).

To provide participants with a reason for utilising the payoff structure, the instruction for Experiments 6 included a rationale for utilising the payoff information additional to that of maximising the number of points gained. In the approach condition, participants were told that the company they worked for was rich and was prepared to risk money. In the avoidance condition, however, participants were told that their company was poor and tended to avoid risking money.

Following a response on every trial, participants were provided with outcome feedback, informing them whether or not their decision was correct, whether or not the perfume was (or could have been) successful and how many points they won or lost on each trial. Participants were asked to respond in their own time. Each response could result in one of four possible outcome feedbacks (see Figure 24 above). The outcomes that participants received were programmed in accordance with the estimated likelihood of each perfume being successful. For example, a perfume that had a likelihood of 40 % of being successful was indeed successful in four out of the 10 trials in which that perfume was presented through the experiment.

Before the beginning of the decision task, participants completed 10 practice trials to familiarise them with the decision-making task. The experimenter stayed in the room during the instructions and the practice, and answered any questions the participant had. The task took approximately 15 to 20 minutes to complete. As in Experiments 4 and 5, there were 10 blocks of 10 trials each (overall, 100 trials). Each block consisted of presentation of 10 perfume bottles (one at a time) each with a different probability level of success (between 10% to 100%). The trials were presented in a random order. The ratio between successful to unsuccessful perfumes in each block was either 5:5 or 6:4. Table 13 shows the trials included in each block.

Table 13: The trials included in each block (Experiment 6)

Block									
1	2	3	4	5	6	7	8	9	10
100.S	100.S	100.S	100.S	100.S	100.S	100.S	100.S	100.S	100.S
10.S	90.US	90.S	90.S	90.S	90.S	90.S	90.S	90.S	90.US
80.S	80.S	80.S	80.S	80.S	80.S	80.US	80.S	80.US	80.US
70.S	70.S	70.US	70.S	70.US	70.S	70.S	70.S	70.S	70.US
60.S	60.US	60.S	60.S	60.US	60.S	60.US	60.US	60.S	60.S
50.S	50.US	50.S	50.US	50.S	50.US	50.S	50.S	50.US	50.US
40.US	40.S	40.US	40.US	40.S	40.US	40.S	40.US	40.S	40.US
30.US	30.S	30.US	30.US	30.S	30.US	30.US	30.US	30.S	30.US
20.US	20.US	20.S	20.US	20.US	20.US	20.US	20.S	20.US	20.US
10.US	10.US	10.US	10.US	10.US	10.US	10.US	10.US	10.US	10.S

Note. The number represents the likelihood (in percentage) of the perfume presented in a trial to be successful; The letter 'S' represents successful perfumes and the letters 'US' represent unsuccessful perfumes.

At the end of the testing session, the old participants were also asked to fill in a health and life-style questionnaire (see Appendix F).

9.3. Results

Trials on which participants did not press either the "yes" or "no" key, and trials on which responses were made in less than 175 ms were excluded from the analyses. In the old group 0.92% of trials were excluded and in the young group 0.39% of trials were excluded. Mixed design ANOVA revealed a significant main effect of probability, $F(3.29, 223.82) = 567.32$, $p < .001$, indicating that participants were more willing to sell the perfume as its probability to be successful increased. There was also a significant main effect of payoff, $F(2, 68) = 9.74, p < .001$ and of age, $F(1, 68) = 4.35, p < .05$. The old participants were more willing to sell the products than the young participants. The old group's mean percentage of "yes" responses was 59.81% (SD = 7.03), and the young group's mean was 56.35% (SD = 1.53). There was also a significant interaction between probability and payoff, $F(6.58, 223.82) = 3.43, p < .001$ and between payoff and age, $F(2, 68) = 4.54, p < .05$, the latter suggesting that payoff differentially affected the two age groups. Figure 25 shows the mean percentage of "yes" responses as a function of probability and payoff collapsed across age. Figure 26 presents the mean percentage of "yes" responses as a function of payoff and age collapsed across probability. Age and probability were collapsed because these variables did not interact.

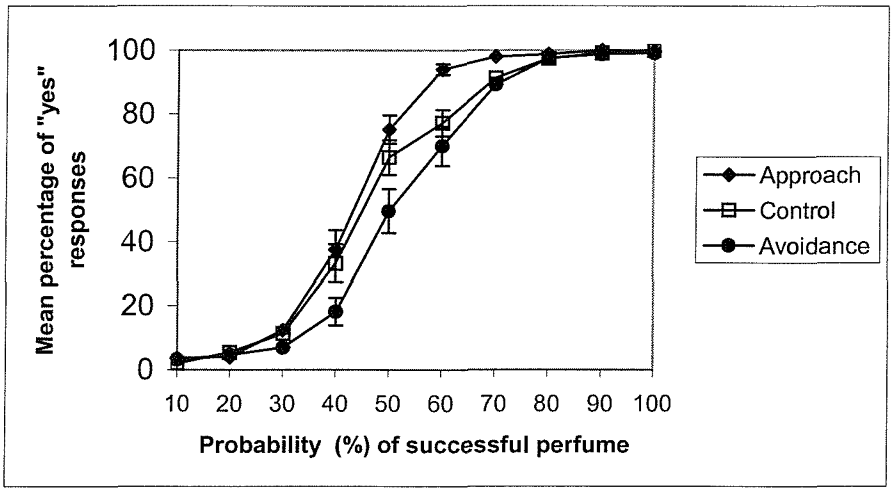

Figure 25: Mean percentage of "yes" responses as a function of success probability and payoff (data of young and old group collapsed)

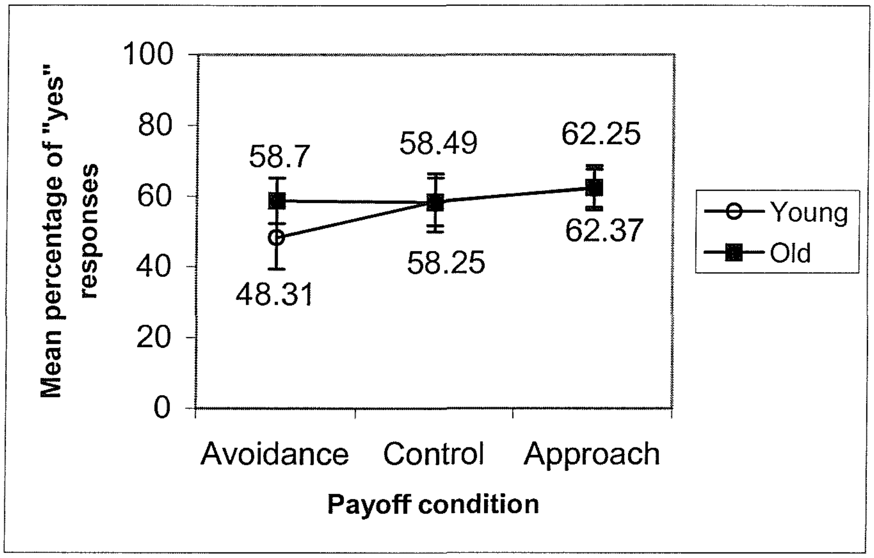

Figure 26: Mean percentage of "yes" response as a function of payoff and age collapsed across probability

There was neither an interaction between probability and age, $F(3.29, 223.82) = 1.96, p > .05$, nor between probability, age, and payoff, $F(6.59, 223.82) = 1.05, p > .05$.

Further to examine the interaction between payoff and age (i.e., to examine which age group showed a significant main effect of payoff), planned comparisons (independent-sample t-tests) were performed on the data of each age group. The analyses on the data of the old group showed no significant differences in the percentage of "yes" responses either between control and avoidance, $t(23) = -0.15, p > .05$, between control and approach, $t(23) = -1.42, p > .05$, or between approach and avoidance, $t(24) = 1.48, p > .05$. The analyses on the data of the young group demonstrated a significant difference in the percentage of "yes" responses between the avoidance and approach conditions, $t(22) = 4.64, p < .001$, and between the avoidance and control conditions, $t(22) = 3.16, p < .01$. No significant difference was observed between the approach and control conditions, $t(22) = -1.51, p > .05$. To examine whether the expected trend (avoidance < control < approach) was significant in the young group, polynomial (linear) contrast analyses were performed on the data of that group. The analyses showed a significant linear trend, $F(1, 33) = 22.76, p < .001$. This finding suggests that the young participants were least inclined to sell the perfume in the avoidance condition and were most inclined to do so in the control and approach conditions.

Figure 27 compares the observed pattern of decisions (i.e., percentage of "yes" responses) of the young and old groups to the optimal pattern, as posited by normative models of decision-making (see also section 8.1).

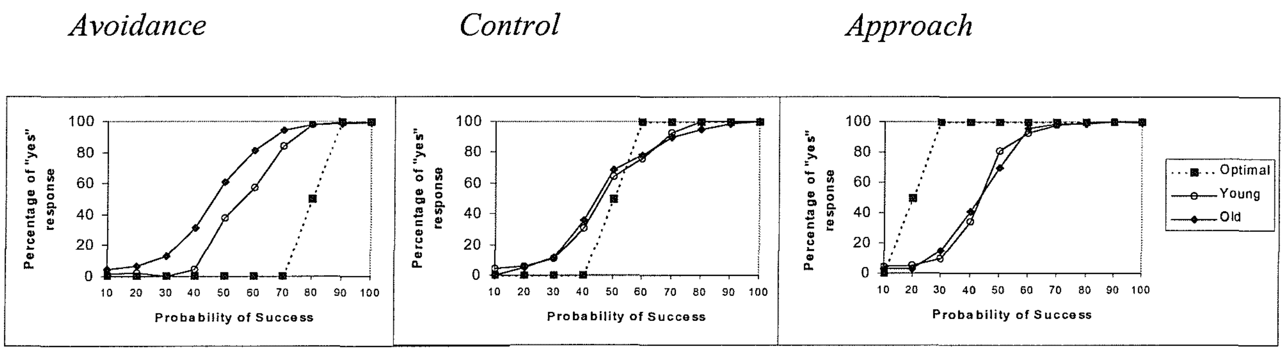

Figure 27: Observed decisions made by the young and old adults in each payoff condition compared to optimal pattern of decisions

As illustrated above, in the control condition, participants from both age groups produced a pattern of decisions that was close to the optimal. In both the approach and avoidance conditions, however, the young and the old participants' decisions were far from optimal, although those of participants in the young group were closer to the optimal pattern (i.e., were more reluctant to sell the perfumes) than the old adults in the avoidance condition.

9.4. Discussion

The results showed that both the young and the old adults made use of probability information, in that they were more willing to sell a perfume as its probability of success in the marketplace increased. These findings replicate those of Experiments 2 and 3, and those of Dror et al. (1998). The most important finding of Experiment 6, however, is that avoidance payoff affected the participants in the young group but not those in the old group. Specifically, participants in the young group were less willing to sell a perfume in the avoidance condition than were those in the control and approach conditions. In contrast, the old participants did not differ in their decisions across the three payoff conditions.

Neither age group was affected by approach condition. Because approach condition did not affect participants in the young group, conclusions regarding the effect of approach condition on the old participants cannot be drawn. Despite the fact that the payoff manipulations employed for the approach and avoidance conditions were of equal magnitude, the young participants responded to approach and avoidance payoffs asymmetrically. Only avoidance payoff affected their decisions. Approach payoff, on the other hand, did not have an effect. The asymmetrical effect on decision behaviour found here is consistent with previous studies that have reported a greater weight given to potential losses than to potential gains (Taylor, 1991; Wallach & Kogan, 1961). The asymmetrical negative effect reflects the notion that "losses loom larger than gains" (Kahneman & Tversky, 1979, p. 279) - that is, a loss is assumed to have a greater impact than a gain of equal magnitude.

The finding that the old group used only probability information, ignoring avoidance payoff information, supports the hypothesis that old adults are more selective in the information they use in making decisions. The utilisation of reduced quantities of information by old adults observed is also consistent with findings of previous studies. Johnson (1990, 1993), for example, found that old participants searched for fewer subsets of information when deciding which car to buy and which apartment to rent. Similarly, Walsh and Hershey (1993) showed that old adults tended to use a smaller subset of information variables than young adults when deciding which retirement account to open. Other studies examining decisions about treatments for a medical condition (e.g., Meyer et al., 1995; Zwahr et al., 1999) have reported similar findings.

As discussed in Chapter 3, the studies mentioned above focused on decision-problems for which experience could explain information selectivity by old adults. Differing from such past research, however, Experiment 6 required participants to make decisions on a decision-problem regarding which experience could not underlie selectivity. To make optimal decisions, participants had to make use of both probability and payoff information provided within the decision-problem. Given that decision-making in the present task could not depend on prior knowledge but must instead be based on the ability of the decision-maker to attend to and process two subsets of information, selectivity as exhibited by the old adults in the avoidance condition cannot be said to result from those participants' more extensive prior experience.

Furthermore, the task demands placed by the task in Experiment 6, greater than those of Experiment 4, impeded the ability of the old adults to make use of avoidance payoff. Thus, under low demands (Experiment 4), old participants were able to make some use of payoff, showing a difference in their response between approach and avoidance payoff. However, under high task demands (Experiment 6), they ignored this information and no differences between any of the payoff conditions were observed. Processing two dimensions of information (i.e., probability and payoff) might therefore have overloaded processing capacity of the old adults, and required them to base their decisions on one dimension of information only. This interpretation is consistent with research reporting age-related declines in divided attention (e.g., Craik & McDowd, 1987; Salthouse & Saults, 1987; for a review see Rogers, 1999) and working memory (e.g., Babcock & Salthouse, 1990; Gick et al., 1988; Morris et al., 1988; Salthouse & Babcock, 1991; Wingfield et al., 1988). Selectivity can therefore be conceived as a compensatory mechanism that allows old adults to perform the decision-making task with reduced processing demands. This selectivity exhibited by the old participants in the avoidance condition resulted in decisions, that were impaired - in comparison both to the young group's decisions and to optimal decisions.

An inevitable question is that of why the old participants in the avoidance group exhibited selectivity by ignoring payoff rather than by ignoring probability. A possible explanation is that the probability information might have been more salient and easy to process in this task than the payoff information. On every trial, participants were presented with information about the success probability of a perfume. Payoff information was not presented at the same time, rather it had to be retrieved from memory (of previous trials or of the instructions). Making decisions based on retrieved information (i.e., payoff) was therefore more demanding than making decisions on presented information (i.e., probability).

Another line of interpretation would attribute differences in information selectivity to differences in metacognitive knowledge (Hertzog & Hultsch, 2000). Old adults who are aware of their memory decline may have believed that they would have difficulty memorising the payoff matrix, hence, preferring to ignore this information. Motivation differences might also account for the findings of Experiment 6. It is possible that the old adults were not motivated enough by the incentives used (i.e., the points), and that playing with real money would have elevated their motivation. However, this explanation seems weak given the fact that taking part in the experiment required the old participants to be highly motivated to make the effort to come to the University for testing. The young participants, by contrast, did not have to make such an effort as they attended the University for their lectures anyway (for further discussion on this issue see section 10.4).

Also possible is that age differences in what was perceived as successful performance could explain the data. The two age groups might have differed in terms of their decision goals. Old adults may have placed more emphasis on accurate responses (see section 1.4.2.1), thus being interested in maximising correct responses (i.e., being successful on every trial). This type of goal is referred to here as a *local goal*. An effective strategy to achieve the local goal would be to base decisions on probability alone. The young group, on the other hand, might have been interested in a *global goal* (i.e., in maximising the overall number of points that could be earned across trials). To obtain the global goal, an effective strategy would be to incorporate probability and payoff. Employing this strategy would result in a larger proportion of incorrect responses as compared with the local goal strategy, but would earn more points. This explanation is consistent with Berg et al. (1994) who showed that old adults have different interpretations of everyday problems. However, this interpretation would seem hard to maintain because participants were told in the instructions that the goal of the game was to earn as many points as possible.

To summarise, the findings of Experiment 6 showed that the old participants were more selective than the young participants. Given the weaknesses of the explanations outlined above (i.e., age differences in motivation and in the interpretation of the task's goal), it could be concluded that the selectivity exhibited in Experiment 6 was the result of the cognitive limitations old adults possess. In comparison to Experiment 4, the findings of Experiment 6 imply that task demands have a role in information selectivity.

10. General discussion

10.1. Introduction

The concluding chapter is constructed as follows. First, the main findings of the empirical work are summarised and related to findings of previous research. Then, limitations of the reported work, suggestion for further research, and practical implications of the present research work are discussed. Next, considerations of selectivity and allocation of increased processing time in decision-making are discussed. Different ways to conceptualise each compensatory mechanism are also considered. Last, implications for theories of decision-making are discussed.

10.2. Summary of main findings

The purpose of Experiment 1 was to explore whether old adults make use of probability and payoff information when faced with decision-problems taken from real-life situations. The data showed that old adults, as well as young adults, made use of both probability and payoff information, although they used probability information in different ways. Specifically, both age groups were more willing to take an action (e.g., undergo an operation) under the approach condition (i.e., for decision-problems that involved more gain than loss), than under the avoidance condition (i.e., for decision-problems that involved more loss than gain). In the approach condition, the willingness of both age groups to take an action increased with increased probability that the outcome of that action would be successful. However, the old participants were less inclined than the young participants to take an action under low probability of success. Under the avoidance condition, the old adults were less willing to take an action with a high probability of success than the young adults. The young adults did not differ in their response to the different probability levels under this condition. The finding that the old group made use of both probability and payoff in Experiment 1 demonstrated that they are able to use these dimensions of information when faced with decision-problems taken from real-life situations. The decision-making task used in this experiment was not optimal, however, in that it did not allow close investigation of the role of cognitive factors in decision-making by old adults, because external factors that could have affected decision-making performance (i.e., experience and perception of risk) were not adequately controlled. The need for a more rigorous decision-making task, allowing the manipulation of cognitive demands in addition to greater control of external factors led to the adoption of a more controlled decision-making task. In this task participants were required to make decisions either when playing a card game or when making decisions on whether or not to sell different perfumes. Information about outcome probability and outcome payoff information was presented numerically. Experiments 2 to 6 made use of this task to examine more rigorously whether cognitive factors affect decision-making in old age. In particular, these experiments sought to examine whether compensation in decision-making by old adults is affected by cognitive limitations.

In Experiment 2, participants played a card game, and made decisions under different levels of uncertainty (i.e., the extent to which a bust outcome could be predicted based on the card value). The experiment varied the processing demands of the task by manipulating the presence of decision outcomes (i.e., outcome and no-outcome conditions). The results showed that young and old adults reached the same decisions under both outcome conditions. Consistent with the findings of Dror et al. (1998), who used a similar decision-making task, the RT data showed that, in general, the old participants took longer to make decisions, and that both age groups showed an increase in RTs as uncertainty increased. The most important finding of Experiment 2 was that the demands of the decision task (i.e., the presence or absence of outcomes) differentially affected the two age groups. First, the old group's slowing was more profound when decision outcomes were provided (i.e., high demands) than when they were not provided (i.e., low demands). The young participants, in contrast, were not affected by the presence of decision outcomes. The finding that the old participants slowed down when provided with outcome feedback is consistent with Hines

(1979) who used a RT choice task.[34] Second, the demands of the task were also observed to have affected the magnitude of the age differences in slowing across uncertainty. When outcomes were not provided, participants in the old group showed the same rate of slowing with increased uncertainty as participants in the young group. When outcomes were provided, the old participants showed a steeper increase in RT with increased uncertainty than did the young participants. This pattern of results was evident in the first phase of the experiment in which participants experienced outcomes on every trial (i.e., current outcomes) as well as in the second phase of the experiment in which no outcomes were presented such that any effect was based on outcomes experience in the first phase of the experiment.

It was proposed that the age differences observed could be accounted for by differences in the efficiency of the decision process itself rather than by differences in the decision criterion. This proposal was supported by the finding that even under time pressure, which according to the SMM is expected to reduce decision threshold, the old participants still showed greater slowing with increased uncertainty than did the young participants. These data appeared to support the compensatory hypothesis - that old adults allocate more time under conditions of increased task demands - a mechanism that allows them to reach the same decisions as young adults. However, processing decision outcomes (i.e., the outcome condition) did not result in decisions that differed from those which had been made without reference to those outcomes (i.e., no outcome condition). Participants in both outcome conditions made the same decisions. This finding can be explained by the fact that the outcomes that participants in the outcome condition experienced were determined by the outcome probability that had been expressed by the card values (i.e., the probability that a certain card value would be paired with another card making a bust total) with which participants in both outcome conditions had been presented. Therefore, if any pattern in

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[34] Nevertheless, Hines's (1979) young participants were faster when provided with outcome feedback than when outcome feedback was not provided – unlike the findings of Experiment 2.

outcome probability was observed by participants in the outcome condition, it was not different from the probability of each card value going bust. Hence, no differences between the decisions made under the different outcome conditions should be expected to occur.

Experiment 3 examined whether old adults are affected in their decisions when decision outcomes provide probability information which is different (i.e., biased) from the probability expressed by card values. In addition, Experiment 3 examined whether old adults' processing of biased outcomes was accompanied by allocation of increased processing time. The results indicated no age differences in the decisions made - outcome bias affected both young and old adults alike. Specifically, participants in both age groups were less willing to take another card under the negative outcome bias condition (i.e., high probability of bust outcomes) as compared to the positive outcome bias condition (i.e., low probability of bust outcome). The RT data showed that the old adults' slowing across uncertainty was more profound that that of the young adults when biased outcomes are experienced. These findings extended those of Experiment 2 by showing that old adults make the same decisions as young adults when they have experienced biased outcomes and that, as do young adults, they are affected in their decisions by biased outcome probability. Further, participants' RTs showed that old adults allocate more time to making decisions when processing biased outcomes. These findings provide further support for the hypothesis that old adults utilise more processing time as a compensatory mechanism, allowing them to reach the same decisions as young adults.

Experiments 4 to 6 examined the hypothesis that old adults are more selective in the information they employ in decision-making as a means of cognitive compensation. Experiment 4 aimed to test this hypothesis by examining the processing and use of payoff information by old adults. Participants were asked to make decisions in a simulated card game task that included only payoff variation. Outcome probability was kept constant across trials (that is, bust and no-bust outcomes were equally likely to occur). The results showed that both age groups processed payoff information. Specifically, in line with predictions of the SSM, the RT data showed that both age groups were faster at making "yes" than "no" decisions in the approach condition, and faster at making "no" than "yes" decisions in the avoidance condition. In the control condition no differences in RT were found between the two responses. Examining the percentage of "yes" decisions revealed that compared to control condition, participants in the young group were less inclined to reveal the cards in the avoidance condition and more inclined to reveal the cards in the approach condition. Although participants in the old group showed a similar difference in their willingness to reveal the cards between approach and avoidance as the young participants did (i.e., they were more inclined to reveal the cards in the approach condition than in the avoidance condition), their responses in the approach and avoidance conditions did not differ significantly from the control condition. In other words, the young participants showed more extreme responses to both approach and avoidance payoff than the old participants. In addition, more young than old participants were observed to have employed approach payoff and, also old participants were found to be less able to recall the payoff matrix, suggesting that the old participants were less able to remember the payoff information. These findings showed that, overall the old adults made some use of payoff information, but that they did so to a lesser extent than the young adults.

Experiment 5 examined whether selectivity (i.e., ignoring either probability or payoff) in old age is affected by increased task demands. The task demands were increased by including both probability and payoff information in the card game participants were asked to play. Consistent with previous research (Dror et al., 1998) and the findings of Experiment 2, the results showed that both old and young adults made use of probability information in decision-making. Specifically, both age groups were more reluctant to take an additional card as the probability of a bust outcome increased. Unfortunately, neither age group used payoff information, thus demonstrating that selectivity is not always confined to old adults. Because of this, it was clear that the task used in Experiment 5 was not suitable for further examination of the hypothesis.

A final experiment was constructed to test the selectivity hypothesis. To encourage participants to make use of payoff information, Experiment 6 employed a decision-making task that again included both probability and payoff information but attempted to make the payoff information more salient than it had been in Experiment 5. The task incorporated more explicit instructions for employing payoff. As in Experiment 5, the aim was to examine whether old adults show information selectivity when making decisions in a more demanding decision-making task than the one employed in Experiment 4. Both age groups utilised probability information. Differences between the two age groups were apparent with respect to the utilisation of payoff in the avoidance condition. The young group incorporated payoff in their decisions in the avoidance condition (i.e., participants were more reluctant to take another card in the avoidance condition than in the control and approach conditions), but the old adults failed to make use of payoff information in the avoidance condition (i.e., their decisions did not differ across payoff conditions). Both age groups failed to make use of payoff in the approach condition. The finding that the old participants in the avoidance condition ignored payoff information is in line with previous research reporting that old adults tend to search for fewer subsets of information than do young adults (e.g., Johnson, 1990, 1993; Meyer et al., 1995; Walsh & Hershey, 1993; Zwahr et al., 1999). The findings of Experiment 6 extended those of previous research by showing that selectivity of information by old adults can occur on decision-problems on which experience cannot guide information use. Furthermore, these findings imply that cognitive factors (i.e., increased task demands) limited decision-making performance of old adults by showing that under conditions that place high processing demands old adults showed information selectivity. Table 14 summarises the main findings of each experiment.

Table 14: A summary of the manipulated variables in each experiment and the main findings

Experiment	Within-subject variables	Between-subject variables[a]	Decision task	Findings
1	probability payoff	___	real-life decisions (questionnaire)	Y[b] & O[b] use probability and payoff.
2	probability	task demands (outcome existence)	card game	Y & O use probability. RTs of O increase under high demands (outcome condition).
3	probability	outcome bias	card game	Y & O use probability and outcome bias. RTs of O show a more profound increase across uncertainty.
4	___	payoff	card game	Y & O use payoff. O use it to a lesser extent.
5	probability	payoff	card game	Y & O use probability but not payoff.
6	probability	payoff (more salient)	commercial decisions	Y use probability and payoff (avoidance). O use probability but not payoff.

[a] Age was a between-subject variable in all experiments.

[b] Y refers to young adults and O refers to old adults.

10.3. Conclusions derived from the findings

The series of experiments reported in this thesis provided evidence that cognitive limitations play a role in decision-making performance in old age. In particular, the data showed that cognitive limitations in old age affect the use of compensation in decision-making. The findings extended those of previous research by demonstrating the use of two compensatory mechanisms by old adults in making decisions: allocation of increased processing time and information selectivity. Based on the findings reported in this thesis, the allocation of more time by old adults appeared to reflect cognitive limitations (i.e., less efficient decision process). In addition, it can be concluded that the information selectivity exhibited resulted from cognitive limitations on the part of the old adults rather than from their experience. In general, previous studies that reported information selectivity in decision-making by old adults confounded cognitive and experiential factors. In addition, no attempt had previously been made to manipulate the cognitive demands of a decision-making task in order to examine the role of cognitive factors in age differences in decision-making. This thesis has provided support for the hypothesis that selectivity of information can be accounted for by cognitive limitations in old age in two ways: firstly, by demonstrating selectivity in old age in decision-problems for which experience cannot guide decision-making, and secondly, by showing that variations in cognitive demands affect selectivity in old age. Further research will benefit from examination of the relative contribution of cognitive and experiential factors in decision-making in old age.

10.4. Methodological limitations and possible improvements of the experiments

The conclusion that increased task demands affected information selectivity in old age should be, however, taken with caution. The findings that old adults were more selective on a decision-making task that placed high processing demands (Experiment 6) than on a task that placed low demands (Experiment 4) were based on comparing participants' performance on two decision-making tasks that differed on other aspects than the demands they placed on information-processing. Firstly, whereas in Experiment 4 the task required decision-making in the context of a card game, in Experiment 6 the task involved commercial decisions. Secondly, the instructions for Experiment 6 placed greater emphasis on payoff information than those of Experiment 4. These differences between the tasks do not permit statistically to compare between decision-making performance in those different experiments. To allow this comparison, a further experiment could be designed, in which the same task is performed under different task demands. For example, requiring participants to perform the same commercial decision-making task under high demands (with both probability and payoff as in Experiment 6) and under low demands (only payoff information). The two tasks could be performed by the same participants in order to reduce individual differences between participants in the different demand conditions.

The two decision-making tasks that were used in this thesis (Experiments 2 to 6) required participants to make a series of decisions, either in the context of a card game, or in a commercial context. Although using different decision contexts, the two tasks were constructed around the same structure (i.e., series of decisions with varying outcome probability). This task structure was used because it had been successfully employed in previous research (Dror et al., 1998; Dror et al., 1999). In particular, this task structure was chosen because it allowed the examination of cognitive factors involved in decision-making in separation from external factors (such as experience) and therefore allowed the controlled manipulation of factors potentially affecting decision-making performance. It must, however, be acknowledged that using such a controlled decision-making task holds limitations for making strong conclusions. First, the decision-making task is rather simple and does not capture the complexity of decision-making problems people are faced with in everyday life. It is, therefore, not clear to what extent the findings generalise to everyday decision-problems. Second, the decision-problem is well structured and defined with regard to the dimensions of relevant information, and thus markedly differs from many real-life decision-problems, for which the goal may not be entirely clear, or relevant information not always available. Third, because of its simplicity, the task was not so challenging that some participants did not find the task interesting. This raised concerns regarding possible confounds arising from low motivation. Further research might aim to make the task more interesting and challenging.

The experimental paradigm employed in Experiment 2 was composed of two phases. In the first phase, outcome presence was manipulated between two outcome conditions, one in which outcomes were included and one in which they were not. In the second phase neither condition included outcome information, but employed time pressure (i.e., participants were required to respond as quickly and as accurately as possible). Thus, the second phase confounded time pressure and absence of outcome feedback information. Removal of time pressure in the second phase of the experiment might constitute an improvement to the experimental design.

In Experiment 2, the second phase allowed examination of whether allocation of more time by the old adults was a result of a slower decision process or a more cautious decision threshold. Although the results indicated that the former underlined the allocation of more time, a more controlled design would perhaps involve careful manipulation of time pressure and outcome existence. This might be achieved by using two outcome groups, each performing the same task, but with and without time pressure. This would provide a controlled design to examine whether there are differences in allocation of processing time by old adults under different outcome conditions, and whether allocation of more time results from a slower decision process or a more cautious decision threshold.

Experiments 5 and 6 included payoff information in addition to the probability information. However, it was already noted that the two types of information were not balanced for saliency. Whereas probability was presented on each trial, payoff information had to be remembered. This could explain why both young and old participants were more inclined to base their decisions on probability rather than on payoff. It would be worthwhile to examine the use of these two types of information in a decision-making task that equalised the saliency of the two. It may be the case that old adults would have been more inclined to use payoff information if it had been as salient as the probability information provided.

On a more general note, the experiments reported here were limited by their cross-sectional design. Because age was not a manipulable variable, random assignment of participants to the different age groups was impossible. This implies that participants from different ages could differ on other characteristics besides age, such as cohort differences. These characteristics might have contributed to the differences found between the two age groups. Therefore, caution must be exercised in making causal inferences regarding age as a variable (i.e., at attributing observed differences to age per se; see Salthouse, 2000b).

It should also be noted that the young adults who participated in the experiments reported above were undergraduate students who were tested in their familiar environment (i.e., the Psychology Department). In contrast, for the old adults, attending the Psychology Department for participating in the experiments meant that they were tested in an unfamiliar environment. This confounding variable may have contributed to performance differences between the two age groups. Future research can control for this factor by testing participants from every age group used in an environment which is either familiar or unfamiliar to them.

In addition, the sample of participants used in the experiments may not have been representative of the general population, as it was composed of volunteers who may differ in their attitude, motivation, and intellectual ability from the general population. Therefore, we cannot conclude that the reported age-related differences reflect the age differences in the population. The sample of old adults was matched to that of the young adults only with relation to education level. Salthouse (2000b) has suggested to include additional measures related to fluid and crystalised intelligence, as a means of comparing the sample population to the general population.

10.5. Future research

This thesis provides initial insights into two compensatory mechanisms used by old adults when making decisions. A number of research questions that warrant investigation have been raised during the research process and are presented below.

10.5.1. Individual differences

In this thesis, decision-making performance was averaged across individuals from each age group. Neverthelss, it is well known that in old age, individual differences are most prominent (e.g., Rabbitt, 1993). It would therefore be interesting to explore how individuals differ in their decision processes as well as why some individuals are more prone to exhibiting compensation. This individual differences approach was applied by Zwahr et al. (1999) who investigated the role of age and cognitive abilities in women's decisions about an effective treatment for menopause. The authors found that cognitive abilities (i.e., perceptual speed, working memory, reasoning, text recall and vocabulary) had a direct influence on treatment decisions. Specifically, participants with higher cognitive abilities perceived more options for treatment, made more comparisons between treatment alternatives, and produced better rationales for their decisions. Including different measures of cognitive abilities in future experiments would allow investigation of which age-related deficits result in the use of selectivity and allocation of extra decision time.

10.5.2. Developmental differences in adults' decision-making

The experiments reported here examined age differences in decision-making by including two extreme age groups, young adults in their 20s and old adults in their 70s. Further to explore developmental change in decision-making it would be useful to include other age groups, for instance, middle-aged adults. This has been done by several studies examining everyday decision-making (e.g., Meyer et al., 1995; Sinnott, 1989; Walsh & Hershey, 1993; Zwahr et al., 1999). Decision-making was shown to differ not only between young and old adults - middle-aged adults were found to exhibit a different decision style from the two extreme age groups (e.g., Sinnott, 1989; Walsh & Hershey, 1993). For example, Walsh and Hershey (1993) found that, compared to young and old adults, middle-aged adults used fewer subsets of information to arrive at quicker decisions regarding opening a retirement account. According to the authors the middle age group was the most efficient age group in terms of the decision process, as they show a similar pattern of decision process to experts.

Similarly, Sinnott (1989) noted that middle-aged adults were superior to both young and old adults when solving problems, because they were utilising both bottom-up and top-down processes, enabling them to use available important information as well as effectively employing their knowledge from previous experience. The young and the old group, on the other hand, were restricted to one style of processing, either bottom-up or top-down, respectively, possibly as a result of limitations in experience on the part of the young adults, and difficulties, on the part of the old adults, at utilising information presented within the problem. However, Meyer et al. (1995) found that middle-aged women did not differ from old women with regard to the amount of information they required to make a decision about breast cancer treatment. Both age groups, however, required less information than did young women in those real-life decisions.

Based on these observations, including a middle age group in follow-up experiments could provide more information regarding the developmental changes in decision-making processes. Salthouse (2000b) has also noted that data from adults across the different age groups can be useful for distinguishing between theories assuming discontinuity versus theories assuming continuity in cognitive development.

10.5.3. Does selectivity reflect inability or unwillingness to make use of information?

The findings of Experiment 6 indicated that old adults were more selective in the information they used to make their decisions, in that they ignored avoidance payoff information. This finding raises the question of whether selectivity reflects the inability of old adults to use a demanding strategy (i.e., to incorporate probability and payoff information) or whether it reflects their unwillingness to do so. This question is pertinent to two versions of the *'production deficiency hypothesis'*; the strong versus the weak version (for reviews, see Cohen, 1988; Verhaeghen & Marcoen, 1994). In general, this hypothesis posits that old adults do not adopt effective cognitive strategies. According to the strong version of this hypothesis old adults are unable to adopt the effective strategy as a result of processing limitations. The weak version postulates that either unwillingness to do so or less practice with using the strategy underlies the employment of less effective cognitive strategies by old adults. A follow-up experiment could therefore be designed to address this question, by examining whether more practice, guidance, or motivation (e.g., including monetary payoff) could induce the old adults to incorporate probability and payoff in their decisions. Demonstrating that selectivity in old age is eliminated under conditions enhancing motivation or practice would provide support for the weak version. Demonstrating that selectivity persists under such conditions would support the strong version.

10.5.4. Can environmental support aid decision-making in old age?

Information selectivity, as demonstrated in Experiment 6, may reflect the difficulties old adults have when required to engage in effortful, self-initiated, processing. This type of processing is required for incorporating both probability and payoff information. Backman (1989) and Craik & Jacoby (1996) proposed that old adults may benefit from the provision of environmental support for carrying out effortful operations. Environmental support refers to the provision of external mediators that support processing for successful completion of a task (Craik and Jacoby, 1996). For example, recognition tasks provide more environmental support than recall tasks, because the former provides a stimulus to elicit memory whereas in the latter participants must retrieve the stimuli by themselves. Environmental support can also be achieved by instructional cues or guidance provided by the experimenter for employing effective strategies to perform a task. Old adults were found to benefit from such external mediators in memory tasks (for a review, see Backman, 1989). It would be interesting to examine whether different forms of environmental support might benefit old adults in decision-making. For example, are old adults able to incorporate probability and payoff information if given attentional guidance by the experimenter to pay attention to that information? Or is selectivity eliminated when old adults are provided with a simple representation of the payoff matrix? This research would carry the potential practical implications for the development of different methods to aid decision-making in old age.

10.5.5. Does selectivity reflect difficulties in strategy selection or strategy operation?

Another question is whether use of selectivity is a result of a failure to adopt the effective strategy (i.e., strategy selection) or in a failure to execute it effectively (i.e., strategy operation). That is, did the old adults fail to incorporate probability and payoff because they failed to realise that this was the optimal strategy? or did they try but failed to incorporate the two dimensions? Cohen and Faulkner (1983) examined this issue using a mental rotation task and a sentence verification task. They found that old and young adults used the same strategies to perform the tasks as revealed by the participants' verbal reports and by their RTs. However, the RT measure also indicated that the old adults were less capable of executing the strategies. This issue clearly warrants further investigation in the decision-making domain, as it carries both theoretical and practical implications. Specifically, locating the reason for the old individuals' limitations in using effective decision strategies would be useful for developing decision-making aids.

10.5.6. The relations between information selectivity and allocation of increased processing time

In the experiments reported in this thesis, two compensatory mechanisms employed by old adults were demonstrated: Allocation of more time and information selectivity. The two mechanisms were investigated separately. A question that emerged during the research process, however, was whether the two mechanisms were inter-related? That is, would allocating more time allow old adults to make use of relevant information such as payoff (i.e., eliminating selectivity)? Would information selectivity eliminate the need to utilise more time for making decisions? These questions could not be answered by the data from the present experiments because of confounding decision outcomes and payoff. As shown by Experiment 2, allocation of more time by the old adults resulted from processing decision outcomes. Decision outcomes were also present in the designs of Experiments 4 to 6 which included also payoff variation. That is, in these experiments, decision outcomes might have been processed by old adults regardless of whether or not payoff information was used, leading to allocation of increased processing time. That is, in such a design, outcome and payoff information were confounded. It would not be clear, therefore, whether allocation of more time occurrs as a result of processing payoff or of processing outcomes. These questions could be addressed using a design that separated the different types of information.

10.5.7. What are the underlying cognitive mechanisms of information selectivity and allocation of increased processing time?

The experiments reported in this thesis demonstrated that cognitive limitations in old age contribute to the employment of information selectivity and allocation of more time in decision-making. Further research should investigate the role of specific cognitive processes in underlying those compensatory mechanisms. For example, a further study could investigate whether limitations in selective attention in old age affect decision-making performance by varying the amount of irrelevant information available in the decision problem. The question to be addressed in such a study would be whether old adults allocate more time than young adults do to making decisions when both relevant and irrelevant information is available as compared to a condition under which only relevant information is present. In addition, the role of episodic memory in information selectivity could be studied by varying the timing at which payoff information is presented. Payoff information could be presented at the same time as probability information or at a prior time (as in Experiments 5 and 6). Such a study would investigate whether the requirement to retrieve payoff information from episodic memory result in disregarding this information.

10.6. Practical implications

Old adults are frequently faced with many crucial decisions - such as decisions about finance, living arrangements, and medical treatments. In addition, old adults experience decline in various cognitive processes that have an important role in decision-making. The work in this thesis could imply potential ways in which old adults could be helped in order to cope efficiently with cognitive deterioration when making decisions.

Given the limitations old adults exhibit in decision-making performance under increased task demands reported, old adults may benefit from a decision-making process that minimises cognitive demands. For example, allowing the old individual to make decisions without time constraints; presenting an individual with one piece of information at a time; providing a simple representation of complex information; or presenting only relevant information. These interventions might be the subject of further research for developing decision aids for old adults. These aids could be applied to the domain of medical decisions in making physicians aware of the limitations of old adults in making decisions, and in providing old adults with extra aid in understanding the information. In the work place, old adults could contribute to decision-making when their prior experience and knowledge are required. In collaborative decision-making, having teams consisting of both young and old workers may benefit the decision process, where both bottom-up and top-down processing modes could be incorporated in the production of sound decisions.

10.7. Reconsideration of information selectivity as a compensatory mechanism

10.7.1. *Information selectivity: the trade-off between reduced task demands and sub-optimal performance*

Positing the term 'bounded rationality', Simon (1955) proposed that individuals do not conform to the principles of normative decision-making because of limitations in their information-processing capacity. Demonstration of young adults' use of simplified decision strategies (or heuristics) which do not follow normative principles of decision-making has a long standing history in decision-making research (e.g., Jacoby et al., 1974; Johnson & Payne, 1985; Kahneman & Tversky, 1979; Payne, 1976; Payne et al., 1988; Wright, 1974). Consistent with the concept of bounded rationality and past research findings, neither the young nor the old participants exhibited optimal performance during Experiments 4, 5, and 6. Nevertheless, the performance of the young participants in Experiment 4 (under low task demands) and of those in Experiment 6 (under high task demands) was closer to optimal than that of the old participants - that is, the old group was far behind the young group, possibly trading optimal performance for minimising the cognitive demands of the task. If selectivity leads to sub-optimal decision performance, then one might argue that selectivity is a deficient strategy.

10.7.2. *Is selectivity a deficient strategy?*

Information selectivity has been defined as a simplified strategy that reduces the total amount of information that is processed during the decision process (Maule & Edland, 1997). In Experiment 6, selectivity by the old adults was reflected in the disregarding of payoff, which led to sub-optimal decisions. Thus selectivity, as demonstrated here, can be seen as a deficient strategy. This conclusion would be consistent with the *'production deficiency hypothesis'* (Cohen, 1988; Verhaeghen & Marcoen, 1994). A different view of age differences in strategy use, however, is concerned with the adaptive or compensatory nature of those strategies (Berg et al., 1994) - rather than viewing the strategies used by old adults as deficient, Berg et al. (1994) proposed that they were actually adaptive in the face of changing experiences and cognitive capacity with old age.

Adopting the latter approach, although selectivity may lead to sub-optimal decision performance, it can nevertheless be viewed as an attempt by old adults to optimise performance, (i.e., to compensate for reduced cognitive capacity, aiming at reducing the gap between actual ability and expected performance). Although this conceptualisation is embodied in the notion of compensation, it could be asked whether or not selectivity reflects compensation.

10.7.3. Does selectivity constitute a compensatory mechanism?

What constitutes compensation is a subject of debate among researchers. A narrow conceptualisation of compensation is held by Salthouse (1987, 1990, 1995), according to whom compensation entails any active effort by an individual that actually leads to successful performance. Therefore, modifications in goals or task demands (see section 1.4.1) are not examples of compensation. According to Salthouse (1987, 1990, 1995), the only mechanism that fulfils these requirements, and that can thus be considered as compensation, involves substitution (see section 1.4.1). This involves development of a new skill by which an old adults develops, through experience, a new ability to perform the task. This new ability counterbalances the effects of reduced ability to demonstrate other task-related skills.

Backman and Dixon (1992), however, have adopted a wider approach to compensation. Their framework includes goal change as a form of compensation in addition to development of substitute skills. According to those authors, compensation may result in either successful or unsuccessful performance. Although it is expected that compensation would result in a benefit or a gain (i.e., adaptive behaviour), it is possible that compensation may not optimise performance (i.e., non-adaptive behaviour). Backman and Dixon (1992) argue, therefore, that although a particular compensatory behaviour may be sub-optimal, it can still reduce the mismatch between accessible skills and task demands.

10.7.4. What is a successful performance?

A central point of divergence between Salthouse's (1987; 1990; 1995) and Backman and Dixon's (1992) concept of compensation is that of whether compensation results in a successful performance. It may prove informative, thererfore, to define what successful performance is.

Marsiske, Lang, Baltes, and Baltes (1995) pointed out that success can be defined in a variety of ways using different criteria. For example, using *ideal criteria*, success can be defined in terms of attaining the original desirable goal. Alternatively, success can be defined in terms of *functional criteria*, referring to the ability to perform a task regardless of the original goal. Adopting the ideal criteria of success, selectivity as demonstrated in Experiment 6, can not be counted as a successful compensatory mechanism, because the old adults did not choose the decision alternative that produced the highest EV. That is, the principle of normative decision-making (i.e., incorporating both probability and payoff information) was not employed. Nevertheless, in functional terms, selectivity, as used by the old adults in Experiment 6 (as well as by the young adults to a lesser extent), can be conceived as successful, because it allowed participants to perform the decision task with reduced processing demands.[35] Under the functional definition of success, selectivity can be seen as compensatory mechanism that allowed the old adults to perform the task.

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[35] It is also possible that age differences in the interpretation of the task contributed to the results. As noted in the discussion for Experiment 6, the old adults might have interpreted the goal of the task differently. These participants might have been interested in maximising the number of trials on which they made a correct response (by responding to probability information only), whereas the young group aimed at maximising the total points that could be gained (by responding to both probability and payoff). This interpretation is

10.7.5. Additional accounts of information selectivity: Age differences in processing style

The finding that old adults are more selective than young adults in the information they use may reflect age differences in processing style. Two distinctions are made and discussed in the following section: Top-down versus bottom-up processing, and rule-based versus analytic-based decision modes.

10.7.5.1. Top-down and bottom-up processing

Previous research showed that old adults tend to seek less information during the decision process relative to young adults when faced with everyday decision-problems (e.g., Johnson, 1990, 1993; Meyer et al., 1995; Sinnott, 1989; Walsh & Hershey, 1993). Consistent with these studies, Experiment 6 demonstrated that old adults ignore part of the information (i.e., payoff) available in the decision-problem. Meyer et al. (1995) pointed out that age differences in information seeking may reflect age differences in the tendency to employ top-down and bottom-up processing.

Using a think-aloud technique, Sinnott (1989) showed that adults of different ages engage in different processing styles when solving problems. She distinguished between different processing styles, two of which are the *youthful style* and the *old style*. The youthful style is characterised by intensive data seeking and bottom-up processing focusing on the data available within the problem, with little weight given to past experience. This type of processing style is useful for individuals lacking relevant knowledge structures. The old style, on the other hand, uses top-down processing, in which they show an intensive reliance

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consistent with findings that older adults demonstrate different interpretations of everyday problems (see Berg et al., 1994 for a review).

on past experience while ignoring the data within the problem. This style is most suitable for an individual possessing limited working memory capacity. This reliance on past experience (i.e., on long term memory) allows the individual to compensate for poor memory abilities.[36]

The idea that with age there is a shift from a data-driven to a conceptually-driven mode of processing is not unique to the decision-making domain. In the memory domain, Reder et al., (1986) have showed that the memory performance of old adults was impaired to a greater extent when they were not able to apply their past knowledge. The authors found that old participants tended to use a conceptually-based plausibility strategy (i.e., making inferences based on the information available) more than a data-based direct retrieval strategy (i.e., retrieving a specific fact) in a memory verification task (see section 1.4.3). As a result, under a condition that required direct retrieval, the performance of the old participants was impaired because they used the inappropriate plausibility strategy.

The finding that old adults exhibit selectivity in Experiment 6 could be thus understood within the top-down bottom-up distinction. The top-down style could be useful for making decisions on everyday decision-problems of which old adults have much experience. For example, in previous studies that have employed everyday decision-problems old adults have been shown to reach the same decisions as young adults, despite the fact that they had been selective in their information search (Johnson, 1990, 1993; Meyer et al., 1995; Walsh

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[36] Consistent with this view, Walsh and Hershey (1993) proposed that old adults are in some cases more efficient than young adults in solving problems and making decisions because, being more experienced in everyday problems, old adults have better developed *mental models* than the less experienced young adults. These mental models are "a person's conceptual understanding of (1) the relevant variables to consider in solving a particular problem and (2) how these variables are interrelated" (p.555).

& Hershey, 1993). Relying on pre-existing knowledge structures, the old adults might have been able to compensate for reduced processing capacity. However, for decision-problems with which old adults are not engaged in everyday life (for example, that used in Experiment 6), the top-down style could not be successfully employed, because there would be no knowledge structures that the old individual could rely on. Under this situation bottom-up processing would be useful. Based on this account, selectivity, as was demonstrated in this thesis, could be interpreted as reflecting old adults' difficulty in engaging in bottom-up processing.

10.7.5.2. Rule-based and analytic-based decision modes

The difference between making decisions based on probability alone, and basing decisions on probability and payoff information together, can also be conceived as the difference between two modes of decision-making: the *rule-based mode* and the *analytic-based mode* (Yates & Patalano, 1999). Yates and Patalano (1999) define the analytic decision mode as "effortfully reasoning through to what action makes sense" (p.35). This includes, for example, comparison of the pros and the cons of each possible decision. A rule-based decision mode is based on a rule developed through experience with similar decision-problems. In terms of cognitive demands the analytic mode is proposed to place heavier demands on working memory, and therefore old adults are less likely to make use of it. In the decision-making task used in Experiment 6 the use of probabilistic information can be accounted for in terms of using a rule-based mode. That is, participants would set a decision rule (such as, deciding to sell a perfume if the likelihood of it being successful is larger than 50%, and deciding not to sell it if its success likelihood is smaller than 50%). However, to incorporate both probability and payoff information in this task participants would have had to have utilised the analytic mode. This would have involved combining the two types of information, and then adjusting or modifying the rule produced by the probability information. For example, using avoidance payoff information, participants would have rejected selling a perfume even if it had a success likelihood of 60%. The process of combining information and modifying the rule necessarily places extra demands on information-processing, and may therefore have not been employed by old adults. Yates and

Patalano (1999) have speculated that old adults minimise the demands of a task by reducing their dependency on the analytic mode. The advantage of using the rule-based mode would therefore be in reducing the processing demands of the task and remaining able to perform it. The disadvantage would lie in producing decisions that are sub-optimal. Selectivity (as was exhibited in the ignoring of payoff information) may reflect the use of rule-based decision mode by the old adults; a decision mode the use of which was aimed to compensate for degraded cognitive capacity.

The decision-making task used in this thesis, however, may have been biased in terms of encouraging the use of rule-based decisions - because the probability information was more salient than the payoff information. The probability information was present on every trial, whereas the payoff information had to be retrieved from memory. Participants may have been encouraged to use probability information alone not being inclined to combine it with payoff. Indeed, not only the old adults, but the young adults were also more prone to base their decisions on probability information than on payoff information (Experiments 5 and 6). As has been suggested above, using a decision-making task that equalises the saliency of both dimensions appear to be more appropriate for testing this hypothesis.

10.7.6. Additional accounts of information selectivity: Age differences in the underlying decision process or age differences in decision threshold?

Throughout this thesis, information selectivity has been regarded as a simplified strategy because it involves processing of a limited amount of information. The definition employed in the thesis for a strategy was that of "one of several alternative methods for performing a particular cognitive task" (Salthouse, 1991, p.197). This may have carried the implication that selectivity reflects a certain way in which information is processed during the decision process, which is different from the way information is processed when all the available information is processed. The question is therefore whether selectivity is indeed a result of a different decision processes old adults utilise, or whether selectivity is a consequence of a change in decision threshold.

This question pertains to a difference between the positions held by the process approach and the sequential sampling approach regarding the effects of increased task demands (e.g., time pressure) on the underlying decision process. According to the process approach, decision-makers tend to shift from one information-processing strategy to a qualitatively different strategy, which encompasses a different pattern of weighting and combining information (e.g., Payne et al., 1988). In contrast, the sequential sampling approach assumes that the decision process is controlled by adjustments of a decision threshold, rather than by strategy switching (Busemeyer, 1993). When the decision threshold is reduced (e.g., under time pressure conditions) the decision is made after sampling small amounts of information. Under an elevated decision threshold, a larger amount of information can be sampled. Thus, decision-makers use a single strategy whether task demands are low or high. Increased task demands lead to a reduction in the decision threshold which, in turn, results in a reduction in the amount of information processed.

In accordance with the sequential sampling approach, selectivity can be seen as a result of a reduction in the decision threshold, and that itself results in processing of a reduced amount of information. Using a similar decision-making task to the one employed in Experiments 2, 3, and 5, Dror et al. (1999) demonstrated that under time pressure conditions young adults become less cautious (i.e., had a more lax decision threshold) which was accompanied by processing less information. In this study, Dror et al. (1999) presented participants with three cards. Two cards belonged to the participant and one card belonged to the opponent (the computer). Participants were required to decide whether or not to take an additional card. Under the time pressure condition, participants showed a reduction in their decision threshold, as indicated by a flattening of the RT curve across the risk levels (see section 5.4). This reduction in decision threshold co-existed with a reduction in the amount of information participants considered when making a decision. Under the no time pressure condition, the computer's card affected the participants' decisions on trials with low risk levels (i.e., low probability to go bust). When the computer's card carried a low risk level participants tended to avoid accepting another card. When the computer's card carried a high risk, participants tended to take another card. However, under time pressure, the computer's card had no effect on the willingness of participants to take another card. This finding showed that under time pressure participants ignored the computer's card - that is, they considered less information as a result of time constraints.

The limitation of processing resources of the young participants in Dror et al.'s study would appear in theory to be similar to the resources limitations evident in old adults. This line of reasoning might suggest that increased task demands (e.g., time pressure) and reduced resources in old age would lead to an adjustment of the decision threshold, rather than to a shift to a different strategy (i.e., modification in the decision process itself). From this speculation would follow the suggestion that selectivity (demonstrated by the old adults in Experiment 6) might not be a different strategy to that used by the young adults. Rather, it may reflect an adjustment (i.e., a reduction) in the decision threshold of the old adults.

The empirical data of the experiments reported in this thesis cannot, however, provide evidence for this speculation. A possible way to tackle this question would be to examine whether, under conditions of time pressure, young adults exhibit selectivity (i.e., ignore avoidance payoff information and respond to probability information only).

10.7.7. Additional accounts of information selectivity: Cohort differences?

The decision-making task used in Experiments 5 and 6 required participants to employ analytical processing (see section 10.7.5.2). Analytical processing may be less likely to be employed by old adults because of their having less experience with this processing mode. This may result from historical differences in the emphasis educational systems have placed on such modes of processing. Furthermore, the young participants included in the present research were Psychology undergraduates who are at present trained to employ analytical mode of thinking. There is also some evidence that old adults approach problems differently from young adults, in that they tend to be more concerned with social realities, and tend to rely more on subjective thinking (Labouvie-Vief, 1986; Sinnott, 1989). Therefore, it is important to be cautious when interpreting selectivity by old adults to be caused by cognitive limitations. Given the limitations of cross-sectional designs employed in the present research, the age differences reported may also be accountable for in terms of cohort differences between the two age groups. However, the findings that variations in task demands affected selectivity (cf. Experiment 4 and Experiment 6) supports the hypothesis that cognitive factors play role in information selectivity in old age.

10.8. Reconsideration of allocation of increased processing time as a compensatory mechanism

10.8.1. Allocation of increased processing time: The trade-off between speed and accuracy

In Experiment 2, the old participants were slowed down to a greater extent than the young participants when the demands of the task increased (i.e., outcome condition); nevertheless, they were able to produce the same decisions as the young adults, under both outcome conditions. Thus, the old adults were able to reach the same decisions as the young adults at the expense of speed of responding. Demonstrations of such a trade-off exist in the literature (see review section 1.4.2). Findings often indicate that old adults place greater emphasis on accuracy than on speed of responding (e.g., Salthouse, 1979; Salthouse & Somberg, 1982; Strayer et al., 1987), and that they may even attain a higher level of performance although being slower (Brebion et al., 1997).

10.8.2. Does allocation of more time constitute a compensatory mechanism?

The locus of age-related slowing is often debated. Does slowing reflect response-related processes (i.e., old adults possess a more cautious decision criteria), or does it reflect slowing of central processes (i.e., slowing of information-processing)? A consideration of the literature addressing this question (see section 1.4.2.1) has led to the conclusion that central processes clearly contribute to this slowing (Hertzog, et al., 1993; Salthouse, 1979; Strayer et al., 1987). The findings of Experiment 2 support this conclusion by showing that old adults are slowed down to a greater extent under conditions of increased uncertainty than young adults, even when the decision threshold is reduced (i.e., under time pressure). These results demonstrate that the decision process is slowed down in old age, and that age differences in decision threshold cannot, in itself, explain the old adults' slowing exhibited in Experiment 2. It is, therefore, concluded that, rather than reflecting cautious behaviour, the allocation of more time can be considered to be a compensatory mechanism by which old adults compensate for inefficient information-processing capacity.

Allocation of greater processing time was demonstrated both when old adults process unbiased outcomes (Experiment 2) as well as when they process biased outcomes (Experiment 3). It has been proposed that employing more time reflects an attempt by participants to find out a pattern (e.g., probability) by which the experienced outcomes are determined. This speculation implies that allocating more time serves a function during the decision process, even when prior outcome information does not affect final decisions.

10.9. Conceptual treatments of compensation

As has been already noted, researchers differ in their conceptualisation of compensation (see section 10.7.3). The findings reported in this thesis, therefore, might be interpreted differently by these different conceptialisations. This section outlines two additional approaches to compensation within which the reported findings in this thesis could be accounted for.

10.9.1. Alternative interpretation of compensation: Deficits in processing

The two compensatory mechanisms, allocation of increased processing time and information selectivity were inferred to operate based on the findings of Experiment 2 and 6, respectively. In Experiment 2 the old participants exhibited slower RT under increased task demands, and reached the same decisions as the young participants. In Experiment 6 decisions of the old participants were based on probability information only, while payoff information has been ignored. Ignoring this information impaired the old participants' decision performance, nevertheless it allowed them to perform the task with some success.

The interpretation of those findings as reflecting compensatory mechanisms can be challenged, however. According to Salthouse (1987, 1990, 1995), compensation should be conceptualised as an active and effortful attempt by the individual to overcome a cognitive deficit. This implies that compensation originates in an awareness of a deficit and a desire to overcome its negative effects. Being aware of the deficit, an individual may deliberately employ a certain strategy to perform a task to counterbalance the deficiency. Because the data of Experiments 2 and 6 does not allow us to determine whether or not the old participants were allocating more time and ignoring payoff information deliberately, this view of compensation would argue that those findings do not reflect compensation. Rather, the findings could be interpreted as demonstrating merely deficits in information processing capacity (i.e., general slowing or memory deficits) on the part of the old adults.

A different view, however, is held by Dixon and Backman (1995). According to their view, compensation may or may not be associated with deliberate intention to compensate. That is, an individual may or may not be aware of his / her attempt to overcome a deficit. It is possible that an individual would be aware of a deficit, but the actual mechanisms of compensation might not be available to him/her, and as such its execution might not be actively planned.

However, holding Salthouse's (1987, 1990, 1995) approach to compensation, one must provide support to the notion of active or deliberate effort in increasing decision time and ignoring payoff information for arguing that the results reflect compensation. Thus, the question arises as to whether the old participants in Experiment 2 actually chose to allocate more time to make decisions on this task, and whether, in Experiment 6, they chose not to make use of payoff information.

Research on cognitive compensation rarely collects information on awareness and intention to employ compensatory mechanisms (Dixon & Backman, 1995). However, a method of collecting such data was introduced by Dixon and Backman (1993). Dixon and Backman (1993) suggested to use verbal reports for collecting information about the attempts old adults make to overcome memory deficits in everyday activities. They devised a Compensation Questionnaire which includes questions regarding the frequency of engaging in particular functional behaviours, such as, using external memory aids (e.g., notes and calendars), mnemonic strategies, or allocating more time to perform a task. Elicited responses can be then examined as to whether or not the reported compensatory behaviours improve performance, and whether age differences exist in the reported behaviours. Such an approach could be employed in the research reported in this thesis. Verbal reports could be obtained in which participants are asked, following the completion of the task, about the strategies they utilised to perform it.

A more rigours or indirect method to separate the compensation and the processing deficit interpretation of the results could employ an experimental manipulation. For example, to address the question of whether or not slowing RT in Experiment 2 originates in deliberate strategy or merely reflects slowing of processing it would be useful to examine how different time constraints affect decision-making performance.

Demonstrating that old people reach the same decisions as the young adults with and without time constraints would support the notion of compensation (e.g., compensating by setting a cautious decision threshold). If performance were impaired under tight time constraints, it would suggest that general slowing is responsible to the slowing of the old adults under no time constraints. Manipulating time constraints could be employed by varying the amount of time allowed for a response (e.g., no time constraints, time constraints of 2000ms, 1000ms, and 700ms). The decisions participants make (i.e., willingness to accept an additional card) under different time constraints should be compared. If old adults deliberately employ more time in performing that task as a result of elevated decision threshold, then when time limit is tight they would not be able to employ as much time as they wish, but they would be able to reach the same decisions as the young adults. If the old adults take more time to respond because they are slower to process the information, then under tight time constraints their performance would be impaired and they will not reach the same decisions as the young adults.

To address the question of whether ignoring payoff in Experiment 6 originated in deliberate effort of compensation or deficits in memory, one could measure recall of payoff structure following the completion of the task, as has been done in Experiment 4. In general, the old participants in Experiment 4 were less able to recall the payoff structure, and their responses to payoff were less affected than those of the young participants. In addition, recall accounted for the use of payoff. Participants that could recall the payoff were more likely to use payoff in their decisions. In Experiment 6, however, payoff recall was not measured. The finding that the old participants did not use payoff may reflect deficits in recall ability. Alternatively, the old participants may have intentionally ignored it (or even did not encode in the first place) in order to reduce task demands (i.e., processing one dimension of information rather than two).

To test these hypotheses it must be ensured that participants understand the instructions for the card game and its payoff structure. This could be done by asking participants to repeat the payoff structure following the instruction. Next, a task which is not related to the card game, could be performed by participants. Following this delay, participants could be asked to recall the payoff structure. Being able to do so as the young participants, would suggest that ignoring payoff, when probability information is also presented, reflects a means of compensation rather than deficit in recall. Not being able to recall the payoff would suggest that recall deficits are the locus of not using payoff information.[37]

10.9.2. A lifespan approach to compensation: Selective optimisation with compensation (SOC)

Baltes and colleagues (e.g., Baltes & Baltes, 1980, 1990; Marsiske et al., 1995) proposed a model of successful development across the life span. The scope of the model is wide and could be applied not only to cognitive development but also to other psychological domains. Successful development is conceived in this model as goal attainment, that is, maximising desired outcomes (i.e., gains) and minimising undesired outcomes (i.e., losses). The model consists of three sub-components: *Selection*, *optimisation*, and *compensation*. Each of these components is thought to facilitate development throughout the life span. Here I describe the model with respect to development in old age. The model assumes that with age there is a shift in the balance between gains and losses. As people age, more losses than gains are experienced. Losses imply reduced cognitive, social, and physical resources. According to the SOC model, individuals can minimise losses that negatively affect their functioning by engaging in the processes of selection, optimisation, and compensation. These processes aim to fulfil two central goals of development; growth (attaining higher levels of functioning) and maintenance (avoiding undesired outcomes).

Selection refers to the “choice of particular behavioural domain or goals” (Marsiske et al., 1995, p. 45). It involves narrowing the range of possible pathways or opportunities as well

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[37] This experiment was suggested by Elizabeth Maylor (personal communication).

as modifying one's goals to accommodate the limits placed on availalble resources. For example, selection in the cognitive domain may be demonstrated in the specialisation in a work domain (Marsiske et al., 1995). Optimisation refers to maintenance as well as improvement of means to achieve desirable outcomes and avoid undesirable outcomes in selected domains of functioning. In the cognitive ageing domain, optimisation may involve intentional investment in activities designed to improve performance, such as, training and practice (Marsiske et al., 1995). Training and practice in old age have been reported to enhance memory and intellectual functioning (e.g., Willis, 1987). Compensation is conceived as an adjustment process, by which the effects of losses are minimised through the employment of other internal or external resources (Marsiske et al., 1995). Compensation includes development of internal, substitutional skill (Charness, 1981b, 1983; Salthouse, 1984; see section 1.4.1) as well as reliance on external support systems, such as, memory aids. Old adults appear to make greater use of physical reminder strategies such as, writing notes (Dixon & Hultsch, 1983). According to the SOC model, selection as well as compensation may or may not involve conscious or deliberate attempt.

An anecdotal example of selection, optimisation, and compensation was expressed by the concert pianist Arthur Rubinstein, as an 80-year-old (Baltes, Staudinger, & Lindenberger, 1999). The pianist was asked at a television interview how, in the face of growing older, he managed to maintain his expertise in piano playing. The pianist admitted at making use of three strategies. Firstly, he chose to play fewer pieces (selection); secondly, he practised these pieces more often (optimisation); and thirdly, he slowed his playing before fast segments in order to create the impression that the latter are faster (compensation).

The SOC model provides a framework within which the findings reported in this thesis could be interpreted. The finding that old adults take longer to make decisions under increased task demands (Experiments 2 and 3) can be seen to reflect compensation. In terms of the SOC model, the old participants in these experiments have made use of an internal resource (i.e., processing speed) to produce equivalent performance (i.e., making the same decisions) to the young participants. The SOC model does not restrict compensation to being an intentional attempt, and therefore, this finding could be qualified as a demonstration of compensation.

The use of less amount of information (i.e., not employing payoff information) in Experiment 6 on the part of the old participants could be interpreted as reflecting selection in terms of the SOC model. The old participants focused on probability information only. Their choice in the probability dimension might have resulted from selecting a certain goal in playing the card game. This goal has been termed as a local goal (see section 9.4) which aims to maximise the number of correct responses and minimise incorrect responses in the expense of earning less number of points (i.e., not attaining the global goal). Alternatively, focusing on the probability dimension may not have been directed by such a goal. Instead, basing decisions on the probability information only might have been a choice in the less demanding strategy the old participants could employ. That is, the old participants used only payoff information because this information was the most accessible (i.e., presented on each trial), and /or because it allowed performance of the decision-making task with minimal demands on processing resources (i.e., processing only one dimension of information rather than two). As with compensation, selection could be intentional or not, thus, the finding that the old participants focused on probability information, neglecting payoff information, does not need to be demonstrated as an intentional attempt on their part for being characterised as compensation.

10.10. Implications for theories of decision-making

Although this thesis focused on the effect of ageing on decision-making, the empirical work reported carries implications for theories of decision-making. First, the data support the notion that decision processes are governed by the information-processing capacity of the decision-maker, as originally was pointed out by Simon (1955). Work in the area of decision-making has repeatedly demonstrated that under conditions of high task demands young adults shift to using simplified strategies (e.g., Jacoby et al., 1974; Payne, 1976; Payne et al., 1988), that they tend to prioritorise information (Ben-Zur & Breznitz, 1981; Dror et al., 1999), and that they adjust their decision threshold (Dror et al., 1999). This thesis extends the above findings exhibited by young adults by showing that reduced processing capacity in old age plays a role in the amount of information old adults make use of when making decisions (Experiment 6) as well as in the allocation of processing time (Experiment 2). Having reduced processing capacity, old adults attempt to reduce task demands when faced with a decision-making task that places high load on information-processing (i.e., increased amount of information).

The experiments also provided further support for the predictions of the SSM by showing that, regardless of information-processing capacity, the decision process (measured in RTs to make a decision) is determined by the amount of information processed, as well as by the decision threshold. Old adults' decision time was affected by the amount of information available in the decision-problem (i.e., showing increased RTs when uncertainty increases or when outcome information was provided) as well as by the magnitude of the decision threshold (becoming less cautious under time pressure). The SSM also appeared to be successful at generating predictions regarding the locus of age differences in decision-making (see Experiment 2), pertaining to the question of whether old adults have a slower decision process or a more cautious decision threshold.

This thesis demonstrates the potential that exists in using decision-making models for studying age-related differences in decision-making. Use of such method could, in turn, facilitate the understanding of the decision-making processes in general.

10.11. Conclusions

This thesis aimed to investigate whether cognitive limitations in old age affect decision-making performance, in particular, how cognitive ageing influences the employment of two compensatory mechanisms in decision-making: allocation of increased processing time and information selectivity. The experiments reported provided evidence that under high cognitive demands, old adults tend to slow down to a greater extent than young adults, while reaching the same decisions as young adults do. The findings also indicated that this slowing could be accounted for in terms of a less efficient decision process rather than a more cautious decision criterion on the part of old adults. The experiments also showed that under high cognitive demands old adults tend to be more selective than young adults in the information they make use of in their decisions. Whereas young adults were able to utilise probability and avoidance payoff information, old adults based their decisions on probability information only, resulting in impaired decision-making performance. It was concluded that cognitive limitations in old age underlie the employment of these compensatory mechanisms. Whereas previous research has demonstrated age differences in decision-making performance, this thesis provided further understanding of the role of cognitive limitations in underlying these differences. Nevertheless, it should be acknowledged that in everyday decision-making cognitive factors as well as external factors (i.e., experience, risk perception) act jointly to produce a decision. Further research investigating the inter-relation between these factors is important in providing further understanding of the relative contribution of these factors. Moreover, the nature of those compensatory mechanisms should be further investigated to provide further understanding of the specific processes that underlie their operation.

11. APPENDICES

APPENDIX A: Decision questionnaire (Experiment 1)

Decision-making (part 1)

PARTICIPANT NUMBER:

AGE: GROUP:

GENDER: DATE:

Which hand do you use for writing? RIGHT/LEFT (Please circle one)

The number of years you spent in school (please circle):

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

Primary-School   Secondary -School

How old were you when you finished / left school? ___________

The number of years you have spent in education after secondary school:

College ________ years

University ________ years

The highest degree earned in school (please circle): Diploma / Bachelor / MA/PhD

3A PRE

Below are decision-problems that people may face in every day life. Please read carefully each decision-problem and make a decision.

For example,

Suppose you suffer from a serious illness. You are offered a new experimental treatment. This new treatment has been proved to be effective for most patients who have already received it.

Will you try the new treatment? YES NO

(please circle)

If you decide to try the new treatment please circle "YES" and if you decide not to try it, please circle "NO".

Below are number of decision-problems. For each problem please make a decision as demonstrated in the example above.

SHOOTING AIRCRAFT

Suppose you work in the army monitoring incoming aircraft on a radar. Your task is to identify enemy aircraft in order to ensure that they are not crossing the border. You spot an aircraft on the radar screen but visibility of the aircraft is obscured.

Will you inform your boss about the aircraft? YES NO

A DRUG

Suppose you are very ill. You are prescribed a drug that is known to cure this illness. The drug is known to have side effects such as drowsiness and head aches.

Will you take the drug? YES NO

MARK IN EXAM

Suppose you had an exam and got the minimum pass mark. You are considering asking your exam to be remarked. You are told that it is possible that remarking will result in either a higher mark, the same mark, or a lower mark. It is known that remarking in most cases does not result in a higher mark.

Will you ask for remarking? YES NO

JOB

You have been working at the same job for years. You have a high position which involves a good salary. You receive a call from a friend offering you the opportunity to join a new company. Salary and position will be determined by your achievements in the new job. If you accept the offer you will have to go through a probation period after which a decision will be made on whether or not to offer you a permanent position. You are not sure whether your skills match the skills required for the new job.

Will you quit your present job and accept the offer? YES NO

OPERATION

You are considering whether to undergo a cosmetic nose operation. The doctor who is about to operate on you has a record of high success in cosmetic nose operations. You have a heart condition that makes the operation risky for you.

Will you decide to undergo the operation? YES NO

VCR

Suppose you have bought a VCR which does not work as you had expected. You wish to return it to the shop and get a replacement but the customer service will not accept it back after such a long time. Customer service in this shop is known to be fair with customers complaints.

Will you write a letter of complaint to the manager regarding the way customer service dealt with your case? YES NO

Please find the experimenter for further instructions.

Below are some more decision-problems that people may face in every day life. Please read carefully each decision-problem and make a decision, as before.

SHOOTING AIRCRAFT

Suppose you work in the army monitoring incoming aircraft on a radar. Your task is to identify enemy aircraft in order to ensure that they are not crossing the border. You spot an aircraft on the radar screen but visibility of the aircraft is obscured.

Will you decide to shoot down the aircraft? YES NO

A DRUG

Suppose you have flu. You were prescribed a drug that is known to remove flu symptoms. The drug is known to have side effects and in rare cases can cause a stroke.

Will you take the drug? YES NO

MARK IN EXAM

Suppose you took an exam and failed. You are considering asking your exam to be remarked. You are told that it is possible that remarking will result in either a higher mark, the same mark, or a lower mark. It is known that remarking in most cases does not result in a higher mark.

Will you ask for remarking? YES NO

JOB

You have been working at the same job for years. Currently, you are not happy as you did not get the promotion you expected, and consequently your salary has not been raised. You receive a call from a friend offering you the opportunity to join a new company. Salary and position will be determined by your achievements at the new job. If you accept the offer you will have to go through a probation period after which a decision will be made on whether or not to offer you a permanent position. You are not sure whether your skills match the skills required for the new job.

Will you quit your present job and take the offer? YES NO

OPERATION

You are severely injured in an accident. You are about to undergo a complex operation which may save your life. The doctor who is about to operate on you has a record of high success in operating this condition.

Will you decide to undergo the operation? YES NO

VCR

Suppose you have bought a VCR which does not work as you had expected. You wish to return it to the shop and get a replacement but customer service will not accept it back after such a long time. Customer service in this shop is known to be fair with customers complaints.

Will you sue the shop? YES NO

Please find the experimenter for further instructions.

Decision-making (part 2)

PARTICIPANT NUMBER:

AGE: GROUP:

GENDER: DATE:

Which hand do you use for writing? RIGHT/LEFT (Please circle one)

The number of years you spent in school (please circle):

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

Primary-School Secondary -School

How old were you when you finished / left school? __________

The number of years you have spent in education after secondary school:

College __________ years

University __________ years

The highest degree earned in school (please circle): Diploma / Bachelor / MA/PhD

3B PRE

Below are decision-problems that people may face in every day life. Please read carefully each decision-problem and make a decision.

For example,

Suppose you suffer from a serious illness. You are offered a new experimental treatment. This new treatment has been proved to be effective for most patients who have already received it.

Will you try the new treatment? YES NO

(please circle)

If you decide to try the new treatment please circle "YES" and if you decide not to try it, please circle "NO".

Below are number of decision-problems. For each problem please make a decision as demonstrated in the example above.

SHOOTING AIRCRAFT

Suppose you work in the army monitoring incoming aircraft on a radar. Your task is to identify enemy aircraft in order to ensure that they are not crossing the border. You spot an aircraft on the radar screen but visibility of the aircraft is obscured.

Will you decide to shoot down the aircraft? YES NO

A DRUG

Suppose you have flu. You were prescribed a drug that is known to remove flu symptoms. The drug is known to have side effects and in rare cases can cause a stroke.

Will you take the drug? YES NO

MARK IN EXAM

Suppose you took an exam and failed. You are considering asking your exam to be remarked. You are told that it is possible that remarking will result in either a higher mark, the same mark, or a lower mark. It is known that remarking in most cases does not result in a higher mark.

Will you ask for remarking? YES NO

JOB

You have been working at the same job for years. Currently, you are not happy as you did not get the promotion you expected, and consequently your salary has not been raised. You receive a call from a friend offering you the opportunity to join a new company. Salary and position will be determined by your achievements at the new job. If you accept the offer you will have to go through a probation period after which a decision will be made on whether or not to offer you a permanent position. You are not sure whether your skills match the skills required for the new job.

Will you quit your present job and take the offer? YES NO

OPERATION

You are severely injured in an accident. You are about to undergo a complex operation which may save your life. The doctor who is about to operate on you has a record of high success in operating this condition.

Will you decide to undergo the operation? YES NO

VCR

Suppose you have bought a VCR which does not work as you had expected. You wish to return it to the shop and get a replacement but customer service will not accept it back after such a long time. Customer service in this shop is known to be fair with customers complaints.

Will you sue the shop? YES NO

Please find the experimenter for further instructions.

3A POST

Below are some more decision-problems that people may face in every day life. Please read carefully each decision-problem and make a decision, as before.

SHOOTING AIRCRAFT

Suppose you work in the army monitoring incoming aircraft on a radar. Your task is to identify enemy aircraft in order to ensure that they are not crossing the border. You spot an aircraft on the radar screen but visibility of the aircraft is obscured.

Will you inform your boss about the aircraft? YES NO

A DRUG

Suppose you are very ill. You are prescribed a drug that is known to cure this illness. The drug is known to have side effects such as drowsiness and head aches.

Will you take the drug? YES NO

MARK IN EXAM

Suppose you had an exam and got the minimum pass mark. You are considering asking your exam to be remarked. You are told that it is possible that remarking will result in either a higher mark, the same mark, or a lower mark. It is known that remarking in most cases does not result in a higher mark.

Will you ask for remarking? YES NO

JOB

You have been working at the same job for years. You have a high position which involves a good salary. You receive a call from a friend offering you the opportunity to join a new company. Salary and position will be determined by your achievements in the new job. If you accept the offer you will have to go through a probation period after which a decision will be made on whether or not to offer you a permanent position. You are not sure whether your skills match the skills required for the new job.

Will you quit your present job and accept the offer? YES NO

OPERATION

You are considering whether to undergo a cosmetic nose operation. The doctor who is about to operate on you has a record of high success in cosmetic nose operations. You have a heart condition that makes the operation risky for you.

Will you decide to undergo the operation? YES NO

VCR

Suppose you have bought a VCR which does not work as you had expected. You wish to return it to the shop and get a replacement but the customer service will not accept it back after such a long time. Customer service in this shop is known to be fair with customers complaints.

Will you write a letter of complaint to the manager regarding the way customer service dealt with your case? YES NO

Please find the experimenter for further instructions.

APPENDIX B: Questionnaire for assessing outcome payoff (Experiment 1)

PART 1

1 DATE: ________

REAL-LIFE DECISION-PROBLEMS:

POSSIBLE GAINS AND LOSSES

NAME: ______________ AGE: ________ GENDER: F/M

Below are various decision-problems that people may face in everyday life. For each decision-problem I would like you to think what is gained and what is lost when a decision is made. I will then ask you to rate the relative relations between the possible gain and the possible loss.

For example,

Suppose you suffer from a serious illness. You are offered to try a new experimental treatment. You are faced with the decision whether or not to try the new treatment.

(1) Please specify what gain and loss the decision to **"try the new treatment"** can produce

GAIN: *cure from a serious illness*

LOSS: *minor side effects* ___

You need NOT make a decision but you are asked to think about the possible things that you may gain or lose from taking the decision to "try the new treatment".

Then, you are asked to rate the relative relations between the possible gain and the possible loss, as follows:

(2) The decision to **"try the new treatment"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

As the possible gain (*cure from a serious illness*) outweighs the possible loss (*minor side effects*), the decision to try the new treatment can produce more gain than loss (thus, number "1" was circled).

Below are number of decision-problems. For each problem please answer the questions as demonstrated in the example.

COURT CASE

You are a judge in a murder case. There is conflicting evidence regarding the case. You are considering whether to send this person to prison or whether to release him/her.

(1) Please specify what gain and loss the decision to **"send the person to prison"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"send the person to prison"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

SHOOTING AIRCRAFT

Suppose you work in the army monitoring incoming aircraft on a radar. Your task is to identify enemy aircraft in order to ensure that they are not entering the country. You spot an aircraft on the radar screen but are not sure whether it is an enemy aircraft. You have to decide whether or not to shoot down the aircraft.

(1) Please specify what gain and loss the decision to **"shoot down the aircraft"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"shoot down the aircraft"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

DRIVING

You are driving your car. You are approaching traffic-lights that have just changed from amber to red. You have to decide whether to keep on driving or whether to stop and wait for the green light.

(1) Please specify what gain and loss the decision to **"keep on driving"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"keep on driving"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

OPERATION

You are severely injured in an accident. You are about to undergo a complex and risky operation which may save your life. You are faced with the decision of whether or not to undergo the operation.

(1) Please specify what gain and loss the decision to **"undergo the operation"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"undergo the operation"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

A DRUG

Suppose you have flu. You were prescribed a drug that is said to remove flu symptoms. The drug is known to have side effects and in rare cases can cause a stroke. You are faced with the decision of whether or not to take the drug.

(1) Please specify what gain and loss the decision to **"take the drug"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"take the drug"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

RESCUE OPERATION

A passenger aeroplane has been hijacked by terrorists. In the plane there are many passengers and crew members. You are the Prime Minister and have to decide whether or not to mount a rescue operation.

(1) Please specify what gain and loss the decision to **"initiate the rescue operation"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"initiate the rescue operation"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

VCR

Suppose you have bought a VCR which does not work as you had expected. You wish to return it to the shop but customer service will not accept it back after such a long time. You are considering whether or not to sue the shop.

(1) Please specify what gain and loss the decision to **"sue the shop"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"sue the shop"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

MARK IN EXAM

Suppose you took an exam and got a fail mark which you feel is unfair. You are considering asking your exam to be remarked. You are told that it is possible that remarking will result in either a higher mark, the same mark, or a lower mark. You have to decide whether or not to ask for remarking.

(1) Please specify what gain and loss the decision to **"ask for remarking"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"ask for remarking"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

Thankyou very much for filling in this questionnaire. If you can think of any other examples of real-life decision-problems that I could use in my study it would be very helpful.

I would also appreciate any suggestions for English style modifications in the decision-problems above.

Thanks again,

Vered.

PART 2

2

DATE: __________

REAL-LIFE DECISION-PROBLEMS:

POSSIBLE GAINS AND LOSSES

NAME: ________________ AGE: ________ GENDER: F/M

Below are various decision-problems that people may face in everyday life. For each decision-problem I would like you to think what is gained and what is lost when a decision is made. I will then ask you to rate the relative relations between the possible gain and the possible loss.

For example,

Suppose you suffer from a serious illness. You are offered to try a new experimental treatment. You are faced with the decision whether or not to try the new treatment.

(1) Please specify what gain and loss the decision to **"try the new treatment"** can produce

GAIN: *cure from a serious illness*

LOSS: *minor side effects* ____

You need NOT make a decision but you are asked to think about the possible things that you may gain or lose from taking the decision to "try the new treatment".

Then, you are asked to rate the relative relations between the possible gain and the possible loss, as follows:

(2) The decision to **"try the new treatment"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

As the possible gain (*cure from a serious illness*) outweighs the possible loss (*minor side effects*), the decision to try the new treatment can produce more gain than loss (thus, number "1" was circled)

Below are number of decision-problems. For each problem please answer the questions as demonstrated in the example.

COURT CASE

You are a judge in a case of shop lifting. There is conflicting evidence regarding the case. You are considering whether to send this person to prison or whether to release him/her.

(1) Please specify what gain and loss the decision to **"send the person to prison"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"send the person to prison"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

SHOOTING AIRCRAFT

Suppose you work in the army monitoring incoming aircraft on a radar. Your task is to identify enemy aircraft in order to ensure that they are not entering the country. You spot an aircraft on the radar screen but are not sure whether it is an enemy aircraft. You have to decide whether or not to inform your boss about the aircraft.

(1) Please specify what gain and loss the decision to **"inform the boss"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"inform the boss"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

DRIVING

You are driving an ambulance with an acutely ill person inside. You are approaching traffic-lights that have just changed from amber to red. You have to decide whether to keep on driving or whether to stop and wait for the green light.

(1) Please specify what gain and loss the decision to **"keep on driving"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"keep on driving"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

OPERATION

You are considering whether to undergo a cosmetic nose operation. You have a heart condition that makes the operation risky for you. You are faced with the decision of whether or not to undergo the operation.

(1) Please specify what gain and loss the decision to **"undergo the operation"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"undergo the operation"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

A DRUG

Suppose you are very ill. You are prescribed a drug that is believed to cure this illness. The drug is known to have side effects such as drowsiness and head aches. You are faced with the decision of whether or not to take the drug.

(1) Please specify what gain and loss the decision to **"take the drug"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"take the drug"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

RESCUE OPERATION

A cargo airplane has been hijacked by terrorists. In the plane there are a few crew members. You are the prime minister and have to decide whether or not to mount a rescue operation.

(1) Please specify what gain and loss the decision to **"go for the rescue operation"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"go for the rescue operation"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

VCR

Suppose you have bought a VCR which does not work as you had expected. You wish to return it to the shop but the customer service will not accept it back after such a long time. You are considering whether or not to write a letter of complaint to the manager.

(1) Please specify what gain and loss the decision to **"write a letter of complaint"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"write a letter of complaint"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

MARK IN EXAM

Suppose you had an exam and got the minimum pass mark which you feel is unfair. You are considering asking your exam to be remarked. You are told that it is possible that remarking will result in either a higher mark, the same mark, or a lower mark. You have to decide whether or not to ask for remarking.

(1) Please specify what gain and loss the decision to **"ask for remarking"** can produce

GAIN: ____________________

LOSS: ____________________

(2) The decision to **"ask for remarking"** can produce

1	2	3
more gain than a loss	equal gain and loss	more loss than a gain

Thankyou very much for filling in this questionnaire. If you can think of any other examples of real-life decision-problems that I could use in my study it would be very helpful.

Thanks again,

Vered.

APPENDIX C: Questionnaire for assessing outcome probability (Experiment 1)

PART 1

1 DATE: __________

REAL-LIFE DECISION-PROBLEMS:

OUTCOME PROBABILITY

NAME: ________________ AGE: ________ GENDER: F/M

Below are various decision-problems that people may face in everyday life. For each decision-problem I would like you to rate how likely is a given outcome to happen.

For example,

Suppose you suffer from a serious illness. You are offered a new experimental treatment. This new treatment has been proved to be effective for most patients who have already received it. You are faced with the decision whether or not to try the new treatment.

What is the likelihood that the treatment will be successful?

1 2 3 4 5

On what information did you base this rating?

The treatment has been shown to be effective for most patients.

Below are number of decision-problems. For each problem please rate the likelihood of a given outcome to happen, and indicate what information made you reach this rating.

SHOOTING AIRCRAFT

Suppose you work in the army monitoring incoming aircraft on a radar. Your task is to identify enemy aircraft in order to ensure that they are not crossing the border. You spot an aircraft on the radar screen but visibility of the aircraft is rather obscured. You have to decide whether or not to inform your boss about the aircraft.

What is the likelihood that the aircraft you spot on the radar is an enemy aircraft?

1	2	3	4	5
very low	**low**	**moderate**	**high**	**very high**

On what information did you base this rating?

....

A DRUG

Suppose you are very ill. You are prescribed a drug that is known to cure this illness. The drug is known to have side effects such as drowsiness and head aches. You are faced with the decision of whether or not to take the drug.

What is the likelihood that this drug will be effective in curing the illness?

1	2	3	4	5
very low	**low**	**moderate**	**high**	**very high**

On what information did you base this rating?

....

MARK IN EXAM

Suppose you had an exam and got the minimum pass mark. You are considering asking your exam to be remarked. You are told that it is possible that remarking will result in either a higher mark, the same mark, or a lower mark. It is known that remarking in most cases does not result in a higher mark. You have to decide whether or not to ask for remarking.

What is the likelihood that you will get a better mark?

1	2	3	4	5
very low	**low**	**moderate**	**high**	**very high**

On what information did you base this rating?

....

JOB

You have been working at the same job for years. You have a high position which involves a good salary. You receive a call from a friend offering you the opportunity to join a new company. Salary and position will be determined by your achievements in the new job. If you accept the offer you will have to go through a probation period after which a decision will be made on whether or not to offer you a permanent position. You are not sure whether your skills match the skills required for the new job. You are considering whether or not to quit your present job and take the offer.

What is the likelihood that you will be get a permanent position in the new job following the probation period?

1	2	3	4	5
very low	**low**	**moderate**	**high**	**very high**

On what information did you base this rating?

....

OPERATION

You are considering whether to undergo a cosmetic nose operation. The doctor who is about to operate on you has a record of high success in cosmetic nose operations. You have a heart condition that makes the operation risky for you. You are faced with the decision of whether or not to undergo the operation.

What is the likelihood that the nose operation will be successful (you will have a prettier nose)?

1	2	3	4	5
very low	**low**	**moderate**	**high**	**very high**

On what information did you base this rating?

....

VCR

Suppose you have bought a VCR which does not work as you had expected. You wish to return it to the shop and get a replacement but the customer service will not accept it back after such a long time. Customer service in this shop is known to be fair with customers complaints. You are considering whether or not to write a letter of complaint to the manager regarding the way customer service dealt with your case.

What is the likelihood that you will get a replacement as a result of writing a complaint letter to the manager?

1	2	3	4	5
very low	**low**	**moderate**	**high**	**very high**

On what information did you base this rating?

....

PART 2

2 DATE: __________

REAL-LIFE DECISION-PROBLEMS:

OUTCOME PROBABILITY

NAME: _________________ AGE: ________ GENDER: F/M

Below are various decision-problems that people may face in everyday life. For each decision-problem I would like you to rate how likely is a given outcome to happen.

For example,

Suppose you suffer from a serious illness. You are offered a new experimental treatment. This new treatment has been proved to be effective for most patients who have already received it. You are faced with the decision whether or not to try the new treatment.

What is the likelihood that the treatment will be successful?

1	2	3	4	5
very low	low	moderate	high	very high

On what information did you base this rating?

The treatment has been shown to be effective for most patients.

Below are number of decision-problems. For each problem please rate the likelihood of a given outcome to happen, and indicate what information made you reach this rating.

SHOOTING AIRCRAFT

Suppose you work in the army monitoring incoming aircraft on a radar. Your task is to identify enemy aircraft in order to ensure that they are not crossing the border. You spot an aircraft on the radar screen but visibility of the aircraft is rather obscured. You have to decide whether or not to shoot down the aircraft.

What is the likelihood that the aircraft you spot on the radar is an enemy aircraft?

1	2	3	4	5
very low	low	moderate	high	very high

On what information did you base this rating?

....

A DRUG

Suppose you have flu. You were prescribed a drug that is known to remove flu symptoms. The drug is known to have side effects and in rare cases can cause a stroke. You are faced with the decision of whether or not to take the drug.

What is the likelihood that this drug will be effective in removing the flu symptoms?

1	2	3	4	5
very low	low	moderate	high	very high

On what information did you base this rating?

....

MARK IN EXAM

Suppose you took an exam and failed. You are considering asking your exam to be remarked. You are told that it is possible that remarking will result in either a higher mark, the same mark, or a lower mark. It is known that remarking in most cases does not result in a higher mark. You have to decide whether or not to ask for remarking.

What is the likelihood that you will get a better mark?

1	2	3	4	5
very low	**low**	**moderate**	**high**	**very high**

On what information did you base this rating?

....

JOB

You have been working at the same job for years. Currently, you are not happy as you did not get the promotion you expected, and consequently your salary has not been raised. You receive a call from a friend offering you the opportunity to join a new company. Salary and position will be determined by your achievements at the new job. If you accept the offer you will have to go through a probation period after which a decision will be made on whether or not to offer you a permanent position. You are not sure whether your skills match the skills required for the new job. You are considering whether or not to quit your present job and take the offer.

What is the likelihood that you will be get a permanent position in the new job following the probation period?

1	2	3	4	5
very low	**low**	**moderate**	**high**	**very high**

On what information did you base this rating?

....

OPERATION

You are severely injured in an accident. You are about to undergo a complex operation which may save your life. The doctor who is about to operate on you has a record of high success in operating this condition. You are faced with the decision of whether or not to undergo the operation.

What is the likelihood that the operation will be successful?

1	2	3	4	5
very low	**low**	**moderate**	**high**	**very high**

On what information did you base this rating?

....

VCR

Suppose you have bought a VCR which does not work as you had expected. You wish to return it to the shop and get a replacement but customer service will not accept it back after such a long time. It is known that customer service in this shop is known to be fair with customers complaints. You are considering whether or not to sue the shop.

What is the likelihood that you will win the case and get a replacement?

1	2	3	4	5
very low	**low**	**moderate**	**high**	**very high**

On what information did you base this rating?

....

APPENDIX D: Results of payoff quality assessment (Experiment 1)

The aim of the assessment was to confirm that the decision-problems designed were judged by participants as possessing the payoff quality (i.e., either approach or avoidance) designed by the experimenter.

Materials

Eight decision situations were constructed. Each decision situation produced two decision-problem: one possessing approach payoff and the other possessing avoidance payoff. Decisions-problems possessing approach payoff were constructed so that a decision to take an action produces more gain the loss; Decision-problems that possess avoidance were constructed so that a decision to take an action produces more loss than gain. The decision-problems were presented on a questionnaire, consisting of two parts (see Appendix B). In each part eight decision-problems were presented with four approach and four avoidance decision-problems. In each part either the approach or the avoidance version of each decision situation was presented.

Participants

Six postgraduate students in the Psychology Department at University of Southampton volunteered to fill in the questionnaires. Five were females and one male. Their age range was 30 to 43 (mean age=36.8).

Procedure

For each decision-problem participants were required to do the following: First, they had to write down the possible gain and the possible loss associated with a given decision. Second, they were asked to rate the relative relations between the possible gain and the possible loss a given decision produces on a 3-scale (more gain than loss; equal gain and loss; more loss than gain). The second part of the questionnaire was administered three days after the first one was completed and returned. The order of administration of the two questionnaire parts was counterbalanced between participants (see Appendix B for the questionnaires).

Decision-problems were defined as possessing a certain payoff (either approach or avoidance) if there was a consistent rating (either '1' or '3') across five out of the six participants. Out of the eight decision-problems five were chosen to be included in the experiment. One more decision situation, with approach and avoidance versions, was produced after the assessment.

APPENDIX E: Results of probability quality assessment (Experiment 1)

The aim of the assessment was to confirm that the decision-problems designed were judged by participants as possessing the probability quality (i.e, either low, moderate or High probability of success) designed by the experimenter.

Materials

The assessment included six decision situations (five of which were chosen following the payoff assessment), with approach version and avoidance version (making 12 decision-problems) for each decision situation. For each payoff version two decision-problems were constructed to have either low, moderate, or high probability that a successful outcome would occur following the decision to take an action. This probability information was provided in the form of contextual information from which outcome probability could be inferred.

The assessment consisted of two parts, with six decision-problems each (see Appendix C). Three of the decision-problems in each part were approach and three were avoidance. From the three problems in each payoff condition one problem was designed to have low probability, another problem designed to have moderate probability, and a third problem - high probability.

Participants

The same participants as in the payoff assessment (appendix D).

Procedure

Participants were asked to rate on a 5-point scale the likelihood of a successful outcome to occur (1 - very low likelihood, 2 – low probability, 3 – moderate probability, 4 – high probability, 5 – very high probability). Then they were required to write down the information on which they based their judgement. Participants were first given the first part of the assessment and after completing and returning it, they received the second part. Order of administration of the two parts was counterbalanced between participants.

Decision-problems were defined as possessing certain probability of a successful outcome (either low, moderate or high probability) if five out of six participants agreed on the probability level. Agreement was defined such that participants judge low probability as either '1' or '2', moderate probability as '3', and high probability as either '4' or '5'. Two decision-problems were amended following the assessment.

APPENDIX F: Health and life-style questionnaire

SOUTHAMPTON UNIVERSITY

Department of Psychology

Cognitive Neuroscience Laboratory

Thank you very much for participating in the study. Below are questions that we would like you to answer. Your name, address, and telephone number will be used for contact purposes only. The information you provide will be kept confidential and will be replaced by a code number to be used only for research purposes in our lab.

Date ________________

Participant Number __________ Group ____________________

First Name ________________ Surname ________________

Date of Birth __________

Gender: Female / Male (please circle)

Address ____

____

Telephone _________________

Education (please circle):

Primary-School / Secondary-School / 'A' Levels/ University / Higher-Degree

The highest degree earned in school (please circle):

H.S. Diploma / Bachelor / Graduate degree (MA or higher)

1. Do you drive? Yes / No

If yes, how often? (how many times a week?) __________

2. How did you arrive to this testing session?

I walked by car by bus by taxi

3. Are you involved in any social activity (e.g., community club)? Yes / No

4. Do you play cards regularly? Yes / No

If yes, please circle:

Rummy BridgePoker 21 (Blackjack) other: _____

5. Do you read? Yes / No

If yes, how frequently? (averaged hours per week) __________

6. Who does your shopping?

Myself Spouse Friend NurseFamily member

7. Please characterise your mental ability relative to when you were

in your 20s and 30s (please circle):

Much better Better More or less the same Poorer Much poorer

8. How would you describe your general emotional mood? (please circle)

Very Happy Happy OK Sad Very sad

9. How would you describe your general health? (please circle)

Very good Good Reasonable Poor Very Poor

10. Is there any illness or disability that prevents you from doing physical or social activity? Yes / No

If yes, please specify: ______________________

11. Do you have high blood pressure? Yes / No

If yes, do you take medication to control it? Name of medication(s)

____

Number of years you have been taking medication for high blood pressure ________

12. Do you experience shortness of breath while sitting still? Yes / No

13. Have you ever had a heart attack? Yes / No

14. Do you have pains in the chest or heart? Yes / No

15. Have you ever had open heart surgery? Yes / No

16. Have you had a head injury with loss of consciousness

for more than 5 minutes? Yes / No

17. Have you ever been resuscitated? Yes No

18. Do you get regular exercise? Yes No

If yes, how many days each week? ____________________

19. Do you have high blood cholesterol? Yes / No

20. Have you ever had rheumatic fever? Yes / No

21. Do you have trouble with your vision that prevents you from reading ordinary print even when you have glasses on? Yes / No

22. Do you use a hearing aid? Yes / No

23. Do you suffer from frequent headaches? Yes / No

24. Do you use oxygen at home? Yes / No

25. Do you often experience spells of dizziness? Yes / No

26. Do you faint frequently? Yes / No

27. Have you ever suffered a stroke? Yes / No

28. Did you ever have convulsions (seizure)? Yes / No

If yes, were you given any medication? Yes / No

29. Do you have Parkinson's disease? Yes / No

30. Do you suffer from Huntington's disease? Yes / No

31. Does anybody in your immediate family suffer from

Alzheimer's disease? Yes / No

32. Do you suffer from multiple sclerosis? Yes / No

33. Have you ever had encephalitis or meningitis? Yes / No

34. Have you ever had brain surgery? Yes / No

35. Have you ever undergone surgery to clear arteries to

the brain? Yes / No

36. Have you ever been diagnosed with brain tumor? Yes / No

37. Do you frequently have to stay in bed because of illness? Yes / No

38. Do you usually take three or more alcoholic drinks a day? Yes / No

39. Have you ever been diagnosed as learning disabled? Yes / No

40. Were you placed in special classes in school because of learning or behavioral problems?

Yes / No

41. Have you ever been hospitalized with mental or emotional problems?

Yes / No

42. Have you ever received electroshock therapy? Yes / No

43. Do you take any medications that affect your ability to perform today's task? (e.g., sleeping pills, drowsiness) Yes / No

44. Do you have any further information you would like to tell us regarding your health? Yes / No

If yes, please specify below: ______________________________

____

____

APPENDIX G: Post experimental questionnaire (Experiments 2 and 3)

PLAYING A GAME CARD EXPERIMENT

POST-EXPERIMENTAL QUESTIONNAIRE

PARTICIPANT NUMBER: NAME:

DATE OF BIRTH: GROUP:

GENDER: DATE:

HANDEDNESS:

HAVE YOU EVER HAD FORMAL TRAINING IN STATISTICS? YES/NO

(Please circle)

IF YES, WHAT LEVEL?

HOW OFTEN DO YOU PLAY BLACKJACK? (Please circle)

Never Seldom Occasionally Frequently Compulsively

1. Did you have an idea of what this study was about? If yes, what?

2. Did you use any criteria to decide whether or not to take an additional card?

YES NO (Please circle one)

If "YES" then go to question 2A

If "NO" then go to question 2B

2A. IF YOU ANSWERED "YES" TO QUESTION #2

a) What was the criteria you used to make your decision?

b) Did you use the same criteria **consistently** throughout the experiment?

2B. IF YOU ANSWERED "NO" TO QUESTION #2,

a) Why did you not use a criterion to make your decision?

b) How did you make your decision whether or not to take an additional card?

3. Did the feedback you got affect your decision?

YES NO (Please circle one)

IF YES, how so?

4. Do you have any other comments concerning this experiment? (Use the back of this sheet for additional space)

5. Would you be interested in taking part in other studies in the future?

YES NO (Please circle one)

APPENDIX H: The effect of time pressure on RTs (Experiment 2)

To check whether time pressure had the effect of reducing the decision threshold, RTs in the first phase (no time pressure) and the second phase (with time pressure) of the experiment were compared within each age group in the outcome condition. Only the outcome condition was examined because in this condition the old participants exhibited a greater slowing with increased uncertainty relative to the young participants, and therefore it was necessary to examine whether the caution explanation can account for these results.

Figure 28 shows the mean RTs as a function of uncertainty and time pressure in the outcome condition for both the young and the old group.

Young *Old*

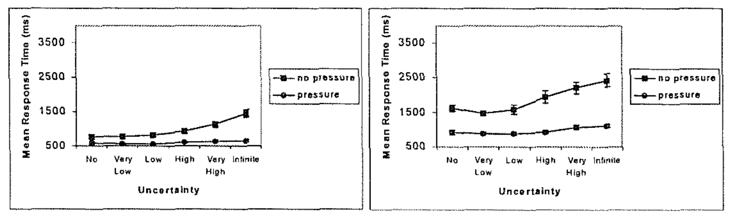

Figure 28: Mean RTs as a function of time pressure for young group and old group

Repeated measures ANOVA in which time pressure (with and without pressure) and uncertainty (6 levels) were the within-subjects factors were performed on the data of the outcome condition in each age group. The analyses excluded four old participants (out of 17) and three young participants (out of 17) who produced RTs which were 2.5 SD above the mean RTs of the rest of the participants in their age group. The analyses showed an interaction between uncertainty and time pressure in both the young group, $F(1.84, 23.86) = 13.12, p < .001$, and the old group, $F(2.82, 33.87) = 9.21, p < .001$, suggesting that time pressure affected the rate of slowing across uncertainty of both young and old adults. That is, time pressure had the effect of reducing the decision threshold (i.e., flattening RT curve across uncertainty levels) for both age groups.

It should be noted that Experiment 2 was not designed to examine the effect of time pressure, and therefore the manipulation is confounded with other elements. First, the time pressure manipulation is confounded with task order, hence, practice (all participants performed the no time pressure condition before the time pressure condition). Second, time pressure was confounded with prior outcomes. In the outcome condition participants performed the no time pressure condition with current outcomes, and the time pressure condition without current outcomes. However, the important effect is that the decision threshold was reduced for both age groups in the outcome condition.

APPENDIX I: Restrictions on outcome bias manipulation (Experiment 3)

1. One trial in each one of eight blocks (out of 10) is changed to either positive (no-bust) or negative (bust) outcome. The blocks that are not changed were the middle ones (i.e., blocks 4 and 6). The rationale for not changing the middle blocks but changing the anchor blocks was that it was aimed to induce a primary and recency impression of the probability manipulation which was found to influence learning best (Ashworth and Dror, 2000).

2. The trials changed from no-bust (from the outcome condition in Experiment 1) to bust trials (to produce the negative condition), and the trails changed from bust (from the outcome condition in Experiment 1) to no-bust trials (to produce the positive condition) had a sum of 7, 8, or 12, 13, respectively (these sums were not a borderline sum, such as, 9,10, or 11).

3. Positive and negative manipulations were of equal size (i.e., +/-0.1 and +/-0.2) and were symmetrical: the trials replaced had sums, which are equally distant from 10 (i.e., +/-2 and +/-3). Similarly, the new sums are equally distant from 10. That is, for the positive condition bust sums (12 and 13) were replaced by no-bust sums (7 and 8). For the negative condition no-bust sums (7 and 8) were replaced by bust sums (12 and 13).

4. The second card which was replaced as well as the replacing second card were of the same distance from 5 (+/-). That is, for the positive condition the additional cards that were replaced had a value of 6, 7, 8, and 9. These cards were replaced by card values 1, 2, 3, and 4. For the negative condition, the cards that were replaced were 1, 2, 3, and 4, by cards 6, 7, 8, and 9. This produces symmetry between the positive and the negative manipulation.

APPENDIX J: Post experimental questionnaire (Experiment 4)

PLAYING A CARD GAME EXPERIMENT

POST-EXPERIMENTAL QUESTIONNAIRE

PARTICIPANT NUMBER:

AGE: PARTICIPANT GROUP:

GENDER: DATE:

Which hand do you use for writing? RIGHT/LEFT (Please circle one)

The number of years you spent in school (please circle):

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

Primary-School Secondary -School

How old were you when you finished / left school? __________

The number of years you have spent in education after secondary school:

College _________ years

University _________ years

The highest degree earned in school (please circle): Diploma / Bachelor / MA/PhD

1. Did you have an idea of what this study was about? If yes, what?

2. How did you decide whether or not to reveal the cards?

3. Did you use the same decision (either "yes" or "no") **consistently** throughout the experiment?

YES NO (Please circle one)

If so, which decision was most dominant?

4. Did the number of points you could win or lose affect your decision?

YES NO (Please circle one)

IF YES, how so?

5. Based on your experience with the card game, what happens when you decide to reveal the cards and the sum of the cards appears to be less than 9?

I win / I lose ______ points.

6. What happens when you decide to reveal the cards and the sum of the cards appears to be above 9?

I win / I lose ______ points.

7. What happens when you decide NOT to reveal the cards and the sum of the cards appears to be less than 9?

I win / I lose ______ points.

8. What happens when you decide NOT to reveal the cards and the sum of the cards appears to be above 9?

I win / I lose ______ points.

9. Do you have any other comments concerning this experiment?

10. Would you be interested in taking part in other studies in the future?

YES NO (Please circle one)

APPENDIX K: Calculated EV and optimal decisions (Experiment 5)

Table 15, Table 16, and Table 17 present the outcome probabilities, EVs, and the optimal decision in the Control, the approach, and the avoidance conditions, respectively.

Table 15: The outcome probabilities, EVs, and the optimal decision for each card value in the control condition

			10	-10		-10	10			
Card value	p(NB)	p(B)	EV "Yes" NB	EV "Yes" B	EV "Yes" NB+B	EV "No" NB	EV "No" B	EV "No" NB+B	Highest EV	Optimal decision
0	1	0	10	0	10	-10	0	-10	10	"Yes"
1	0.9	0.1	9	-1	8	-9	1	-8	8	"Yes"
2	0.8	0.2	8	-2	6	-8	2	-6	6	"Yes"
3	0.7	0.3	7	-3	4	-7	3	-4	4	"Yes"
4	0.6	0.4	6	-4	2	-6	4	-2	2	"Yes"
5	0.5	0.5	5	-5	0	-5	5	0	0	"Yes"/"No"
6	0.4	0.6	4	-6	-2	-4	6	2	2	"No"
7	0.3	0.7	3	-7	-4	-3	7	4	4	"No"
8	0.2	0.8	2	-8	-6	-2	8	6	6	"No"
9	0.1	0.9	1	-9	-8	-1	9	8	8	"No"

Note. B means bust outcome; NB means no-bust outcome; p(B) means probability of a bust outcome; p(NB) means probability of no-bust outcome.

Table 16: The outcome probabilities, EVs, and the optimal decision for each card value in the approach condition.

			16	-4		-16	4			
Card value	p(NB)	p(B)	EV "Yes" NB	EV "Yes" B	EV "Yes" NB+B	EV "No" NB	EV "No" B	EV "No" NB+B	Highest EV	Optimal decision
0	1	0	16	0	16	-16	0	-16	16	"Yes"
1	0.9	0.1	14.4	-0.4	14	-14.4	0.4	-14	14	"Yes"
2	0.8	0.2	12.8	-0.8	12	-12.8	0.8	-12	12	"Yes"
3	0.7	0.3	11.2	-1.2	10	-11.2	1.2	-10	10	"Yes"
4	0.6	0.4	9.6	-1.6	8	-9.6	1.6	-8	8	"Yes"
5	0.5	0.5	8	-2	6	-8	2	-6	6	"Yes"
6	0.4	0.6	6.4	-2.4	4	-6.4	2.4	-4	4	"Yes"
7	0.3	0.7	4.8	-2.8	2	-4.8	2.8	-2	2	"Yes"
8	0.2	0.8	3.2	-3.2	0	-3.2	3.2	0	0	"Yes"/"No"
9	0.1	0.9	1.6	-3.6	-2	-1.6	3.6	2	2	"No"

Table 17: The outcome probabilities, EVs, and the optimal decision for each card value in the avoidance condition.

Card value	p(NB)	p(B)	4 EV "Yes" NB	-16 EV "Yes" B	EV "Yes" NB+B	-4 EV "No" NB	16 EV "No" B	EV "No" NB+B	Highest EV	Optimal decision
0	1	0	4	0	4	-4	0	-4	4	"Yes"
1	0.9	0.1	3.6	-1.6	2	-3.6	1.6	-2	2	"Yes"
2	0.8	0.2	3.2	-3.2	0	-3.2	3.2	0	0	"Yes"/"No"
3	0.7	0.3	2.8	-4.8	-2	-2.8	4.8	2	2	"No"
4	0.6	0.4	2.4	-6.4	-4	-2.4	6.4	4	4	"No"
5	0.5	0.5	2	-8	-6	-2	8	6	6	"No"
6	0.4	0.6	1.6	-9.6	-8	-1.6	9.6	8	8	"No"
7	0.3	0.7	1.2	-11	-10	-1.2	11.2	10	10	"No"
8	0.2	0.8	0.8	-13	-12	-0.8	12.8	12	12	"No"
9	0.1	0.9	0.4	-14	-14	-0.4	14.4	14	14	"No"

APPENDIX L: Post experimental questionnaire (Experiment 5)

PLAYING A CARD GAME EXPERIMENT

POST-EXPERIMENTAL QUESTIONNAIRE

PARTICIPANT NUMBER:

AGE: PARTICIPANT GROUP:

GENDER: DATE:

Which hand do you use for writing? RIGHT/LEFT (Please circle one)

The highest degree earned in school (please circle): Diploma / Bachelor / MA/PhD

1. Did you have an idea of what this study was about? If yes, what?

2. How did you decide whether or not to take another card?

3. Did you use the same decision (either "yes" or "no") **consistently** throughout the experiment?

YES NO (Please circle one)

If so, which decision was most dominant?

4. Did the number of points you could win or lose affect your decision?

YES NO (Please circle one)

IF YES, how so?

5. Do you have any other comments concerning this experiment?

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