FACTORS INFLUENCING SINGLETON SEARCH AND COGNITIVE INTERVENTION WITH OLDER ADULTS.

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Abstract

The current thesis aimed to investigate visual attention in relation to the effects of stored knowledge and ageing, as well as the contribution of top-down and bottom-up processes in visual search. A first set of experiments focused on 'singleton search', where in the first experiment the singleton was a distractor, and in the second, the singleton was either the target or a distractor. The performance of younger adults was compared to older adults. In addition eye-tracking data was collected from the younger adults. Results of these experiments revealed that when the singleton was the distractor search is not always guided by bottom-up processing, but rather there is evidence that the presence of a singleton distractor can sometimes facilitate search as reported by Geng & DiQuattro (2010), however when the target is sometimes a singleton participants adopt a 'singleton mode' (Bacon & Egeth, 1994). Apparent differences between the groups were found to be attributable to the ageing process, thus younger and older adults are equal in their ability to utilize top-down guidance. In the second set of experiments a singleton search paradigm was used to examine the impact of stored knowledge and colour associations on search. In the first of these experiments the target was always incorrectly coloured, and in the second the target was either correctly or incorrectly coloured. Results of these experiments revealed when the target was always incorrectly coloured there was no evidence that stored knowledge representations impacted on search. However when the target could be either correctly or incorrectly coloured there was evidence of an impact of stored knowledge. Here search was more efficient when the target was incorrectly coloured relative to correctly coloured, and singleton distractors caused less interference than when the target was correctly coloured. Again apparent differences between the groups on these 2 experiments were found to be attributable to the ageing process, and thus older adults and younger adults are equally influenced by stored knowledge representations. Finally I carried out a cognitive intervention aimed at improving attention and working memory in older adults, and compared the performance of an intervention group to a control group. Results immediately after the intervention (Time 2) demonstrated that this computerised attention training programme (CPAT) can improve cognitive functions which otherwise decline with age. Results of the follow-up demonstrated that some benefits of the training last over a 4-month period after training. The implications of these findings are discussed, and suggestions made for future research.

For my beautiful and precious children Amelia, William and Theo

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CHAPTER 1

GENERAL INTRODUCTION

1.0 Introduction

Visual search is a common perceptual task, people are constantly engaged in. The ability to successfully perform this task is crucial in order to efficiently adapt to our rapidly ever-changing environment, and as such visual search is vital to our survival. As we age it seems our ability to search efficiently changes, and understanding the changes which occur is crucial in helping older adults to have a good quality of life and maintain their independence. Currently the exact mechanisms underlying the engagement of attention, and how these change with age, are not definitively known although various theories have been developed in a bid to explain how attention is guided during the search process. As such the aim of this thesis is to investigate visual attention as a function of age and the impact of stored-knowledge that participants bring to bear on visual selection, as well as to establish whether a cognitive intervention with older adults can improve attention and working memory.

1.1 How attention guides visual search

There are many theories of attention (e.g. Treisman's (1964) Attenuation theory; Broadbent's (1958) Filter theory; Kahneman's (1973) Capacity model; Deutsch & Deutsch's late selection model (1963); Johnston & Heinz's (1978) Multimode theory, and Graziano & Kastner's (2011) Attention schema theory). Among the many theories of attention are a number of theories that propose mechanisms of how attention guides visual search: **The Feature Integration Theory** (FIT) (Treisman & Gelade, 1980) proposes that search involves a two stage process. At stage 1 features such as colour, orientation, brightness, frequency and movement are registered automatically in a parallel manner. As such, feature search (e.g. looking for a singleton) performance should be efficient, and little affected by the number of distractors present. In contrast when search is conjunctive e.g. looking for a red rose amongst red poppies and pink roses, the display is processed in a serial manner (second stage) which happens, according to the theory, because focal attention must become engaged in order to code the features which form a particular or specific object which is done by binding the feature information in to a single object. If this integration does not occur illusory conjunctions may result whereby the features of the target and those of the distractors are inaccurately combined. However Wolfe, Cave and Franzel (1989) reported that performance on a conjunction search task was in some instances very similar to performance on a feature search task, suggesting that similar levels of attention were required for both types of search.

The **Guided Search Theory** (GST) was originally devised in 1989 by Wolfe et al. and has been updated several times with the latest version being produced in 2007 by Wolfe. This theory was developed in an attempt to address some of the shortcomings of the FIT. Like the FIT it maintains a two stage theory of processing - however in this case the parallel stage determines, via a signal control, which objects or features are further processed by the serial stage of processing. During the parallel stage there is top-down activation of the features of the target e.g. colour, shape and orientation and these features activate locations in a saliency map (which calculates the likelihood that each object is the target based on the activity created, the more activity there is the more likely the object is the target). A conjunction target will be activated by the top-down set for both features e.g. colour and shape, enhancing selection (as two maps are activated) when the feature values of the stimuli mean that the disturbance from one feature to another is minimal i.e. when both the features are distinct from one another.

Activity is driven both in a bottom-up and top-down manner; bottom-up activation is caused by the differences between the target and distractors of the relevant feature whereas top-down activation is driven by existing knowledge regarding the target or the task. It is acknowledged that information from the parallel stage may not always be totally accurate because the total possible units of activation of a particular feature has a limit (approximately 200). Wolfe (1994) posits that if this were not the case and the possible units of activation were infinite, performance would be hindered by a greater difference between the target and distractors in conjunction searches, as bottom up activation caused by the activation of the two features would interfere and transfer in to noisy data. However when the target is substantially different from the distractors and the distractors are increasingly similar to one another (as reported by Duncan & Humphreys in 1989) bottom-up activation allows for efficient search. Top-down activation is required to guide attention in circumstances where the feature properties of an object are not uncommon - here guidance occurs according to how closely the stimulus represents the relevant properties of the target. For each object, top-down guidance creates a channel for each property and the channel that carries the most weight produces the largest signal for the target than the other objects (Wolfe, 2007).

Attentional Engagement Theory (Duncan & Humphreys, 1989) is another two stage theory of attention and as with FIT and GST the first stage is processed in a parallel manner. However, rather than attention involving the combining of features, the initial stage places objects in to structural units, these units are grouped together as a function of similarity and compete for access into visual short-term memory (VSTM) and access to attentiveness thus resulting in a response.

The units are given weightings which vary the likelihood of that unit's chances of gaining access to VSTM (second stage). Weights vary according to how closely the unit resembles an internal template of the target, with more similarity gaining more weight, as well as linkage between the weights given to the units. Also, because there is limited capacity, when one unit gains weighting another unit decreases its weighting. This means that there is a 'spreading suppression' where an object lacks similarity to the target and this can make search more efficient as a particular coloured distractor will lead to suppression of other distractors of that colour also being suppressed. This account can explain the sometimes observed findings of efficient conjunction search based on parallel feature suppression when distractors are sufficiently dissimilar to targets.

Taken together, the theories of visual search emphasise that attention mediates the efficiency of visual search by 'extracting' target features and linking them to a target template. The theories raise an important question of whether the visual search reflects top-down or bottom-up factors driving allocation to a target.

1.2 Top-down and bottom-up processes in visual search

1.2.1 Three accounts of visual search guidance

Whilst the attentional models outlined above all offer differing accounts of what guides search, the overall implication seems to be that search for a simple feature target is possibly driven by its physical salience and as such is likely to be a bottom-up process (e.g. Pashler, 1988). Whereas search for a conjunctive target is likely to be utilizing both bottom-up and top-down processes and thus aspects of both parallel and serial search (Wolfe, Butcher, Lee & Hyle, 2003). However it has been argued that top-down processing cannot be used when the search is parallel due to this type of search being largely automatic and as such attention is likely to be captured by whichever features are immediately available (Theeuwes, 1991).

It has been claimed that when search is parallel, bottom-up processing alone is utilized and the singleton task has been used in an attempt to demonstrate this (Olivers & Humphreys, 2003; Song & Nakayama, 2007; Theeuwes, 1991). A singleton search task involves search for a specific target which is set amongst a display that consists of several distractor items. The distractor items are usually similar in some respect – typically colour or shape, with the exception of one item within the display being particularly salient because it is in some way unique - the ‘singleton’. The presence of a singleton distractor is purported to increase reaction time because it captures attention and distracts from the search for the target; in contrast a singleton target should attract attention and so facilitate responses (e.g., Maljkovic & Nakayama, 1994; Kristjansson, Wang, & Nakayama, 2002; Theeuwes, Reimann, & Mortier, 2006).

The issue about bottom-up (or top-down) processing is addressed by looking at whether detection of singletons elicits an involuntary shift of spatial attention (i.e. ‘‘attentional capture’’) that is immune from top-down modulation (Theeuwes,1991; Folk & Remington, 2006; Theeuwes et al., 2006). There are three lines of research that contribute to the debate.

The first line supports pure attentional capture (i.e. bottom-up processing). For example, Theeuwes (1991) suggests that parallel search is very quick and guided by preattentive processes. Therefore, in a parallel search task irrelevant salient items should hinder search for the task-relevant item (target). In an attempt to demonstrate this, Theeuwes (1991) employed a (compound) singleton task in which there were two salient items each having a unique feature in three separate experiments. Participants were asked to search for the target which was either a completely horizontal or vertical line, (as opposed to distractors which were slightly tilted lines). The lines (distractors and target) were set within a shape – the shape sometimes served as a singleton distractor and other times as a singleton which contained the target. There were three distractor conditions, one where there was no singleton distractor, a second where the singleton was different from the shape containing the target according to another feature and a third where the singleton shape was identical to the one containing the target. In experiment 1 the target was placed within a circle which was unique either in colour (red or green) or intensity (high or low). Participants were split in to two groups in which the trials were based on colour or intensity. As such the shape within which the target was placed was always unique on some dimension. In some conditions there were no distractor shapes, and in other conditions there were distractor shapes which were different from the shape on another dimension. Also sometimes the distractor shape was identical to the singleton shape which contained the target, but it contained a slightly titled line rather than the target horizontal or vertical line.

In experiment 2 the target was placed within a shape that was either unique due to colour (red or green) or shape (circle or square) - all other aspects of the experiment were otherwise the same as experiment 1. In experiment 3 the target was unique again due to colour (however the colour difference was this time less salient) and form (but this time rather than circle or square the shapes were circles or diamonds to increase the extent of difference). This experiment had no distractor condition where the distractor shape was identical to the shape containing the target, also the conditions of the experiment were varied within participants – as such all participants experienced all aspects of the experiment.

The results of experiment 1 indicated the presence of an irrelevant singleton slowed reaction time (RT) and a singleton distractor which was unique on a different dimension to the target-containing singleton was less distracting than an irrelevant singleton identical to that containing the target. Results for experiment 2 showed that search for a unique colour shape containing the target was not hindered by an irrelevant distractor of a different shape. However search for the target when it was within a unique shape was hindered by a distractor of a unique colour. The results for experiment 3 demonstrated that search for the target contained within a unique colour was hindered by an irrelevant singleton of a different shape, however search for the target within a unique shape was not hindered by an irrelevant singleton of a different colour. Thus it was concluded that a singleton distractor interfered with the search for a target. This in turn was taken to demonstrate that attention is captured by salience during parallel search; with top-down processing only being used after bottom-up processes generate selection of the most salient item. According to Theeuwes' (1991) the results suggest not only that attention is captured but that it is not possible to ignore an irrelevant singleton at speed.

This argument stands in contention to the models of visual search that posit visual attention is activated by a combination of both top-down and bottom-up guidance. In an attempt to demonstrate further that attention is unintentionally captured, Theeuwes and Burger (1998) conducted a study to specifically show that individuals are unable to ignore a highly salient item despite it being irrelevant to the task. A series of typical singleton experiments were carried out involving search for a target letter (E or R) coloured green or red which was set amongst distractors (other non-target letters). In the control condition there was no colour singleton, and in the colour singleton condition, the colour singleton was the odd colour out in the display i.e. the only red letter amongst all other green letters. Also, sometimes the colour singleton was compatible with the target letter i.e. E or R, and other times it was incompatible with the target letter i.e. H or P etc. The results showed the presence of a colour singleton slowed RTs to the target and that when the singleton was incompatible with the target, RTs were slower than when the singleton was compatible. Theeuwes and Burger (1998) also found that when participants were aware of the exact features of the target and the exact features of the irrelevant singleton, there was no difference in RT to the target irrespective of whether the singleton was present or absent. As such it was concluded whilst generally the irrelevant singleton does capture attention, it is possible to ignore when the exact details (colour and letter) of both the target and the singleton are known. Therefore it would seem to suggest that full top-down guidance is only possible when the individual knows exactly what to expect thus suggesting bottom-up guidance will be the method of search utilized in the majority of circumstances, as it is rarely the case that we know exactly what we expect to see.

It has to be noted that whilst the evidence presented above highlights how the singleton task has been utilized to demonstrate that unique salient objects do not always interfere with search, the targets tend to be abstract items. Targets typically are a shape, a letter or even a line and when colour is used to make the search conjunctive there is no real relationship between the colour and the target object (shape/letter/line). Olivers, Meijer and Theeuwes (2006) looked at the effect of working memory on selective attention using the rationale that when participants are asked to identify a target from an up-coming display it is likely the participant will form a representation of the target item which will be pre-activated by working memory, and thus the target should have an advantage. Results indicated amongst other things that interference caused by a distractor is greater when the distractor matches the content of working memory. This finding was corroborated by another study by Olivers, Peters, Houtkamp and Roelsema in 2011 where it was reported that working memory representations bias attention. However whilst it is not always the case that memorised items activate attention, it does seem that objects activated by working memory do appear to work as an attentional template and thus have a direct impact on our attentional set. This evidence seems to indicate that search for a real life item might differ from those which tend to be used in singleton search studies (shapes, letters etc.).

Another line of the debate about bottom-up/top-down processing of a singleton suggests that top-down modulation guides attention. For example, Folk, Remington and Johnston (1992) argue that whether or not a salient singleton captures attention is dependent on the attentional goal settings of the participant, and they put forward the contingent capture model as an explanation of how top-down processing is used in parallel search. Folk et al. (1992) used a cueing paradigm to examine the impact of cues on identification of a target and found that invalid abrupt onset cues slowed RTs to targets which had abrupt onset but not to singleton colour targets. Also invalid colour cues slowed RTs to a greater extent for singleton colour targets than for abrupt onset targets. These results were reported as providing evidence that attention is captured according to attentional control programming which is brought about by a top-down control setting; objects which do not fit this control setting will be ignored.

Supporting the top-down modulation account, Bacon and Egeth (1994) argued that, in Theeuwes's experiments (1991) the participants had been adopting a strategy of merely searching for the odd feature out. In an attempt to confirm this Bacon and Egeth (1994) carried out a series of experiments where they initially replicated Theeuwes's paradigm and findings. They then carried out further experiments where the participants were unable to use the strategy adopted in the first experiment. This was done by presenting the target more than once in some of the trials so that it was no longer a singleton, and subsequently one of the distractors became a singleton in addition to the target singleton. Bacon and Egeth (1994) reported that, in both these conditions, colour singleton distractors did not impact on search performance. They stated that when the conditions of the experiment prevent singleton detection strategy from being used participants were able to attend to the target feature and ignore irrelevant distractors. Thus they concluded that top-down processing is possible in parallel search. The results indicate that the attentional set of the participant dictates whether salient singletons distract from search for a target.

Using a conjunction search task, Lamy and Tsal (1999) looked at the effect of a singleton in relation to search for a target. The stimulus consisted of two letters in two different colours with the target being constant and the only one of its kind but similar to the distractors, with the singleton being unique in either shape or colour and salient because it was the only unique item in the display. Participants were asked to indicate whether the target was present or absent. The conditions were target present and singleton present; target present and singleton absent; target absent and singleton present, and target absent and singleton absent. The results of Lamy and Tsal's (1999) study showed that RTs were faster in target present conditions than target absent conditions and with regards to the singleton distractor conditions – RTs were faster when the singleton was absent relative to present. Furthermore there was a significant interaction between target presence and singleton presence whereby the presence of a singleton seemed to be causing slower RTs in the target absent condition, however there was no effect of singleton in the target present condition. The authors state that these results provide evidence that top-down processing is utilized for a conjunction search (which is more cognitively demanding than feature search) with no bottom-up activation inference. The results of Lamy and Tsal's (1999) study do seem to suggest top-down guidance is used when the task is demanding and that this process is less open to distraction than bottom-up guidance.

The third line of this debate supports the 'combined view' (i.e., when searching for a singleton target, attention is guided by a mix of both top-down and bottom-up processing (Wolfe et al*.,* 2003)). For example, Wolfe et al. (2003) carried out experiments where both the dimension and feature of the target swap to become a distractor preventing the participant from using strategies and limiting top-down information. The results suggest that efficient search was still possible even when the target on one trial became a distractor on another. However the increased uncertainty did result in increased RTs - indicating that whilst top-down information regarding the target was heavily reduced, efficient search was still possible utilizing bottom-up processing alone.

Despite the fact that all three of these lines of research have experimental evidence to support their arguments, the question of whether bottom-up/top-down modulation guides visual search is still unclear, and therefore additional research is required in order to attempt to shed more light on the circumstances in which bottom-up/top-down guidance drives attention.

1.2.2 Eye-tracking evidence in relation to top-down and bottom-up processing

Eye-tracking is now one of the most common methods used to investigate visual search. It has been used to examine the processes involved in visual search as it is seen as providing a particularly informative measure of attention capture (Findlay, 1997). It provides evidence of what happens during the initial stages of search i.e. what first captures attention, how long this stage lasts, and then what happens after this initial capture, as well as whether eyes return to previously viewed regions deemed to be relevant or important. All of this information provides information on how participants interact with visual displays.

Eye tracking experiments collect measures either on saccades i.e. eye movements, or fixations (over 80ms) when it is believed information is registered (Hoffman, 1998). For example, Theeuwes, Kramer, Hahn and Irwin (1998) carried out eye tracking experiments to examine whether the appearance of an irrelevant object would distract from search for a singleton target. In these experiments participants were asked to move their eyes to a colour singleton target (all circles started grey and then all but one changed to red whilst the target remains grey). However on some trials there could also be an abrupt onset of a new object at the same point as all the circles (except the target) change colour. The results showed not only were eye movements directed to the irrelevant object (and then moved on to the target) but that when the irrelevant distractor was present RTs were slowed for identifying the target, which was interpreted as being representative of the time taken to inhibit the eye movement to the irrelevant item. As such it was concluded that the goal directed behaviour (top-down processing) was disrupted by an irrelevant object, thus suggesting that salience (bottom-up processing) over-rides goal-directed behaviour.

Chen and Zelinsky (2006) looked at eye movements in order to investigate how bottom-up and top-down processes combine to guide visual search. They used pictures of well-known real objects where a distractor object was presented as a colour singleton (in an attempt to encourage bottom-up processing) amongst non-coloured target objects which had the search-target (+ or x) superimposed on top of the picture of an object. In addition there was a target object preview condition whereby on some trials participants were shown a preview of the target object (not search-target). There were three conditions for this; one was a long preview (1000ms), the second was a short preview (100ms) and the third was no preview. It was believed the preview conditions would mean top-down processing was utilized, therefore pitting top-down and bottom-up processes against each other. The results showed that RTs were faster when there was a preview (both long and short) than when there was no preview. However no effect of colour singleton distractor was found. With regards to eye movements a greater number of initial eye movements were made to the target, with the colour singleton distractor only being fixated in the no preview condition. It was concluded that top-down processing will prevail over bottom-up processing when the two processes are pitted against each other when the participant is aware of what they are looking for. If however there is no preview of the target, bottom-up processing will guide attention. Chen and Zelinsky (2006) did however acknowledge in other situations it is possible that a different combination may be utilized i.e. bottom-up processing may predominate.

Research carried out by Donk and van Zoest (2008) used eye tracking to demonstrate that whilst salience drives attention this is only for a short period after the display onset. They presented participants with a screen filled with either horizontal or vertical lines and within this display there were two salient items (tilted lines). There were two conditions of salience, one where the lines were tilted to degrees of 20/70 and the other where the lines were tilted to degrees of 30/60. In experiment 1 participants were asked to move their eyes quickly to the most salient item. Results here indicated that of the fastest eye movements made by participants more correct eye movements were made to the most salient item when the lines were titled to degrees of 20/70 than degrees of 30/60. However when latencies were longer more correct movements were made to degrees of 30/60 than to degrees of 20/70. In the second experiment, instead of being instructed to move eyes quickly participants were instructed to use the keyboard to indicate which side of the screen the most salient item was on, and display times varied. The results for experiment 2 indicated that when there was less time, participants were better at accurately identifying the most salient item. Donk and van Zoest (2008) believe this shows that salient information is only available for a short period and disappears after a longer period. They conclude that, as bottom-up and top-down processes have different time courses, their interaction in guiding search may be less than is generally assumed.

As this evidence demonstrates, eye tracking can provide additional and important information in addition to analysing accuracy rates and RTs. Without the use of eye tracking it would have been difficult for the experiment used (above) by Chen and Zelinsky (2006) to separate the cost of the no preview condition from that of the cost of the singleton on visual search. Similarly, in the Donk and van Zoest (2008) experiments it would not have been possible to know about the time course of attention deployment without eye movement data. According to Theeuwes et al. (1998), eye movements are initially made without awareness to the area which may be of interest, but typically the eyes fixate where attention is captured. As such, using eye tracking to examine fixations as an indication of captured attention is beneficial and informative when investigating bottom-up and top-down guidance of attention.

1.3 Factors influencing visual attention

There is evidence that various factors can influence attentional capture during visual search. Stored knowledge can impact on search efficiency, for example Belke, Humphreys, Watson, Meyer and Telling (2008) reported that distractors taken from the same semantic category as the target slowed search times for that target (but not distractors taken from a different semantic category), demonstrating that stored associations influence search in a top-down manner. Moreover there is evidence to suggest that active working memory representations can also guide attention. According to Olivers et al. (2011) when we require information about an object we are familiar with the representation in working memory is likely to be active. When such active working memory representations are used for visual search the representation guides attention by working as an attentional template driving selection of the relevant visual object. Thus our active representations of items we are familiar with (and thus have stored knowledge of) guide attention during a visual search task.

In addition Tanaka and Presnell (1999) conducted a study to investigate the role of colour on object recognition. In order to do this objects were categorised as high colour diagnostic (HCD) items (including items such as fruit), and low colour diagnostic (LCD) objects (including items such as furniture). The objects were categorised on the basis of typical responses to a feature-listing exercise. The results revealed that colour facilitated the correct response to all items and that, when the HCD items were presented incongruently and achromatically, more errors occurred in comparison to LCD objects. Also colour versions of congruent HCD objects were named faster than incongruent and achromatic versions of the HCD objects. These results indicate that search is more efficient when items are presented in colour, and this is especially true for HCD objects.

Furthermore research has shown that when targets have a strong colour association, search is facilitated when the target is correctly coloured relative to when it is incorrectly coloured (Anderson & Humphreys, 2015; Rappaport, Humphreys and Riddoch, 2013; Wildegger, Riddoch and Humphreys, 2015 (see chapter 4 for further details on these studies)). The findings of Rappaport et al. (2013) also indicated that search for the target was further facilitated when the target was correctly coloured but the distractors were incorrectly coloured.

1.4 Attention and ageing

It is well documented that some aspects of cognition decline with age and both higher level and basic cognitive functions are affected. Higher level cognitive functions include executive control processes (Kramer, Hahn & Gopher, 1999) and according to West (1996) this is linked to the decline in the function of the prefrontal cortex which is associated with the ageing process. According to Miyake et al. (2000), the three main cognitive functions which comprise executive functioning are mental set shifting, inhibition of over-riding responses and information updating and monitoring. Reports indicate that, whilst these functions are moderately correlated with one another, they are also dissociable. Nevertheless it is possible that if just one of these three functions were to decline as a result of ageing, performance could suffer on any task which required overall executive functioning. All three of these cognitive functions are involved in attentional processes.

Indeed, attention is posited to decline in varying degrees with age, with some aspects of attention seeming to decline more than others. Whilst attention is considered to be a basic function it is also multi-faceted involving various complex and specialised processes, to such an extent that some aspect of attention is integral to the majority of cognitive functions. According to Glisky (2007), declines in attention are likely to have a wide ranging impact on daily living. In a review carried out by Verhaeghen and Cerella (2002) it was reported that the aspects of attention which are most commonly associated with ageing decline, and therefore tend to be the most commonly studied in this field, include selective attention, dividing and switching attention, and sustained attention, as these aspects are posited to involve the executive control processes. Examples of executive control processing include processes which involve problem-solving and response monitoring (Alvarez & Emory, 2006).

There are two main competing accounts which attempt to explain the effects of ageing on cognitive functioning, one of these accounts posits specific aspects of cognition are effected by ageing and the other posits general cognitive functions are effected by the ageing process. The account of ageing which posits that the effects of age on cognition is general is synonymous with Salthouse's (1996) theory of cognitive ageing which focuses on the speed of information processing which is categorised as a basic cognitive function. This theory postulates that there are various capacities which limit our performance as we age and information processing speed is one such capacity which impacts on memory and other cognitive functions. Salthouse (1996) using a Raven's progressive matrices test, as well as letter and pattern comparison tests demonstrated that over 50% of age-related variance in working memory was related to measures of processing speed. The overall conclusion was that processing speed in older adults is impacted upon by two mechanisms. The first mechanism is the simultaneity mechanism, when processing is fast (e.g. in younger individuals) there will be a large amount of simultaneous information available which in turn would facilitate other cognitive functions which are reliant on the combined input of various forms of information. When processing is slow or slower (as in older adults) information gained from early processing is lost by the time the later processing has occurred, thus information which is relevant or required is not available. The second mechanism posited by Salthouse's (1996) processing-speed theory of ageing to contribute to the decrease in processing speed with age is the limited time mechanism. According to the theory this mechanism is impacted upon by the time to carry-out later processes being largely restricted by a greater amount of the time available being taken up by carrying-out earlier processes. Thus when there is a speed restriction or the task is complex i.e. requiring several operations e.g. divided attention tasks, as the speed of performing many processes is slower, less processing can be performed in the available time by older adults in comparison to younger adults. According to Salthouse (1996) these mechanisms could therefore explain the deficits related with ageing often seen in tasks requiring encoding, search, rehearsal etc.

Salthouse (1985) previously had reported that ageing is associated with a decline in fluid intelligence which is largely attributable to the slowing of processing speed, and further support for this was reported by Bors and Forrin (1995). Furthermore Salthouse (2004) stated that, in order to understand the psychology of ageing more fully, it is necessary to answer the questions of how, why, what, when and where, as the reason for cognitive ageing is not really known, although considerably more is known regarding the what and when than the how, why and where. Salthouse (1994 & 1996) claimed that, based on a great deal of data recorded in his laboratory, it was possible to say that age-related declines are relatively large, begin reasonably early on in adulthood, are evident in variety of cognitive functions and affect the majority of people.

A study carried out by Ritchie, Tucker-Drob and Deary (2014) examined the efficiency of perceptual processing in a bid to establish the extent to which processing speed and age-related cognitive declines are associated. They used a large cross-sectional sample (n = 628) aged 70, 73 and 76 years old, and measured performance on four different cognitive tasks designed to measure aspects of fluid intelligence as well as a visual inspection time task. The results showed significant correlations between inspection time and fluid intelligence, as well as significant declines in fluid intelligence and inspection time with age. As such it was concluded that processing speed is strongly associated with changes in the higher cognitive functions which are themselves associated with age-related declines. However as this evidence is correlational, further research is required to establish whether the relationship revealed by this study is bottom-up (from speed to cognition) or top-down (from cognition to speed) based.

Intrinsic to the specific account of the effect ageing has on cognition is the Hasher-Zacks (1988) framework which posits that inhibition is intrinsic to various cognitive functions and thus difficulty with inhibiting responses can impact on many aspects of daily life. Hasher, Stoltzfus, Zaacks and Rypma (1991) used a letter-naming task to highlight that the RTs of older adults in comparison to younger adults' did not appear to be influenced by inhibition. In this study participants were asked to identify one of two letters on the basis of colour. On sequential trials participants were presented with a target that had previously been a distractor all other trials were used as a control measure. Younger adults' RTs were slower suggesting that they were demonstrating a negative priming effect and inhibiting the previous response to this object when a distractor; in contrast older adults' RTs were very similar in the sequential trials as in the control trials and thus not demonstrating a negative priming effect. As such it was concluded that as we age we have less inhibitory control. These findings provide further support for the Hasher-Zacks (1988) framework. Furthermore Lustig, Hasher and Tonev (2001) went on to demonstrate that older adults relative to younger adults were impaired by information that is no longer relevant to the current task, not only on experimental tasks but also on everyday tasks such as reading and communicating. Moreover Gazzaley and D'Esposito (2007) conducted a study to investigate older adults' ability to select relevant information and suppress irrelevant information. The authors collected fMRI, EEG and TMS data on a delayed-recognition task which was modified to also involve selective working memory. Results revealed an age-related decrease in the ability to suppress irrelevant information. Gazzaley and D'Esposito (2007) conclude these findings demonstrate support for the inhibitory deficit hypothesis of ageing.

The account of specific effects of ageing on cognition is further supported by evidence related to multitasking and divided attention. Multitasking involves attending to a number of differing goals and tasks simultaneously, and whilst Somberg and Salthouse (1982) carried out a study looking at age differences in divided attention and reported that there was no difference between younger and older adults' ability to divide attention between two simultaneous tasks. Other evidence contrasts with this, for example, Tsang and Shaner (1998) carried out a study where participants were required to perform five different dual tasks and they reported that differences were evident on the Planikin rotation task; on a tracking task which involved maintaining a cursor in a stationary position; as well as on the Sternberg memory task. The authors nonetheless did conclude that the deficits seen in the older adults could be attributed to reduced processing efficiency. Thus it seems generalized slowing may account for apparent age-related changes in divided attention. However differences in ability between younger and older adults to multitask was also reported by Angurea et al. (2013). Here the performance of participants aged between 20-79 years old were compared on a video game which required a response to two different conditions: one of which was a sign only condition; the second condition required a response to the same sign as before whilst simultaneously maintaining the position of a car in a specific location on the screen. Results indicated that performance in the second condition diminished significantly in a linear manner with age. Anguera et al. (2013) state that these findings are consistent with previous research which has demonstrated declines in fluid cognitive abilities, reasoning and working memory with age. In addition in the meta-analysis conducted by Verhaeghen and Cerella (2002) which looked at ageing and attention reported with regards to divided attention and global task-switching (tasks are switched) there was an effect of age, which was not the case for local-switching (switching within a task). It is possible that these age related deficits in task-switching are mediated through perceptual speed (Salthouse et al., 2000).

As mentioned above, certain aspects of attention are reported to change in varying degrees with age which is perhaps why findings about effects of ageing on attention may be inconsistent sometimes. Furthermore inconsistency in findings has also been attributed to the differences in the types of tasks utilized. For instance, a study carried out by Staub, Doignon-Camus, Bacon and Bonnefond (2014) compared younger adults' performance to older adults' on two types of sustained attention tasks. One of the tasks required only a response to a rare target, whilst the other tasks required participants to withhold a response to a rare target. Results indicated that on the task where responses to the rare target needed to be withheld younger adults out-performed older adults, whereas the opposite was true on the other type of sustained attention (responses made only to a rare target). However older adults reported higher levels of motivations and less mind wandering. The authors state that the data and literature on sustained attention in ageing shows not only a deficit in sustained attention with age, but also preservation and even levels of improvement. As such they posit the inconsistency in findings are likely to be related to the different approaches utilized by different studies.

Dror and Kosslyn (1994) compared older adults to younger adults on attention tasks which required forming mental images of objects which were not currently present, and thus placed demand on working memory and long-term memory. Dror and Kosslyn (1994) reported that older adults were found to be equal (based on error rather than RT data) relative to younger adults in their ability to generate an image of a shape, and the ability to mentally scan a previously seen image. However age related declines were evident on the ability of image maintenance, and image rotation. Furthermore Vecchi and Cornoldi (1999) examined working memory and visuo-spatial processing in terms of passive (composing mental images) and active (following directions) processing. Results indicated an age related decline on the active processing tasks, but not on the passive processing tasks. Thus confirming that age related declines in attention are varied. Whilst it is evident that age related declines exist in spatial search tasks, and this seems to be attributable to age related deficits in selective attention, it is still unknown whether this is due to declines in top-down or bottom-up processing (Zanto & Gazzaley, 2014).

Selective attention is perhaps most relevant to this thesis and is concerned with the ability to focus attention on specific positions or objects in the visual field whilst controlling this focus in order to enable the stimuli to be scanned until the target is identified or it is decided that the target is absent. The ability to correctly select relevant information is essential for successful visual search – both in experimental conditions and everyday life. In search tasks which involve identifying a target among distractors – such as the tasks being utilized in this project – older adults' RTs tend to be slower than younger adults' RTs, however this difference can usually be attributed to the general slowing associated with ageing (Gilsky, 2007). Selective attention in ageing has been examined by Gottlob and Madden (1998) using a peripheral cueing task to demonstrate that whilst older adults seem to show evidence of a decline in sensory processing, there is no evidence of a decline in attention allocation. This finding corroborated previous findings using the same paradigm (Hartley, Kieley & Slabach, 1990; Nissen & Corkin, 1985). In addition with regards to age-related deficits Verhaeghen and Cerella (2002) demonstrated that whilst there was a greater effect of age-related slowing on Stroop tasks relative to negative priming tasks, there was no evidence that age-related deficits exist where participants are required to actively select relevant information, or ignore and inhibit responses to irrelevant information. That is, Brinley plots indicated that the younger adults' performance predicted the older adults' performance well, thus any differences on the selective attention tasks were attributable to the slowing of the central nervous system which occurs with age. The authors therefore concluded that overall the evidence did not support the notion that selective attention declines with age.

The capture of attention has been examined in ageing using the Simon task. This task looks at ability to successfully ignore irrelevant and thus controlling interference caused by the irrelevant information by presenting participants with stimuli which is either congruent or incongruent to the required response i.e. pushing the button on the right when a red object is presented regardless of the location of the object. Performance is usually more efficient when the stimuli (a red object) is presented in congruence with the response key i.e. on the right side, even though location is irrelevant to the task. Juncos-Rabadan, Pereiro and Facal (2008) reported that the older adults relative to younger adults experienced a greater Simon effect i.e. suffered higher levels of interference from the stimuli being incongruent to the response. These results held even when the general slowing process was accounted for. Thus demonstrating that older adults' attention was captured by irrelevant information and that they were unable to overcome this and inhibit interference. These findings corroborate the findings of previous research (Pick & Proctor, 1999; Van der Lubbe & Verleger, 2002).

Another aspect of cognition which is posited to change with age is intelligence. It is generally accepted that crystallised intelligence i.e. fact based knowledge in contrast to fluid intelligence is not associated with age related decline (Horn & Cattell, 1967). Moreover it seems that older adults may benefit from their fact based knowledge on tasks where stored knowledge is utilized, an example of which is performance on a television show quiz where older adults out-performed younger adults when answering questions based on general knowledge (Maylor, 1994). In addition McGillivray and Castel (2010) demonstrated that on an associative memory task older adults benefitted from their prior knowledge relative to younger adults. Also older adults have been found to benefit from stimuli which is congruent with their prior knowledge on an associative memory task (Badham & Maylor, 2015). Taken together this evidence indicates that attention and memory are influenced by stored knowledge, and that older adults may be influenced to a greater extent (relative to younger adults) by their stored knowledge.

1.5 Singleton search and ageing

Singleton search tasks are commonly used to measure selective attention and attention capture. When measuring selective attention using singleton search tasks where the target shares one or more features with non-singleton distractors Madden and Whiting (2004) reported that older adults were slower and made more errors when identifying non-singleton targets. This finding was corroborated by other research (Hommel, Li & Li, 2004). However older adults have been reported to equal younger adults' performance when the target is a singleton and differs from the distractors (Dennis, Scialfa, & Ho, 2004; Humphrey & Kramer, 1997). Results also indicate that when the singleton is a distractor older adults' attention is captured by the irrelevant object and search is hindered (Pratt & Bellomo, 1999). Plude and Doussard-Roosevelt (1989) demonstrated that older adults show specific deficits on target absent trials, whereby older adults compared to younger adults are significantly impacted up on by display size in the target absent conditions. Plude and Doussard-Roosevelt (1989) conclude this could be indicative of a difference in age for rechecking negative responses i.e. older adults are more cautious when saying 'absent' than younger adults. Leber and Egeth (2006) reported that top-down knowledge of the target may help to limit the effects of bottom-up distraction.

In 2004 Madden et al. demonstrated that older adults were equally able to utilize top-down processing when searching for a singleton target. In Madden et al.'s study (2004) stimuli consisted of letters with the singleton being red and all others (3 or 5 items) being grey on a black background. The target was either E or R and differed from the distractors, however on some occasions (25%) the colour singleton was also the target. In addition there was a guided search condition whereby a message was given to indicate that the singleton was likely to be the target (guided condition) or unlikely to be (baseline condition). Participants were required to indicate which letter the target had been (E or R). The results indicated top-down processing had guided search in that there was a larger difference in RTs in the guided condition between the target being the colour singleton and a distractor being the colour singleton, and this effect was found to be more pronounced for the older adults relative to the younger adults. In addition, the results showed that older adults' performance was hindered to a greater extent relative to younger adults' by a larger display size, and by the target not being the colour singleton. However, a Brinley plot demonstrated that these age-related differences could be explained by a generalised slowing effect. Madden et al*.* (2004) conclude that the faster RTs to the singleton target relative to the non-singleton target indicates engagement of top-down processing, and that in some conditions older adults are more prone to being distracted by an irrelevant singleton, but nonetheless overall the evidence suggests there is no difference in ability between younger and older adults to search using top-down guidance.

In addition Madden, Whiting, Spaniol, and Bucur (2005) reported that top-down knowledge of the target benefits older adults' search (relative to younger adults). This study compared performance between younger and older adults on two experiments. The first experiment examined explicit (knowledge-based) and implicit (priming by repetition) top-down guidance when the singleton target and distractors (simultaneously) were either consistent (blocked condition) or variable (mixed condition). Participants were required to indicate whether the target (singleton) was present or absent in two different display sizes. In the blocked condition results indicated that the difference in performance between the display sizes for younger and older adults demonstrated that the older adults were still performing efficient search despite having slower RTs. In the mixed condition performance between the groups was comparable. Furthermore in this experiment (1) priming was evident for both groups in the six item display, however for the four item display there was a greater effect of priming for the older adults relative to the younger adults. Thus there seemed to be no age related differences in implicit or explicit priming in an efficient search task. In experiment 2 the conditions were the same except that the target and distractor colours varied independently (the purpose of which was to discriminate between target activation and distractor inhibition). Whilst the older adults were slower than the younger adults there was no evidence of age related differences in performance in the blocked condition. In the target-primed and distractor-primed condition however there was evidence of a difference in the priming effect between groups. In the distractor-primed trials older adults demonstrated an explicit top-down effect for both display sizes whereas no such effect was evident for the younger adults. In the target-primed trials when there were 4 items in the display (only) the explicit top-down effect was larger for the older adults than the younger adults. A Brinley plot was produced and indicated that the difference found here was not attributable to the ageing process. Madden et al. (2005) maintain this provides further evidence that older adults benefit equally to younger adults from having prior knowledge regarding the target, and that the contribution of top-down attentional guidance is greater for older adults than younger adults.

Additionally, more recent research carried out by Christ, Castel and Abrams (2008) used a singleton search task to examine whether there was a difference between younger adults and older adults in the ability to use bottom-up processing in visual search. The authors adopted a singleton search task where the target was a letter which could be S or H and participants were required to identify which target was present on each display. The display also contained distractors which were made up of the letters E and U. The singleton was an item which would move, this could be the target or a distractor, and movement could be: present from onset, newly moving (suddenly started after onset of display), motion ceased or not occurring at all. Results indicated that search was most efficient for both groups when the target appeared in the newly moving singleton, as well as both groups being faster in the static condition than the motion from onset, motion ceased and no motion conditions. As such it was concluded that there was no difference between younger adults and older adults in bottom-up processing.

Taken together the evidence on ageing detailed above shows that the higher levels of cognition i.e. executive functioning (Miyake et al., 2000) may be affected if one of the three major functions (set shifting, inhibition and information updating) are impacted upon by declines associated with age. Empirical evidence demonstrates older adults are less able to exercise inhibitory control (Hasher et al., 1991; Hasher, Zacks, Rose & Doren, 1985; Hasher, Zacks & May, 1988 & 1999); and experience declines in fluid intelligence which in turn is associated with declines in information processing speed (according to Salthouse (1985) much of the age-related differences in fluid intelligence can be accounted for by age-related declines in information processing speed); and working memory (Salthouse, 1994 & 1996). Therefore it would seem that these deficits in inhibitory control, information processing speed and working memory are likely to result in executive functioning deficits which could have a negative impact on daily life. Furthermore, there is evidence that older adults also show declines in some aspects of attention i.e. visuo-spatial processing (Dror and Kosslyn, 1994; Vecchi and Cornoldi, 1999), divided, and switching (Verhaeghen & Cerella, 2002). However according to Verhaeghen & Cerella (2002) whilst older adults RTs are slower relative to younger adults on selective attention tasks there is no evidence of age-related deficits on these tasks. Moreover despite reports that show older adults are less able to ignore irrelevant singletons (Pratt & Bellomo, 1999), there is evidence that older adults show no declines in ability to use top-down processing (Madden et al., 2004), as well as bottom-up processing Christ et al. (2008).

1.6 Thesis overview

Chapter 2 investigates the theory that visual search is not always a bottom-up process as posited by Theeuwes (1991) using a singleton distractor experiment, measuring both reaction times, and errors. It also compares the performance of younger adults to that of older adults. In the first experiment the target was the only circle amongst squares, with an irrelevant colour singleton distractor present on some trials. The second experiment for this chapter looked at the impact of the target sometimes being a colour singleton. The colour singleton distractor was never present simultaneously with the singleton colour target. Chapter 3 uses the same two experiments outlined for chapter 2, however here eye-tracking data from younger adults is examined. There is no eye tracking data for the older adults to enable comparison between the groups using this data. Chapter 4 compares the performance of older and younger adults during singleton search when the items are real life objects

- fruit and vegetables, which have relatively strong colour associations (Tanaka & Presnell 1999) and stored knowledge representations (Olivers et al. 2011). In the first experiment the target was always an incorrectly coloured banana set amongst homogenous distractors which were all also incorrectly coloured. In the second experiment the target is presented as sometimes correctly coloured and sometimes as incorrectly coloured. For both experiments on some trials a singleton distractor appeared that was different from the homogenous distractors but still an incorrectly coloured fruit/vegetable, while on other trials the singleton distractor was presented as a correctly coloured fruit/vegetable – again different from the homogenous distractors.

In Chapter 5 an intervention was carried out and evaluated which aimed to improve attention in older adults. A computerised attention training program (CPAT) was used which involved the participants playing three games each targeting a different aspect of attention (Shalev, Tsal & Mevorach, 2007). A global-local task trained executive functioning; a continuous performance task trained sustained attention; and a search task trained selective attention. The performance on the outcome measures was compared to performance at baseline i.e. Time 1 was compared to Time 2. Comparisons are made between the experimental (CPAT) group and active control group who spent the same amount of time playing widely, freely available computer games as the experimental group spent on training. In addition evaluation of the long-term effectiveness of the intervention carried out was undertaken. The two groups of older adults were tested once again on the outcome measures (outlined above) 4-months after training had finished (Time 3).

Overall the results indicate that relative to younger adults older adults are equally able to utilize top-down processing, and stored knowledge during singleton search.

Furthermore they indicate cognitive declines can be offset by cognitive training and the benefit of faster information processing speed is largely maintained over a 4-month period.

CHAPTER 2

SINGLETON EFFECT ON SEARCH FOR A TARGET: A COMPARISON BETWEEN OLDER AND YOUNGER ADULTS

2.0 Introduction

Efficient visual search requires deployment of attention; typically an observer scans the environment or a display in an attempt to locate a specific item but the exact mechanisms underlying engagement of attention are not definitively known; however various theories have been developed in a bid to explain how attention is guided.

Models of search generally assert that visual attention is captured initially according to the salience of an object (e.g. Itti, Koch & Niebur, 1998). The impact of salient objects on visual search has been examined using a singleton paradigm (Bacon & Egeth, 1994; Chen & Zelinsky, 2006; Donk & van Zoest, 2008; Folk et al., 1992; Lamy & Tsal, 1999; Theeuwes, 1991; Wolfe et al., 2003). For example, in search for a feature target, the display typically consists of a target which is different from the distractors on one dimension (often shape or orientation), a singleton distractor which differs from the other distractors on another dimension (often colour), with the other objects (non-singleton distractors) being homogeneous. The common findings are that the presence of an irrelevant singleton distractor slows reaction time (RT). As detailed in Chapter 1, Theeuwes (1991) reported that during a compound search although search for a unique colour shape containing the target was not hindered by an irrelevant singleton distractor of a different shape, search for the target when it was within a unique shape was hindered by a distractor of a unique colour (experiment 2). Furthermore Theeuwes (1991) reported (in experiment 3) the target contained within a shape unique in colour (which was only subtly different) was hindered by an irrelevant singleton of a (very obviously) different shape, however search for the target within a unique shape (which was obviously different) was not hindered by an irrelevant singleton of a (subtly) different colour. The results of these studies suggest that attention is captured by salience during parallel search; top-down processing is only used after bottom-up processes generate selection of the most salient item; the results indicate that it is not possible to ignore an irrelevant but salient singleton at speed.

In contrast, subsequent research has demonstrated that it is not always the case that visual search is guided by bottom-up processing which cannot be overcome (as previously outlined in Chapter 1). Theeuwes and Burger (1998) showed that it is possible to ignore an irrelevant singleton when we know exactly what to expect. Lamy and Tsal (1999) used a conjunction search singleton paradigm (using letters and colour) to show that when the task is cognitively demanding (searching for a conjunction) top-down guidance is utilized with no interference from bottom-up activation. In addition, Bacon and Egeth (1994) reported that when the conditions of the experiment prevent a singleton detection strategy being used it is possible to attend the target features and ignore irrelevant distractors; concluding that top-down processing is possible during parallel search (see Chapter 1 for further detail of these studies). Olivers, Meijer and Theeuwes (2006) demonstrated that working memory can impact on selective attention by pre-activating a representation of an object, they reported when a distractor matches the content of working memory it causes greater distraction than when it does not match what is held in working memory. Olivers et al. (2011) went on to show that representations activated by working memory work as an attentional template and thus have a direct impact on our attentional set. According to Folke et al. (1992) attention is captured according to attentional control programming which is brought about by a top-down control setting. Taken together this evidence suggests salience will not always capture attention in a bottom-up manner, but rather that it is possible to use top-down processing and ignore irrelevant salient singleton distractors.

A considerable amount of research has been carried out in an attempt to better understand changes in cognitive functions which occur as a result of the normal ageing process. These include decline in sensory-motor reactions, deterioration of information processing, decrements in the selectivity of processing visual information, detecting changes to visual scenes in older adults in comparison to younger adults (Fisk & Rogers, 1991; Madden et al., 2004; Owsley, Sekuler & Boldt, 1981; Plude & Hoyer, 1986; Rensink, 2002), to name a few. Indeed, a typical finding in the cognitive ageing literature is that healthy older adults experience age-related cognitive decline across a variety of task conditions (see Craik & Salthouse, 2011, & Madden, 2001 for a review), and it is proposed that ageing effects are most pronounced in tasks where participants are required to utilize executive processes (Hasher & Zacks, 1988; Mayr, Kliegl & Krampe, 1996; Mayr, Spieler & Kliegl, 2001).

However specific deficits have been reported in older adults on visual search tasks especially on target absent trials. For example, Plude and Doussard-Roosevelt (1989) investigated whether ageing deficits in selective attention originate in the earlier stages of visual processing (parallel) or the later stages of processing (serial). Comparisons were made of older and younger adults' performance on a feature search, relative to a conjunction search. Participants were required to indicate whether the target was present or absent on each trial. The stimuli consisted of objects differing in colour (red and green) and form (X and O), and there were 3 display sizes (5, 15, 25). The target type differed but was counterbalanced across participants within each age group. When the target was a red X, for a feature search task the distractors were then all green Os; for the conjunction task half of the distractors were red Os and the other half were green Xs. Results showed that RTs increased from the feature search to the conjunction search (i.e. here RTs were slowest). Also in the feature search there was no effect of display size for both groups, whereas in the conjunction search task for older adults display size significantly impacted on performance relative to the younger adults. Plude and Doussard-Roosevelt (1989) state that this demonstrates that whilst older adults' performance is equal to younger adults' during parallel search ageing deficits appear during serial processing. Plude and Doussard-Roosevelt (1989) conclude that the older adults' being significantly impacted up on (relative to younger adults') in the conjunction task by display size in the target absent conditions could be indicative of a difference in age for rechecking negative responses i.e. older adults are more cautious when saying 'absent' than younger adults. However they also state that it is possible that the general slowing which is associated with ageing could be exacerbated in conjunction searches.

It has also been demonstrated that older adults are equal to younger adults in their ability to utilize top-down processing during visual search. For example, Madden et al. (2004) conducted a colour singleton search study with older and younger adults (as detailed in Chapter 1). The results indicated top-down processing had guided search in that there was a larger difference in RTs in the guided condition between the target being the colour singleton and a distractor being the colour singleton, and this effect was found to be more pronounced for the older adults relative to the younger adults. In addition, the results showed that older adults' performance was hindered to a greater extent relative to younger adults' by a larger display size, and by the target not being the colour singleton. However, a Brinley plot demonstrated that these age-related differences could be explained by a generalised slowing effect. Madden et al. (2004) consequently concluded that although older adults' RTs were slower than younger adults', overall there was no difference in ability between younger and older adults to search using top-down guidance.

Taken together this evidence on visual search in ageing demonstrates that where age deficits are apparent these deficits can be attributed to the generalised slowing which is associated with ageing or perhaps a tendency for older adults to exercise greater levels of caution (relative to younger adults), rather than actual differences in search behaviour. We aim to replicate these findings in the present study using an adaptation of the singleton task.

The present study aims to validate a new singleton search paradigm in order to compare younger and older adults' performance. In particular, we design the task so that it will enable (at a later stage) investigation of the effects of stored knowledge on search and how this may be mediated by age (see Chapter 4). Using this new paradigm, we hope to replicate previous findings relating to age in visual search tasks (Plude and Doussard-Roosevelt, 1989) and specifically in a singleton search task (Madden et al., 2004). Thus, we have used a singleton search task whereby both target and singleton distractor could be present or absent in each trial. Furthermore, in order to test whether group differences are dependent on the type of search (feature vs. conjunctive; Plude and Doussard-Roosevelt, 1989), these two conditions were included in two experiments (Experiment 2.1 and 2.2, for simple and complex search, respectively).

Whilst Theeuwes (1991) used a compound search task to investigate the effects of a colour singleton, this has been criticised for apparently making it difficult to determine whether the effects found are due to the outside shape or the target contained within the outside shape (Olivers & Meeter, 2006). As the aim here is to extend the current study to examine the effect of stored knowledge relating to colour associations a compound search has not been used to avoid the issue of whether results are a reflection of the outside shape or the target.

It is assumed that older adults will have slower RTs than younger adults, due to the natural slowing of the central nervous system that is associated with the ageing process (Salthouse, 1996). As participants will have some prior knowledge regarding the target it is expected that top-down guidance will direct attention. As the findings by Madden et al. (2004) indicate that there is no difference between older and younger adults' ability to use top-down guidance, it is also expected that there will be no differences in search type found here between older and younger adults.

2.1 Singleton (distractor) search: Comparing older and younger adults (Experiment 2.1)

The aim of Experiment 2.1 was to control for the colours and conditions selected for use in Experiments 4.1 and 4.2 (Chapter 4). The colours used were chosen for their learned colour associations with items of fruit and vegetables, which typically show strong associations (Tanaka & Presnell, 1999). This experiment also aimed to replicate findings, which demonstrate that irrelevant singletons do not always capture attention and that this is the case across age groups. Experimental hypothesis 1 is that whilst younger adults will have faster RTs than older adults, there will be no other significant differences in performance between younger and older adults on this feature singleton search task. Experimental hypothesis 2 is that it will be possible to ignore irrelevant salient colour singleton distractors (because the target is never the colour singleton here typically there would be a reduced singleton effect (Bacon & Egeth, 1994)).

2.1.1 Method

Participants

Participants were 20 younger adults aged between 18 and 21 years (mean age = 20.15, SD = .93) and 24 older adults aged between 55 and 82 years (mean age = 64.90 years, SD = 7.16). However, four participants were excluded due to high error rates (>10%) leaving 21 older adults and 19 younger adults. The young participants were University of Birmingham undergraduate students who participated to fulfil course requirement. The older adults were recruited from a data base of older adult volunteers held by the Psychology department at the university. These participants were paid a small fee (£6) to compensate for their time. All participants had normal or corrected to normal vision. The experiment was carried out in accordance with the ethical guidelines of the University of Birmingham and the BPS (2009). Each participant provided informed consent before taking part.

Stimuli and Apparatus

Participants sat in a dimly lit room approximately 60 cm from a 17-inch computer screen (so that each cm represented .95 degrees of visual angle) to carry out this search task for a target which was a singleton shape (circle amongst squares), with an additional colour singleton distractor (square). The stimuli consisted of a target circle (3.2cm in diameter), as well as an array of homogeneous distractor squares (3.2cm in width and height). All stimuli were filled with colour, the target (circle) and normal distractors (squares) were presented in either yellow or purple, and the singleton distractor (square) was presented sometimes in red and sometimes in orange, on a white background. The trial conditions were target present or absent, display colour yellow or purple and singleton red, orange, or absent. The display size was four or six items, and the singleton distractor position could be left or right of centre. The normal distractors were always the same colour as the target (yellow or purple), when the target was present, with the exception of the (square) colour singleton distractor (red or orange), when this colour singleton distractor was present. In the singleton distractor present conditions, the singleton distractor was always placed on the opposite side (left or right) to the target. In the four item displays one item was placed in each quadrant of the screen (at 45˚, 135˚, 225˚, and 315˚ angles), whereas with the six item displays the items were placed as if around a clock face at approximately 1 o'clock, 3 o'clock, 5 o'clock, 7 o'clock, 9 o'clock and 11 o'clock (Figure 2.1).

Overall two colour conditions (yellow and purple) were used (participants were not informed of this). The target and colour singleton distractor were sometimes present and sometimes absent. The conditions when the target was present and yellow were: i) target (circle) present, colour yellow, singleton red; ii) target present, colour yellow, singleton orange; iii) target present, colour yellow, singleton absent. These conditions occurred as both a four item display and a six item display, and with the singleton on the right hand side and again on the left hand side. These conditions were then all repeated but with the display colour being purple (which will be the incorrect colour for the target when used for the object colour association stimuli used to examine stored knowledge in chapter 4), and also all occurred with the target absent. As such there were a total of 48 display screens which were each presented 20 times, creating a total of 960 trials. In order to allow for rest periods the trials were divided in to four blocks of 240 trials.

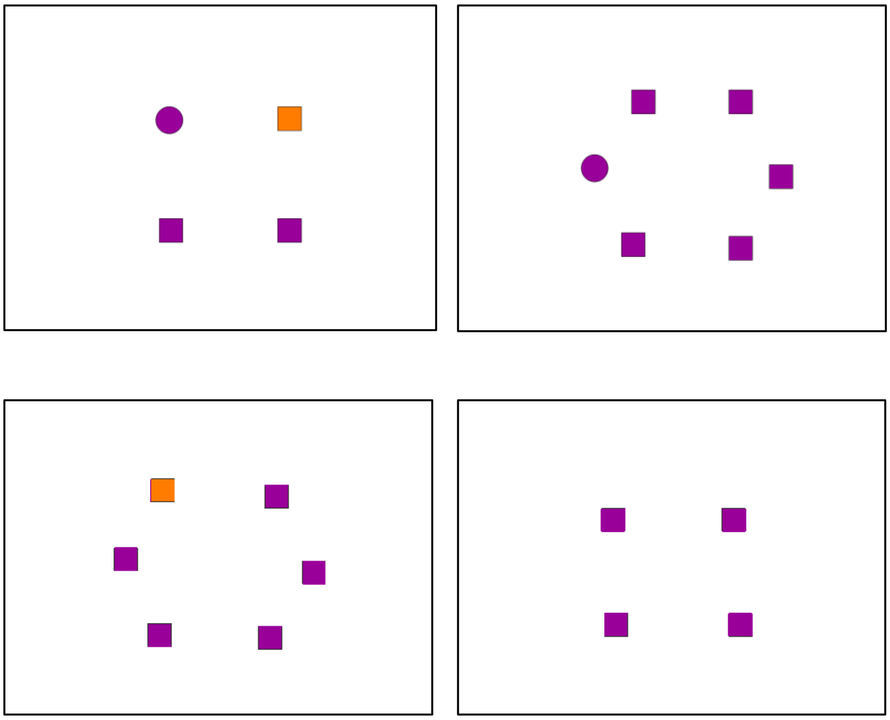


Figure 2.1. Trial conditions: Target present, Singleton present, 4 items (top left); Target present, Singleton absent, 6 items (top right); Target absent, Singleton present, 6 items (bottom left); Target absent, Singleton absent, 4 items (bottom right).

Design and procedure

The target was either present (on half of all trials) or absent (on half of all trials) and within these conditions the singleton distractor was present (red or orange) or absent (each of these singleton conditions occurred equally i.e. on one third of all trials, so that when this design was used in relation to stored knowledge colour associations in Chapter 4 there was an equal chance of the singleton being coloured both correctly and incorrectly, and being absent). Display sizes consisted of 4 or 6 items (equally likely). Age of the participant was a between-subjects factor. Participants completed the experiment in a small quiet room, at their own speed having been advised that they were required to indicate whether a circle was present or absent on each screen whilst responding as quickly and accurately as they could. They were instructed to press the ‘1’ key using their index finger to indicate the presence of the circle and the ‘2’ key using their middle finger for absent. The number pad or the keyboard numbers could be used in order to allow for left and right handedness. On average the experiment took approximately 45 minutes to complete.

The participant initiated the start of the experiment by pressing the space bar to begin. Each display was preceded by a central fixation cross which appeared for 250ms and followed by a blank screen for 500ms. The display of stimuli remained on the screen until a response was recorded. At the end of each block the participant was instructed to have a rest and press the space bar to continue when they were ready. Eprime was programmed to display the stimuli in random order.

2.1.2 Results

Accuracy

The average percentage of errors across all conditions for the younger adults was 3.02%, and for the older adults it was 2.38%. The data indicate there was no speed-accuracy trade-off (Appendix A, Table 1).

Response time

Before analysing response times (RT), trials with extreme RTs (±2.5 SD; or longer than 5000ms) were deleted. This resulted in an average of 2 trials per older participant being excluded; the maximum number of trials excluded for one participant was 14 trials, and the minimum was 0. The trials excluded thus represented 0.2% of trials in the older adult group.

The Reaction Time (RT) data were analysed using a mixed design ANOVA with Target Presence (present vs. absent) Singleton Presence (present vs. absent) and Display Size (4 vs. 6) as within subject factors and Group as the between subjects factor. The effect of Group was significant $F(1, 38) = 25.901$, $p = .0001$. Older adults RTs (M = 1081.29ms, SE = 83.97) were on average slower than younger adults' (M = 461.27ms, SE = 88.27).

Main effects were also revealed for Target Presence ($F(1, 38) = 6.775$, $p = .013$) - where target present trials were responded to quicker than target absent trials (M = 751.83 vs. M = 790.74), Singleton Presence ($F(1, 38) = 7.179$, $p = .011$) – where singleton present trials were responded to slower than singleton absent trials (M = 776.97 vs. M = 765.60), and Display Size ($F(1,38) = 7.487$, $p = .009$) – where responses where overall quicker to the smaller set size (*M* = 760.85 vs. *M* = 781.72). Furthermore, significant interactions were revealed between Target Presence and Singleton Presence $F(1, 38) = 7.044$, $p = .012$ (Figure 2.2), and Singleton Presence and Display Size $F(1, 38) = 8.497$, $p = .006$.

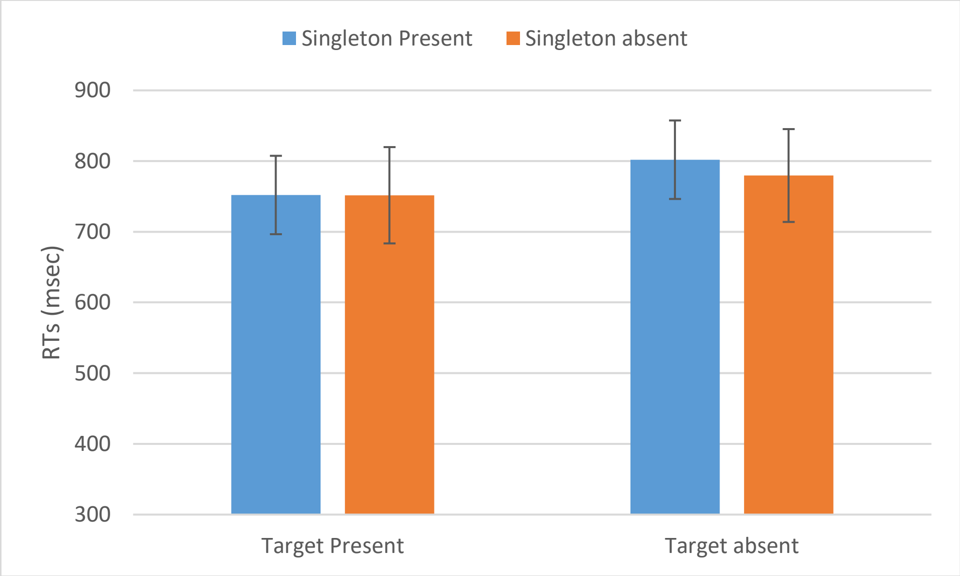


Figure 2.2. Mean RTs for target presence and singleton presence (with standard error bars).

Furthermore, a significant three-way interaction was revealed for Group x Singleton Presence x Display Size, $F(1, 38) = 7.291$, $p = .01$ (Figure 2.3).

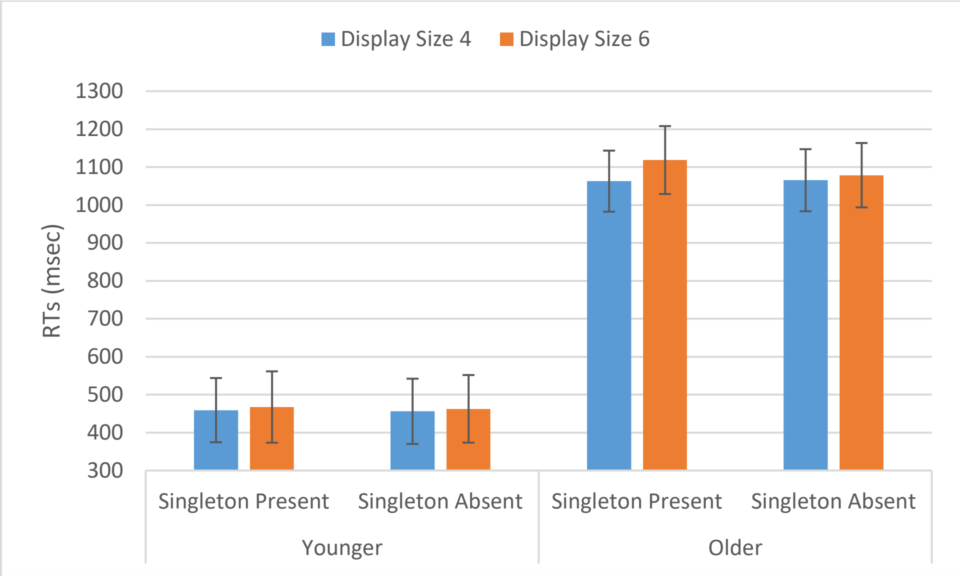


Figure 2.3. Mean RTs for both groups according to Singleton Presence and Display Size (with standard error bars).

This interaction was decomposed by splitting the data according to group and conducting two way ANOVAs with the within factors being Singleton Presence (present vs. absent) and Display Size (4 vs. 6). In respect of the older adults there were significant main effects revealed for both factors: Singleton Presence $F(1, 20) = 5.614$, $p = .028$; and Display Size $F(1, 20) = 5.681$, $p = .027$. In addition the interaction between Singleton Presence and Display Size was also significant $F(1, 20) = 9.094$, $p = .007$ (see Figure 2.3).

For the younger adults significant main effects were revealed for both Singleton Presence $F(1, 18) = 5.805$, $p = .027$; and Display Size $F(1, 18) = 17.215$, $p = .001$, but the interaction between Singleton Presence and Display Size was non-significant $F(1, 18) = <1$, $p = .615$ (see Figure 2.3). RTs were significantly faster when there were 4 items in the display in comparison to 6 items (4 items $M = 459.15$, $SE = 8.11$, 6 items

M = 467.37, *SE* = 8.68), *t*(18) = 4.616, *p* = .0001. RTs were faster when the singleton distractor was present relative to when it was absent (M = 459.29ms and M= 463.26ms). Paired t-tests indicated that for the younger adults there was a significant difference both when the singleton distractor was present and when the singleton distractor was absent, between display size 4 and 6 (singleton present *t*(18) = -4.616, *p* = .0001, singleton absent *t*(18) = -2.312, *p* = .033. However for the older adults Paired t-tests indicated that although there was a significant difference when the singleton distractor was present between display size 4 and 6 (*t*(20) = -3.215, *p* = .004) this was not the case when the singleton distractor was absent *t*(20) = <1.

Brinley Plot

To assess whether the 3-way interaction involving the groups (see Figure 2.3) is attributable to the general slowing associated with ageing or is indicative of a more specific difference in processing a Brinley plot was produced. Brinley plots enable relative comparison of RTs between older and younger adults, in an attempt to account for the variance in performance between the groups. If older adults' RTs are proportionally slower than younger adults the Brinley plot shows a linear relationship between performance in the older and young groups – as can be seen here in Figure 2.4.

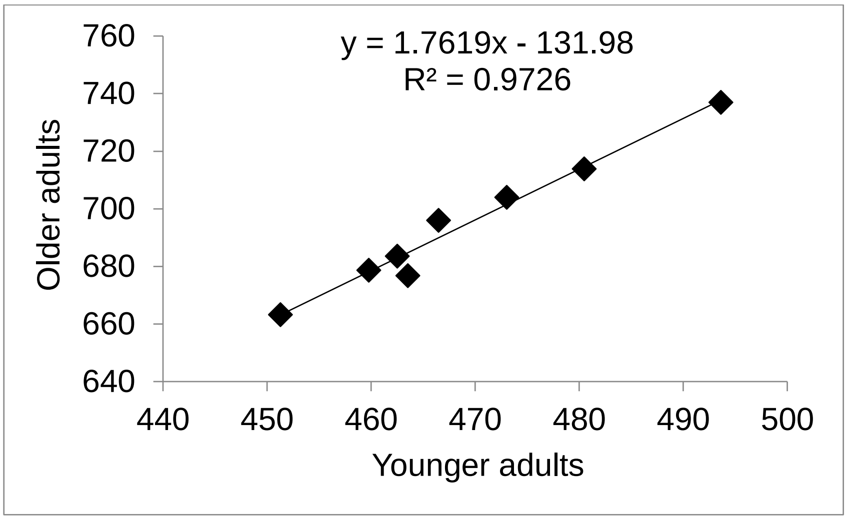


Figure 2.4. Brinley Plot showing RTs to each experimental condition (black diamonds) for each group. The solid line shows the regression line relating to the values for the groups.

Figure 2.4 shows there is a relationship between the mean response times of older and younger adults for each condition, thus suggesting the group differences which are evident in Experiment 2.1 are due to the general slowing which is associated with ageing. The slopes and intercepts evident in Figure 2.4 correspond with results of previous studies (Cerella, 1991; Faust, Balota, Spieler & Ferraro, 1999). Another interpretation of this result may be that as reported by Ratcliff, Spieler and Mckoon (2000) the linear relationship arose from a larger range in the mean RTs for older adults than younger adults. Furthermore, Ratcliff et al. (2000) demonstrated that differences in the pattern of RTs between older and young groups might be due to older adults using more conservative response criteria.

2.1.3 Discussion

The results of Experiment 2.1 demonstrated that as expected, older adults were slower than younger adults, but accuracy rates were equal between the groups. Older adults' RTs and accuracy rates were correlated to explore the possibility that their performance was indicative of a speed-accuracy trade off, however the results suggested no systematic variations in speed and accuracy across the conditions (see additional analysis in Appendix A, Table 1). A significant three-way interaction was revealed for Group x Singleton Presence x Display Size and further investigation of this indicated that the younger adults were always faster when there were 4 items in the display regardless of the singleton distractor being present or absent. However this was not the case for the older adults who demonstrated no significant difference between display size 4 and 6 when the singleton distractor was absent. The Brinley plot demonstrated that although the data indicated there were some differences between groups, the younger adults RTs predicted the older adults RTs well, thus it seems that any differences were due to age related slowing, or possibly older adults using different response criteria/information (e.g. Ratcliff et al., 2000). Therefore these results support experimental hypothesis 1, in that as predicted older adults had slower RTs than younger adults, and any evidence of differences in this search task between the groups seems to be due to the natural slowing associated with the ageing process.

As was expected when the target was present, the presence or absence of the singleton had no significant impact on search for the target, whereas when the target was absent the presence of the singleton hindered search. This seems to suggest that search was not completely determined by bottom-up saliency, and thus supports experimental hypothesis 2 in that it was possible to ignore a salient singleton distractor, but only when the target was present. This finding provides further support for Lamy and Tsal (1999) who also found the presence of a singleton seemed to be causing slower RTs in the target absent condition, despite there being no effect of singleton in the target present condition. The evidence here seems to show that it is possible to ignore an irrelevant but salient distractor when the target is present, but less so when the target is absent. It could thus be argued that this is indicative that the target captures attention rather than salience when the target identity is known and thus it is possible to use top-down processing.

2.2 Singleton (target and distractor) search: Comparing older and younger adults (Experiment 2.2)

The aim of Experiment 2.2 was to investigate whether any differences exist between younger and older adults when the target is sometimes a colour singleton. Here the design is mixed regarding the singleton, as unlike the experiment above (2.1) where the singleton was always a distractor, in the current experiment (2,2) the singleton can either be a target or a distractor. This design differs from Theeuwes' (1991) singleton task in that here the singleton can be one of two colours (as opposed to just one). The present study aims to replicate Madden et al.'s (2004) study and experimental design with regards to the target sometimes being a colour singleton in Experiment 2.2. Futhermore the current study uses two display sizes, which consist of four and six items, this is also a factor which replicates Madden et al.'s (2004) design. Madden et al. (2004) demonstrated that older adults show no difference relative to younger adults in their ability to use top-down guidance (Madden et al., 2004). Therefore, it is predicted that there will be no differences between younger and older adults here. Thus Experimental hypothesis 1 here is that there will be no difference between the groups, other than RT differences which are associated with the ageing process. Experimental hypothesis 2 is that search will be facilitated (due to an increased singleton effect (Theeuwes, 1991)) when the target is a singleton colour relative to non-singleton distractor colour.

2.2.1 Method

Participants

Participants were 20 younger adults aged between 18 and 21 years (mean age = 19.9, SD = .91), and 21 older adults aged between 55 and 82 years (mean age = 66.10, SD = 7.19). However four participants were excluded due to high error rates (>10%) leaving 19 older adults and 18 younger adults. The younger participants were University of Birmingham undergraduate students who participated to fulfil course requirement. The older adults were recruited from a data base of older adult volunteers held by the Psychology department at the university. These participants were paid a small fee (£6) to compensate for their time. All participants had normal or corrected to normal vision. All participants had normal or corrected to normal vision. The experiment was carried out in accordance with the ethical guidelines of the University of Birmingham and the BPS (2009). Each participant provided informed consent before taking part.

Stimuli and Apparatus

All stimuli and apparatus were exactly the same as in Experiment 2.1 with regards to the stimuli size, shapes and colours, and the equipment used. However the trial conditions here were target present (distractor colour i.e. a yellow or purple circle), target absent, or singleton colour target (i.e. a red or orange circle). All non-singleton distractors were coloured yellow or purple. The singleton distractor when present was red or orange, and there was also a singleton distractor absent condition. The display size was four or six items, and the singleton position could be left or right of centre. The non-singleton distractors were always the same colour as the non-singleton target (yellow or purple), when the non-singleton target was present, with the exception of a square singleton (red or orange), when this singleton distractor was present. The singleton colour target was never present together with the singleton distractor (Figure 2.5). In the singleton distractor present conditions, the singleton distractor was always placed on the opposite side (left or right) to the non-singleton target.

Two colour conditions were used (yellow and purple). The target and singleton distractor conditions (for the yellow condition) were: i) target (circle) present (colour yellow), singleton distractor (square) red; ii) target present (colour yellow), singleton distractor orange; iii) target present (colour yellow), singleton absent; iv) target colour singleton present (colour red), singleton distractor absent; v) target colour singleton present (colour orange), singleton distractor absent. In respect of the target being absent the conditions (for colour yellow) were: i) target absent, non-singleton distractors yellow, singleton distractor red; ii) target absent, non-singleton distractors yellow, singleton distractor orange; iii) target absent, non-singleton distractors yellow, singleton distractor absent. These conditions occurred as both a four item display and a six item display, and were then all repeated but with the display colour being purple (the incorrect colour for object colour association stimuli used in Chapter 4).

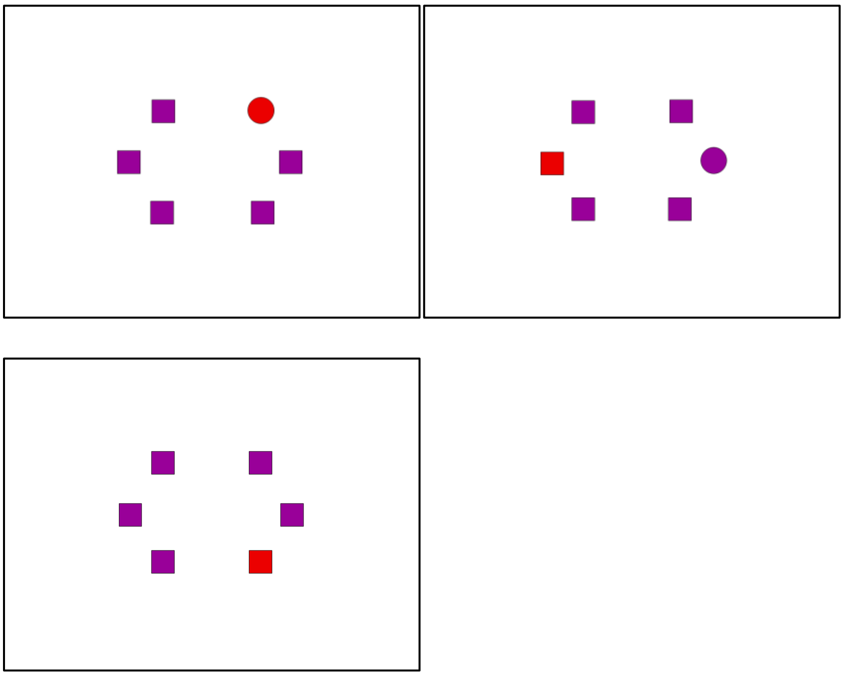


Figure 2.5. Singleton colour target conditions. Target singleton present, six item display, singleton distractor absent (top left). Target present (distractor colour), six item display, singleton distractor present (top right). Target absent, six item display, singleton distractor present (bottom left).

Design and procedure

The target was either present (as a non-singleton, in 12 of the 32 conditions) absent (in 12 of the 32 conditions) or present as a colour singleton (in 8 of the 32 conditions) and when the target was a non-singleton, the singleton distractor was present (on half of all trials), and equally likely to be red or orange, or absent (on half of all trials), with display sizes consisting of 4 or 6 items (equally likely). The target singleton and distractor singleton conditions never occurred simultaneously. Age group served as a between-subjects factor. The procedure for this experiment was exactly as described above for Experiment 2.1, except that there were a total of 32 displays (each of which was presented 20 times, making a total of 640 trials which were split in to four blocks of 160 trials), and on average the experiment took approximately 35 minutes to complete.

2.2.2 Results

Accuracy

The average percentage of errors across all conditions for the younger adults was 3.17%, and for the older adults it was .55%. These figures do not include the participants (2 from each group) who were excluded for relatively high error rate (10% or above). A correlation was carried out to examine the data for evidence of a speed-accuracy trade-off, the results indicated this was not the case (Appendix A, Table 2).

Response time

Response times were calculated by eliminating RTs which were larger than the overall average response time plus 2.5 standard deviations and smaller than the overall average minus 2.5 standard deviations (±2.5 SD).

Singleton Distractor Absent Data

To assess the differences between the types of singleton (target vs. distractor) the data were analysed according to the presence (or absence) of the singleton (Olivers and Humphreys, 2003), this also allowed for fully nested designs. For the distractor singleton absent condition when the target was the colour singleton the data were analysed using ANOVA with Target Colour (colour singleton vs. same colour as distractors) and Display Size (4 vs. 6) as within-subject factors, and Group as the between-subjects factor. The effect of Group was significant $F(1, 35) = 23.694$, $p = .0001$; older adults (M = 660.85ms, SE = 30.129) were slower than younger adults RTs (M = 450.59ms, SE = 30.96). Significant main effects were also revealed for Target Colour ($F(2,35) = 9.860$, $p = .003$), and Display Size ($F(1,35) = 7.004$, $p = .012$). RTs were fastest when the Target was a colour singleton (M = 547.73ms, SE = 27.76) compared to when the target was not a singleton (M = 566.58ms, SE = 21.691). In respect of Display Size RTs were faster when there were 6 items in the display (M = 552.14ms, SE = 21.567) in comparison to 4 items (M = 559.30ms, SE = 21.714). All other results for this ANOVA were non-significant (see Appendix A, Table 3). There was no evidence here for a contrast between the data for younger and older adults.

Singleton Distractor Present Data

For the singleton distractor analysis (where the target was not the colour singleton) a mixed design ANOVA was carried out with Target Present (target as distractor colour only: present vs. absent), Singleton Distractor (present vs. absent), and Display Size (4 vs. 6) as within factors, and Group as the between factor. A significant difference was revealed between the Groups $F(1, 35) = 20.002$, $p = .0001$, with older adults having slower RTs (*M* = 694.10, *SE* = 35.13) in comparison to younger adults (*M* = 468.85, *SE* = 36.09). A significant main effect of Target Presence was revealed $F(1, 35) = 8.875$, $p = .005$, whereby RTs were faster when the target was present (*M* = 567.40ms, *SE* = 21.75) in comparison to absent (*M* = 595.55ms, *SE* = 28.98). In addition a significant main effect of Singleton Distractor was revealed $F(1, 35) = 35.795$, $p = .0001$, with RTs being faster to singleton absent (*M* = 574.28ms, *SE* = 24.62) than present trials (*M* = 588.67ms, *SE* = 25.79).

Furthermore there were several significant interactions: Target Presence and Singleton Distractor $F(1, 35) = 5.286$, $p = .028$; Target Presence and Display Size $F(1, 35) = 22.759$, $p = .0001$; Singleton Distractor and Display Size $F(1, 35) = 5.146$, $p = .030$. All other interactions were non-significant and critically no significant interactions involving Group. Paired t-tests were carried out to explore these significant interactions further. The Target Present x Display Size interaction arose because, when the target was present there were no significant differences in RTs according to display size (4 items *M* = 572.60ms, *SE* = 28.45, 6 items *M* = 568.06, *SE* = 27.64), $t(36) = 1.412$, *n.s*. However when the target was absent RTs were significantly faster when there were 4 items (*M* = 592.32ms, *SE* = 34.67) in comparison to 6 items (*M* = 605.11ms, *SE* = 34.57), $t(36) = 4.735$, $p = .0001$ (see Figure *2.6*).

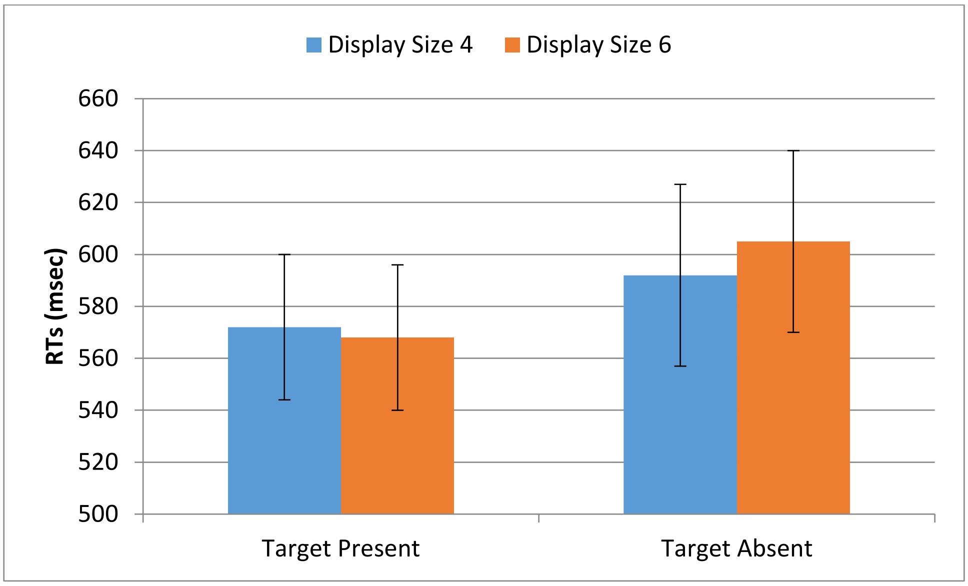


Figure 2.6. RTs according to Target Presence and Display Size (with standard error bars).

The Singleton Distractor x Display Size interaction arose because, when the singleton distractor was present for all participants RTs were faster when there were 4 items in the display (*M* = 586.24ms, *SE* = 31.86) than when there were 6 items (*M* = 597.29, *SE* = 30.98), *t*(36) = 5.126, *p* = .0001; however when the singleton distractor was absent there were no differences in RTs according to display size (4 items *M* = 578.67, *SE* = 30.98, 6 items *M* = 575.88ms, *SE* = 30.17), *t*(36) = .563, *n.s*.

The Target Presence x Singleton Distractor interaction arose because RTs were faster when the singleton was absent (*M* = 587.97ms, *SE* = 33.64) than present (*M* = 609.46ms, *SE* = 35.64), *t*(36) = 5.170, *p* = .0001 when the target was absent; as well as when the target was present, (singleton distractor absent *M* = 566.58ms, *SE* = 27.76, singleton distractor present *M* = 574.07ms, *SE* = 28.36), *t*(36) = 2.095, *p* = .043 (see Figure *2.7*). The difference in RTs was calculated between singleton distractor present and singleton distractor absent when the target was present, and when the target was absent. Paired t-tests indicated that the difference between the singleton distractor being present vs. absent was significantly greater when the target was absent (*M* = 21.49, *SE* = 4.16) relative to when the target was present (*M* = 7.49, *SE* = 3.57), $t(36) = -2.334$, $p = .025$, demonstrating that the presence of a singleton distractor caused greater interference when the target was absent.

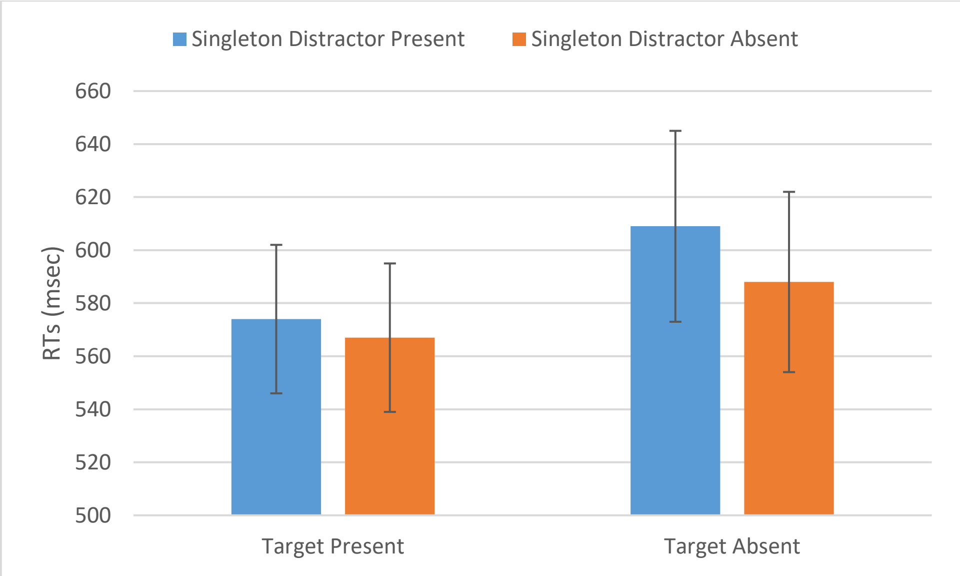


Figure 2.7. RTs to Target Presence (distractor colour only) according to presence of singleton distractor (with standard error bars).

All other results for the mixed design ANOVA can be seen in Appendix A, Table 4.

2.2.3 Discussion

The results of Experiment 2.2 show RTs were faster when the target was a singleton colour in comparison to when the target was the same colour as the distractors, corroborating previous findings (Olivers & Humphreys, 2003; Theeuwes, 1991) where it was also reported that a target singleton was associated with faster RTs. Furthermore, in-line with Madden et al. (2004) no differences were found here between the younger and older adults regarding benefiting from the target being a colour singleton. The results of the current experiment thus support both experimental hypothesis 1 and 2. Also as expected RTs were faster to target present (distractor colour only) than to target absent suggesting as claimed by Chun & Wolfe's (1996) activation threshold hypothesis, search on absent trials is more likely to be extensive and termination of absent trials occurs with greater reluctance. The finding here that RTs were faster to singleton absent than to singleton present trials provides some support for Theeuwes' (1991), as it seems in some circumstances salience and thus bottom-up processing does guide attention. Unlike Experiment 2.1, there were no interactions involving the group factor here. This can be interpreted that, as concluded by Madden et al. (2004) younger adults, like older adults, are equal in their ability to utilize top-down control over search.

2.3. Comparison of Experiment 2.1 and Experiment 2.2

Comparison of the experiments was carried out in order to explore the extent of the differences between the experiments. A mixed design ANOVA was carried out with Target Presence (distractor colour only: present vs. absent), Singleton Distractor

Presence (present vs. absent) and Display Size (4 vs. 6) as within subjects factors, and Experiment and Group as the between subjects factor. A significant difference was revealed between Experiment $F(1,73) = 7.683$, $p = .007$, and between Groups $F(1,73) = 39.461$, $p = .0001$. Significant main effects were revealed for all the factors: Target Presence $F(1,73) = 14.782$, $p = .0001$; Singleton Distractor Presence $F(1,73) = 27.223$, $p = .0001$; Display Size $F(1,73) = 5.632$, $p = .02$.

Experiment Based Interactions

As this was a comparison of experiments only the interactions involving the Experiment between subjects factor are reported here. Significant interactions which were revealed in respect of Experiment can be seen in Table 2.1.

Table 2.1. *Significant interactions involving Experiment*

Effect	F Value	p value
Exp x Gp	8.663	0.004
SDP x Exp x Gp	6.040	0.016
TP x SDP x Exp	6.014	0.017
TP x SDP x Exp x Gp	7.707	0.007
TP x DS x Exp	7.221	0.009
TP x DS x Exp x Gp	7.754	0.007
SDP x DS x Exp	4.144	0.045
SDP x DS x Exp X Gp	7.672	0.007
TP x SDP x DS x Exp	5.020	0.028

Note. SDP = Singleton Distractor Presence; TP = Target Presence; DS = Display Size; Exp = Experiment; Gp = Group.

All the above interactions were subsumed by a five way interaction between all factors: Target Presence x Singleton Distractor Presence x Display Size x Experiment x Group $F(1,73) = 4.686$, $p = .034$. This 5-way interaction arose because the differences between older and younger adults arose on Experiment 2.1 rather than Experiment 2.2 (where the target was sometimes a colour singleton), which is verified by the significant 4-way interaction revealed for Experiment 2.1, but not for Experiment 2.2. On Experiment 2.1, the older adults appeared to be more affected by the presence of a singleton distractor, on target absent trials, and at the larger display size, however the Brinley plot showed these differences were most likely to be due the slowing which is associated with the ageing process (see Figures 2.8 and 2.9).

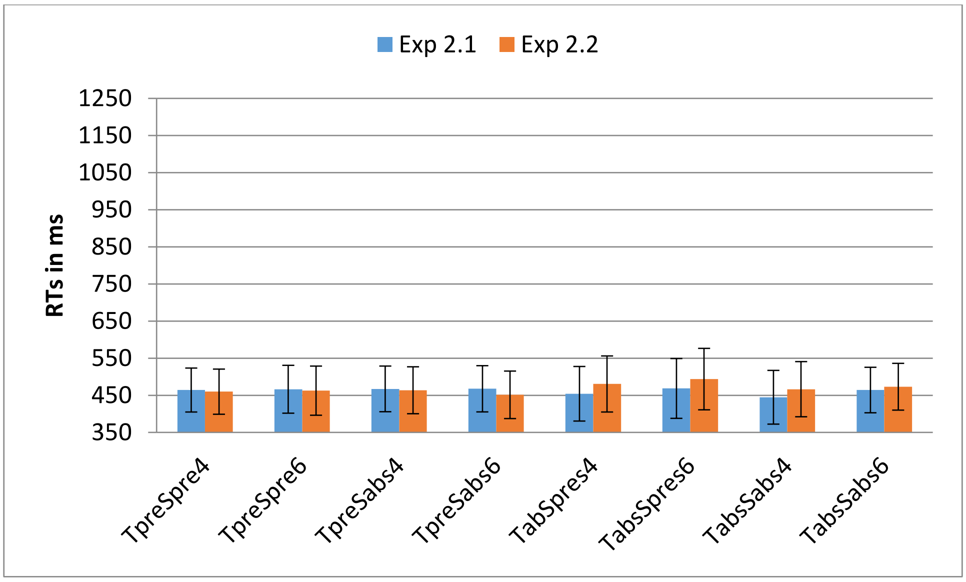


Figure 2.8. Younger adults' RTs according to Target Presence, Singleton Presence and Display Size across experiments (with standard error bars).

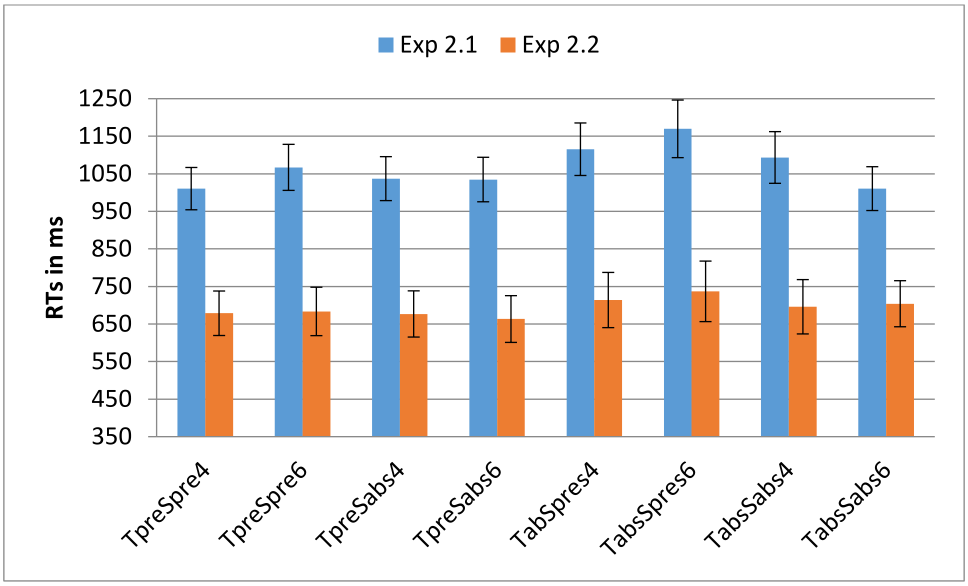


Figure 2.9. Older adults' RTs according to Target Presence, Singleton Presence and Display Size across experiments (with standard error bars).

2.3.1 Discussion

The results of this comparison of groups across experiments indicates that there is a difference in search behaviour across experiments. In relation to Experiment 2.1 the older adults' performance was slower due to the natural slowing associated with ageing, thus indicating a decline in performance, whereas in Experiment 2.2 the performance of the older adults remains equal to the younger adults'. This seems to fit with Madden et al.'s (2004) findings that older adults are equal to younger adults in their ability to use top-down guidance, given that Lamy and Tsal (1999) reported that a more complicated search was more likely to utilize top-down processing.

These results correspond with previous findings that found older adults had improved efficiency for many-conjunction targets (Dennis et al., 2004; Humphrey & Kramer, 1997). For example, Humphrey and Kramer (1997) reported that both older and younger adults benefited equally when an additional feature was available to define the target. Moreover the improvement in search performance was similar for both younger and older adults in a triple-conjunction search relative to a conjunction search.

2.3.2 Conclusion

There were stronger effects of the singleton in Experiment 2.1 than in Experiment 2.2, and interestingly, in Experiment 2.1 the older adults demonstrated age associated slowing which did not arise in Experiment 2.2. The finding that older adults here demonstrated equal ability in Experiment 2.2 runs counter to the usual finding that older adults experience greater impairment as task difficulty increases (Vecchi & Bottini, 2006), but does suggest that as reported by Madden et al. (2004) older adults are equally able to utilize top-down processing as younger adults. Nonetheless, there is no conclusive evidence of particular impairment in bottom-up processing in older adults.

Chapter 3

SINGLETON EFFECT ON SEARCH FOR A TARGET: EYE-TRACKING STUDY

3.0 Introduction

The automatic process of visual selection has been widely studied with the aim of determining whether visual attention is guided in the first instance by bottom-up processing which is posited to be quick and parallel in nature. As was mentioned in Chapter 1, Theeuwes (1991) posits that salient stimuli captures attention in a bottom-up manner and thus it is difficult to ignore an irrelevant singleton distractor. However Lamy and Tsal (1999) demonstrated that it is possible to ignore irrelevant singletons, and that top-down guidance is used in cognitively demanding conditions (see Chapter 1 for details of this study). In addition (as outlined in Chapter 1) Bacon and Egeth (1994) reported that top-down processing is possible during parallel search.

Furthermore eye-movement studies have been used to examine the processes of visual selection. As outlined in Chapter 1 Theeuwes et al. (1998) carried out an eye-movement study using a singleton search task whereby participants searched for a colour singleton target, and during some trials there was an abrupt on-set of an irrelevant item. Results indicated when the irrelevant distractor was present RTs were slowed for identifying the target. According to the authors this was representative of the time taken to inhibit the eye movement to the irrelevant item, and it was concluded that the irrelevant item interfered with goal directed behaviour (top-down processing), thus suggesting that salience (bottom-up processing) over-rides goal-directed behaviour.

However Chen and Zelinsky (2006) also carried out an eye-movement study (details are given in Chapter 1) using a singleton search task to demonstrate that salience does not always capture attention and thus cause interference when searching for a target. In fact, in contrast to Theeuwes et al. (1998) they reported finding no effect of a colour singleton distractor. Also a greater number of initial eye-movements were made to the target, with the colour singleton distractor only being fixated when the target was unknown. Thus it was concluded that when there is previous knowledge of the target top-down processing prevails over bottom-up processing when the two processes are pitted against each other.

Another eye-movement study (van Zoest, Donk & Theeuwes, 2004) using a singleton search task aimed to distinguish between bottom-up, and top-down processing as well as examine the timing of visual selection. In the first of the four experiments carried out for this study participants were asked to move their eyes towards the target (a tilted line) set amongst distractors (vertical lines). On half of all the trials a singleton distractor was present (a line tilted in the opposite direction from the target). The results of this experiment indicated that first eye-movements were shorter when they were directed to the singleton distractor than to the target, however eye-movements were equally likely to be directed to the target and the singleton distractor. Thus it was concluded that early visual selection is salience driven.

The second experiment of this study was the same as the first experiment (3.1) except that in this experiment half of all participants the target was a horizontal line set amongst diagonal right-tilted distractors, with the singleton distractor being a vertical line (present on half of all trials). Whilst for the remaining half the target was a vertical line set amongst right-tilted distractors, here the singleton distractor was a horizontal line (present on half of all trials). The results of this experiment were the same as those in experiment 1 i.e. first eye-movements were shorter when they were directed to the singleton distractor than to the target. Also, even though the target and singleton distractor were maximally dissimilar in this experiment, eye-movements were still equally likely to be directed to the target and the singleton distractor. Furthermore, there were a large number of errors, on which 82% of the eye-movements had been directed at the singleton distractor. It was concluded that it was likely that participants were adopting a singleton selection mode (Bacon & Egeth, 1994) which was causing confusion between the target and singleton distractor.

In the third experiment of this study the target was a titled line, and distractors were vertical lines, the singleton distractor this time however was a red vertical line. The results of this experiment revealed that first eye-movements were shorter in duration to the target when the singleton distractor was absent relative to the target when the singleton distractor was present. Also more eye-movements were directed to the target than the singleton distractor. With regards to incorrect eye-movements i.e. of those which had been directed to the singleton distractor 90% then went to the target. The results also showed that early in the search eye-movements were more often directed to the singleton distractor than the target, with only 37% of eye-movements being correctly made to the target. However this improved with time, and later in the search i.e. in the slowest eye-movements, the eyes were directed to the target rather than the singleton distractor 90% of the time. The authors concluded that as the target and singleton distractors differed in dimension it was easier for top-down processing to guide search; however it did take time for this to become operational.

In the fourth and final experiment of this study van Zoest et al. (2004) looked at the effect of singleton distractor saliency, here the singleton was presented in comparison to the target as less salient, equally salient and more salient. Saliency this time was on the same dimension as the target i.e. orientation. Singleton distractor type was varied between blocks of trials. The results showed in the condition where the singleton distractor was less salient than the target 80% of first eye-movements were incorrectly made to the singleton distractor. Also there was an effect of singleton distractor saliency and first eye-movement latency whereby latencies to the target increased with saliency. Furthermore when looking at the proportion of correct eye-movements in relation to timing according to singleton distractor saliency it was evident that there were significant differences in the early stages of processing but not the later stages. It was concluded that these results provide evidence that most of the time participants could not ignore the irrelevant singleton distractor despite a blocked design being used, suggesting therefore that top-down processing was not able to prevent bottom-up saliency from impacting on performance. However the authors state that the evidence does not support the view that bottom-up processing was always occurring and thus suggest that the two different processes operate on two different time courses.

Donk and van Zoest (2008) also looked at the time course of visual selection, using an eye-movement study (details are given in Chapter 1) to investigate singleton search. Here results corroborated those of van Zoest et al. (2004) by demonstrating that whilst salience drives attention this is only for a short period after the display onset. This was taken to show that salient information is only available for a short period and disappears after a longer period. Thus the authors conclude that, rather than bottom-up and top-down processes competing, bottom-up and top-down processes have different time courses, and suggest the interaction of these two processes in guiding search may be less than is generally assumed.

Moreover Geng and DiQuattro (2010) used an eye-movement study to examine the effect of salience on search for a target, and demonstrated that rather than hinder search the presence of a singleton distractor can facilitate search for a target. In Geng and DiQuattro's (2010) experiment there were three conditions i) The target was present alone, with no distractors; ii) The target was presented together with a non-salient distractor; iii) The target was presented together with a salient distractor. There was no target salient condition and participants were advised of this prior to starting the task. The results showed there were a greater number of first eye movements made to the target on trials with no salient distractor present than on trials where the distractor was salient – indicating that bottom-up capture was still over-riding top-down knowledge. However RTs were fastest when the target was present without the presence of a distractor, and slowest on the trials where there was no salient object present – and both of these were different from trials where the salient distractor was present; RTs here showed that a salient distractor appeared to benefit search in comparison to a non-salient distractor being present. Eye movement data indicated that when the first eye movement was made to the salient singleton there was less likelihood that a second eye movement would be made, unlike when the target was the first object fixated and a second movement was likely to the distractor. In addition there was a speeded rejection of the salient distractor when it had been fixated. These results show that prior knowledge regarding the target enabled efficient search and to a salient distractor being beneficial to the search.

In a further experiment by Geng and DiQuattro (2010) in order to examine whether a non-salient distractor which differs distinctly from the target can also benefit search, the stimuli (target and distractor) were presented in either light blue or pink (of equal luminance), and the target could once again be presented alone; with a distractor of the same colour (counterbalanced between pink and blue); or the target could be presented in a different colour to the distractor (i.e. where the distractor was blue the target would be pink, and vice versa). The results of this experiment showed there was no difference in RTs according to whether the distractor was present in the same colour or different colour from the target. The overall conclusion here was that bottom-up and top-down processing work together during selective attention tasks. The argument put forward is that whilst the salient distractor captures attention (in a bottom-up processing manner), top-down processing ensures that it is rapidly rejected because prior knowledge that this object is not the target guides selection top-down search in a rapid and flexible manner.

The above evidence demonstrates once again that salience alone does not always guide search, and provides some support for Chen and Zelinsky (2006) who also demonstrated that previous knowledge about the target results in top-down processing preventing bottom-up attention capture from hindering search. Thus it seems that whilst salience does lead to attentional capture, the impact on visual search varies seemingly according to the condition of search, and in some circumstances a salient distractor which may in other circumstances hinder search can in fact facilitate search.

This chapter uses the same singleton paradigm used in Chapter 2, however here eye tracking data are collected (from young adults only) in order to extend the findings of the previous chapter (2). In Experiment 3.1 the conditions and stimuli of Experiment 2.1 are used to carry out an eye tracking experiment, and in Experiment 3.2 the conditions and stimuli of Experiment 2.2 are used to carry out an eye tracking experiment. These experiments also served the purpose of being precursors to examining the effects of stored colour knowledge on singleton distraction (Chapter 4), as the colours used here were also employed in the experiments on colour knowledge.

3.1 Singleton (distractor) search: eye-tracking (Experiment 3.1)

To replicate the previous findings (reported in Chapter 2) and provide converging evidence to the RT data collected in Chapter 2 Experiment 2.1 was carried as an eye tracking experiment, using Eprime and Eye-Link ii. All conditions and trial blocks were the same as in Experiment 2.1. The experimental hypothesis here is that the eye-tracking data (from younger adults only) will demonstrate (as was found in Chapter 2) that attention is not captured by an irrelevant singleton distractor when the target is present.

3.1.1 Method

Participants

Participants were 14 (10 females) undergraduate students at the University of Birmingham, aged between 18 years and 22 years (mean age = 19.71, SD = 1.38). All of the participants participated to fulfil course requirement, and had normal or corrected to normal vision. The experiment was carried out in accordance with the ethical guidelines of the University of Birmingham and the BPS (2009). Each participant provided informed consent before taking part.

Stimuli and Apparatus

All stimuli and trial conditions were exactly the same as in Chapter 2 (Experiment 2.1) the stimuli consisted of a target which was a circle and thus a unique shape, set amongst a display of homogeneous distractor squares (see Figure 3.1). The stimuli were presented and controlled using E-Prime software (http://www.pstnet.com/eprime.cfm).

Eye movements were recorded using an Eye-Link ii. The gaze position accuracy was 0.5°, with a sampling rate of 50 Hz. The eye-tracking camera was linked to a separate PC to the one displaying the search stimuli. IViewX (version 1.07.00) software was used to calibrate the camera and collect data. Eye movements were calibrated after each trial.

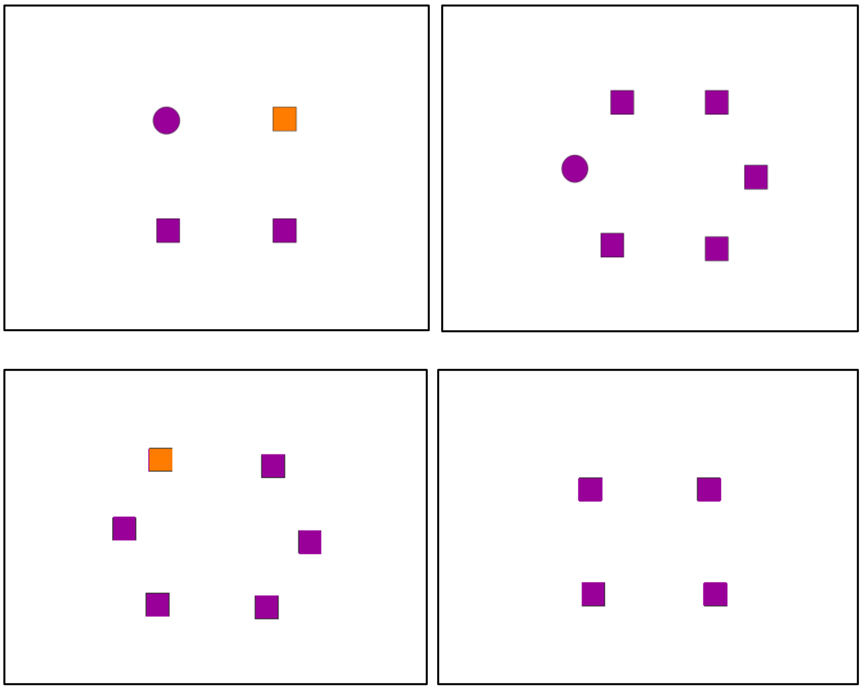


Figure 3.1. Trial conditions: Target present, Singleton distractor present, 4 items (top left); Target present, Singleton distractor absent, 6 items (top right); Target absent, Singleton distractor present, 6 items (bottom left); Target absent, Singleton distractor absent, 4 items (bottom right).

Design and procedure

As in chapter 2 (Experiment 2.1) the target was either present or absent and within these conditions the singleton distractor was present (red or orange) or absent (each of these singleton conditions occurred equally i.e. on one third of all trials), with display sizes consisting of 4 or 6 items. Participants (different from those in chapter 2) completed the experiment in a small quiet, dimly lit room, at their own speed having been advised that they were required to indicate whether a circle (the target) was present or absent on each screen whilst responding as quickly and accurately as they could. Participants were instructed to fixate the central fixation cross until the stimuli appeared when they could move their eyes freely, and to use the keyboard to indicate their response regarding the presence of the target (the circle) on each trial. They were instructed to press the ‘1’ key to indicate the presence (using their index finger) of the circle and the ‘2’ key for absent (using their middle finger), the number pad or the keyboard numbers could be used in order to allow for left and right handedness.

The participant initiated the start of the experiment by pressing the space bar to begin. Each display was preceded by a central fixation cross which appeared for 250ms and was followed by a blank screen for 500ms. The display screen remained until a response was recorded. At the end of each block the participant was instructed to have a rest and press the space bar to continue when they were ready. On average the experiment took approximately 55 minutes to complete.

3.1.2 Results

Accuracy

The average error rate was very low at .2%, indicating no need for further investigation.

Inaccurate trials were disregarded as were fixations detected within 80ms of array onset (see van Zoest, Donk, & Theeuwes, 2004). This resulted in an average of .2 trials per participant being excluded; the maximum number of trials excluded for one participant was 4 trials, and the minimum was 0.

Eye-Movements

As the aim of this experiment was to examine what guides attention, first fixations were analysed (Theeuwes et al., 1998).

As is often the case with eye-movement studies it was the initial eye movements which was of interest here (Chen & Zelinsky, 2006; Geng & DiQuattro, 2010; Theeuwes et al., 1998) thus it is the first fixation frequency data which were analysed in regards of eye-movements in this Chapter. In order to analyse the first fixation data in a fully nested design only the conditions where both the target and the singleton distractor were present were analysed. The first fixation data were analysed using repeated measures ANOVA, the within subject factors were First Fixation (Target, Singleton and Distractor) and Display Size (4 & 6 item). A significant main effect was revealed for First Fixation $F(2,26) = 19.136$, $p = .0001$. Paired *t*-tests revealed that on average there were significantly more First Fixations to the target ($M = 67$, $SE = 10.77$) than to the singleton distractor *t*(13) = 3.419, *p* = .005, *M* = 32, *SE* = 9.97, which in turn were more frequent than first fixations to non-singleton distractors *t*(13) = 2.906, *p* = .012, *M* = 7, *SE* = 1.76. All other results were non-significant (Display Size *F*(1,13) = <1.; First Fixation x Display Size *F*(2,26) = <1.) (see Figure 3.2).

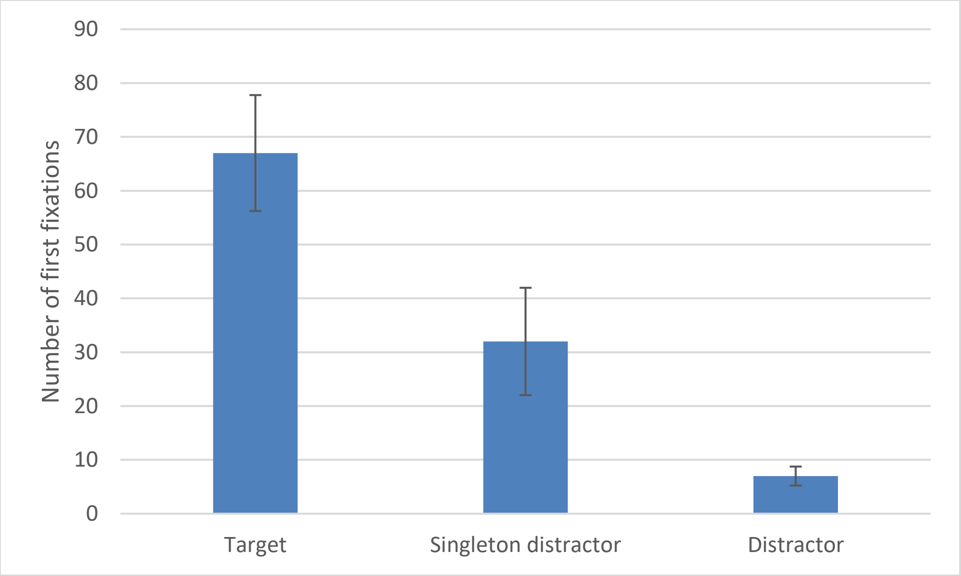


Figure 3.2. Mean number of first fixations according to object type (with standard error bars).

These first fixation numbers are from a total of 320 trials (target and singleton distractor present) and are averaged over all participants. The number of first fixations made by one participant to the target ranged from 17 to 135; for the singleton distractor the range was from 0 to 115; and to the non-singleton distractors the range was from 0 to 20. These results indicate that the target was more likely to capture attention even when a singleton distractor was present. Thus, the finding supports the notion that attention is not necessarily automatically captured by a salient distractor as was suggested by Theeuwes (1991).

Target absent

Another repeated measures ANOVA was carried out to analyse first fixations to the Target absent data with the factors being Item First Fixated (Singleton and Distractor) and Display Size (4 and 6 items). A main effect of Item First Fixated was revealed $F(1,13) = 16.428$, $p = .001$, with more first fixations made to the singleton distractor ($M = 22$, $SE = 4.84$) than to the non-singleton distractors ($M = 6$, $SE = 1.05$), suggesting that when the target was absent salience had captured attention. Here again the number of first fixations represent the average for all participants out of 320 trials (target absent and singleton distractor present). The number of first fixations made by one participant to the singleton distractor ranged from 5 to 110; whereas for the non-singleton distractor the range was from 1 to 28. No other significant findings were revealed (Display Size $F(1,13) = 1.700$, *n.s.*; First Fixation x Display Size $F(1,13) = 1.620$, *n.s.*).

Singleton Distractor absent

The Singleton Distractor absent data were also analysed using a repeated measures ANOVA with the factors being Item First Fixated (Target and Distractor) and Display Size (4 and 6 items). Again there was a main effect of First Fixation $F(1,13) = 25.317$, $p = .0001$, with more first fixations made to the target ($M = 16$, $SE = 2.48$) than the distractors $M = 3$, $SE = .84$. The other results were non-significant (Display Size $F(1,13) = 4.235$, *n.s.*: First Fixation x Display Size $F(1,13) = 3.375$, *n.s.*). The number of first fixations represent the average number for all participants out of 160 trials (target present and singleton distractor absent). The number of first fixations for any one participant made to the target ranged from 9 to 59; whereas to the non-singleton distractor it ranged from 0 to 22.

Duration of Fixation

Duration of fixation average tends to range between 200ms and 500ms (Hoffman, 1998). The results here show the average duration of fixation ranged between 202ms and 359ms, indicating no cause for concern. A repeated measures ANOVA was carried out on the duration of first fixation data in the Target present condition; the factors were First Item Fixated (Target, Singleton and Distractor) and Display Size (4 and 6 items). There was a near significant effect for Item First Fixated $F(2,26) = 3.141$, $p = .085$ (see Figure 3.3). Paired t-tests indicated that there was a significant difference in the duration of fixation when the first item fixated was a target ($M = 338.68$, $SE = 31.83$) relative to a singleton distractor ($M = 264.89$, $SE = 44.67$) $t(13) = 2.816$, $p = .015$; as well as between the duration of fixation when the first item fixated was a target ($M = 338.68$, $SE = 31.83$) relative to a non-singleton distractor ($M = 219.12$, $SE = 36.98$) $t(13)$ 2.195, $p = .047$. The difference between the duration of fixation when the first item fixated was a singleton distractor relative to a non-singleton distractor was non-significant $t(13) = <1$. The effect of display size was non-significant, $F(2,26) = <1$, as was the interaction Item first fixated x Display Size $F(2,26) = 2.640$, $p = .097$.

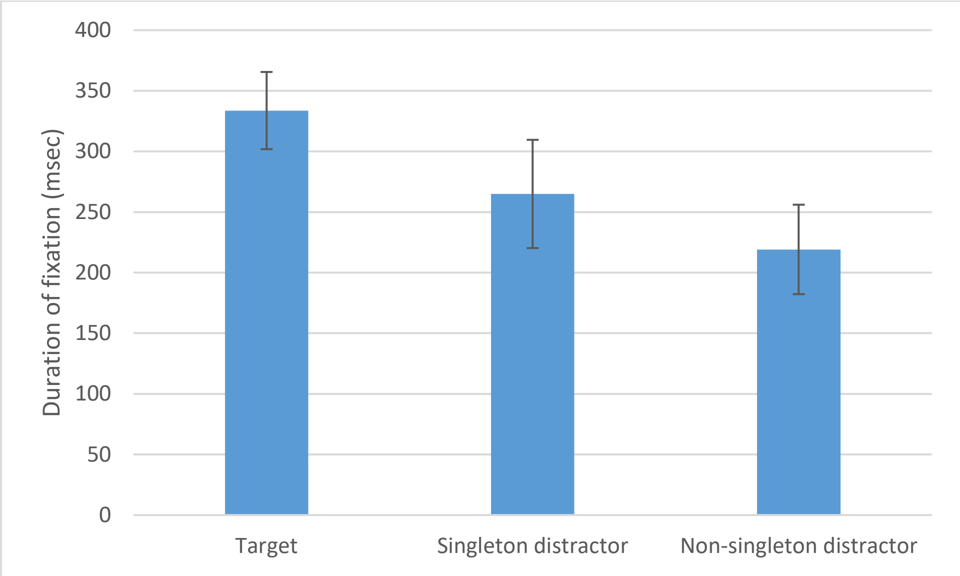


Figure 3.3. Mean duration of fixation to each item type when that item was the first to be fixated (with standard error bars).

Target absent and Singleton absent

A further repeated measures ANOVA was carried out on the duration of first fixation in Target absent conditions. Again, the factors were First Item Fixated (Singleton and Non Singleton Distractors) and Display Size (4 and 6 items). Here too, there were no significant differences (First Item Fixated $F(1,13) = <1$; Display Size $F(1,13) = 1.107$, $p = .312$; First Item Fixated x Display Size $F(1,13) = 1.130$, $p = .307$).

Finally, a repeated measures ANOVA was also carried out to analyse duration of first fixation in the singleton absent conditions with factors being First Item Fixated (Target and Non Singleton Distractors) and Display Size (4 and 6 items). In this case a main effect of First Item Fixated was revealed $F(1,13) = 5.031$, $p = .043$, here fixations were longer on the target than on a non-singleton distractor (M = 340ms, SE = 27.27 vs. M=244ms, SE=35.39.

3.1.3 Discussion

The results of Experiment 3.1 mirror the RT findings in Experiment 2.1, in that when the target was present the effect of a singleton distractor was moderated. In particular, the data show that when the target was present in the display it was the item that was most likely to be fixated. Thus, although the singleton distractor colour was the most salient aspect of the display (Wolfe & Horowitz, 2004) it was not the item that was first fixated the most (c.f., Theeuwes et al. 1998). Nevertheless, a singleton distractor was still more likely to be fixated than a non-singleton distractor (both when targets were present and absent). In addition it was found here that non-singleton distractors were more rapidly rejected, thus demonstrating further that attention is not always captured in a bottom-up manner as suggested by Theeuwes (1991).

It is interesting that when the singleton distractor was absent fewer actual fixations were made, it is possible that attention on these trials was covert and thus the participant indicated the presence of the target during the experiment without having made any eye-movements. It would be interesting for future studies to examine this further.

3.2 Singleton (target and distractor) search: eye-tracking (Experiment 3.2)

This next experiment (3.2) is an eye-tracking version of Experiment 2.2 (Chapter 2), examining the effect of the target sometimes being a colour singleton. The purpose of this was to investigate whether there is an effect of the target being a colour singleton relative to being distractor coloured and thus in terms of colour a non-singleton. The experimental hypothesis is that there will be more first fixations to the target when it is a colour singleton relative to when it is the colour of a non-singleton distractor (as attention will be directed to a target singleton and thus search will be facilitated relative to when it is the same colour as the non-singleton distractors).

To enable further investigation of attention capture in the conditions of Experiment 2.2, the current experiment (3.2) used the conditions of Experiment 2.2 to carry out an eye tracking experiment, using Eprime and Eye-Link ii.

3.2.1 Method

Participants

Participants were 15 (10 females) University of Birmingham undergraduate students who participated to fulfil course requirement. They were aged between 18 years and 28 years old (mean age = 20.93, SD = 2.28), with normal or corrected to normal vision. The experiment was carried out in accordance with the ethical guidelines of the University of Birmingham and the BPS (2009). Each participant provided informed consent before taking part.

Stimuli and Apparatus

The stimuli and conditions were exactly the same as those used in chapter 2 (Experiment 2.2), whereby the target was a circle and was the odd object out, set amongst a display of homogeneous distractor squares, however the target was also sometimes a colour singleton (see Figure 3.4). E-Prime was used to control the stimuli presentation (http://www.pstnet.com/eprime.cfm). Eye movements were recorded using an Eye-Link ii. The gaze position accuracy was 0.5°, with a 50 Hz sampling rate. The eye-tracking camera was linked to a separate PC to the one displaying the search stimuli. IViewX (version 1.07.00) software was used to calibrate the camera and collect data. Eye movements were calibrated after each trial.

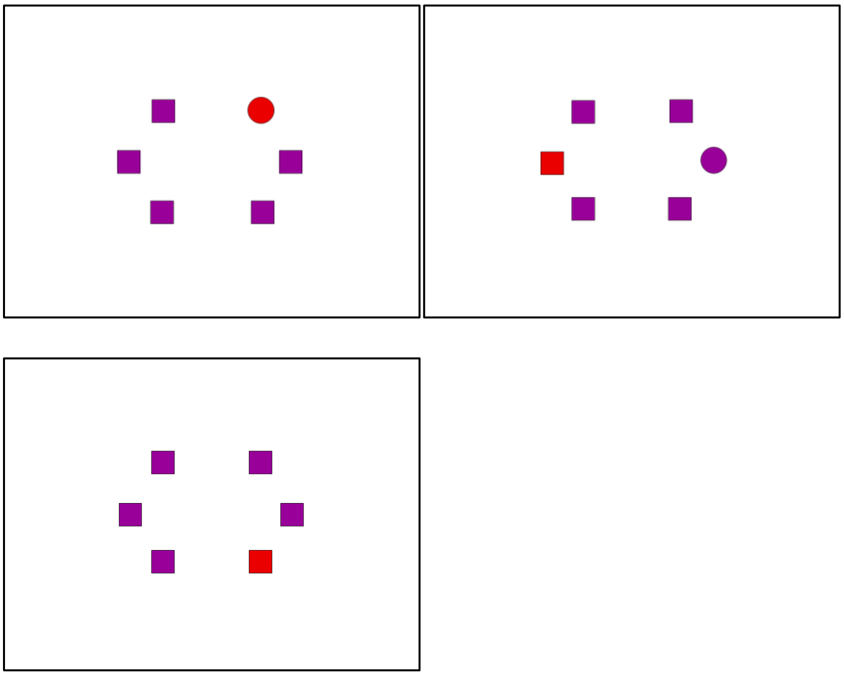


Figure 3.4. Target conditions. Target singleton present, six item display, singleton distractor absent (top left). Target present (distractor colour), six item display, singleton distractor present (top right). Target absent, six item display, singleton distractor present (bottom left).

Design and procedure

As in Chapter 2 (Experiment 2.2) the target was always a shape singleton (circle amongst squares) and when present was either the same colour as the distractors or a colour singleton; in addition there was a target absent condition. When the target was present and the same colour as the distractors, and also when the target was absent, there was a distractor colour singleton condition whereby the singleton was red, orange or absent, however for the target colour singleton condition there was never a distractor singleton present. In addition there were two display sizes (4 and 6).

Participants completed the experiment in a small quiet, dimly lit room, at their own speed. They were advised that they were required to indicate whether a circle (the target) was present or absent on each screen whilst responding as quickly and accurately as they could. Participants were instructed to fixate the central fixation cross until the stimuli appeared when they could move their eyes freely, and to use the keyboard to indicate their response regarding the presence of the target (the circle) on each trial. They were instructed to press the ‘1’ key to indicate the presence (using their index finger) of the circle and the ‘2’ key for absent (using their middle finger), the number pad or the keyboard numbers could be used in order to allow for left and right handedness.

The participant initiated the start of the experiment by pressing the space bar to begin. Each display was preceded by a central fixation cross which appeared for 250ms and was followed by a blank screen for 500ms. The display screen remained until a response was recorded. At the end of each block the participant was instructed to have a rest and press the space bar to continue when they were ready. On average the experiment took approximately 50 minutes to complete.

3.2.2 Results

Accuracy

The average error rate was extremely low at .3% indicating no further error analysis was necessary.

As with Experiment 3.1 inaccurate trials were disregarded as were fixations detected within 80ms of array onset and only first fixations were analysed (see van Zoest, Donk, & Theeuwes, 2004). This resulted in an average of .28 trials per participant being excluded; the maximum number of trials excluded for one participant was 5 trials, and the minimum was 0.

Eye-Movements

As above (in Experiment 3.1) the first fixation frequency data were analysed in regards of eye-movements in this experiment. In order to analyse the first fixation data in a fully nested design only the conditions where the singleton distractor was absent were analysed.

A repeated measures ANOVA was carried out with Target Type (colour singleton or same colour as the distractors), First Fixation (target and distractor) and Display Size (four or six items) as within subject factors. A significant main effect was revealed for Target Type $F(1,14) = 7.728$, $p = .015$ and Item First Fixated $F(1,14) = 35.773$, $p = .0001$. Here the number of first fixations represent the average for all participants out of 240 trials (target present and singleton distractor absent). The number of first fixations made by one participant to the target when it was a singleton ranged from 30 to 152; when the target was distractor colour the number of first fixations ranged from 17 to 105. There was no main effect of Display Size (*F*(1,14) = .507, *n.s.*).

In addition a significant interaction was found for Target Type x First Fixation *F*(1,14) = 50.679, *p* = .0001. When the target was a singleton, more first fixations were made to the target (*M* = 39, SE = 5.29) than distractors (*M* = 2, SE = .52), *t*(14) = 6.688, *p* = .0001. However when the target was the same colour as the distractors more first fixations were made to distractors (*M* = 28, SE = 3.81) than the target (M = 24, SE = 3.59), *t*(14) = -4.678, *p* = .0001. These results provide yet more evidence that salience does capture attention when aligned with the target, as the singleton colour target was more likely to capture attention than the feature target suggesting search benefits from a colour singleton Target.

Target Absent

A further repeated measures ANOVA was carried out to analyse the Target absent data. The factors were First Fixations to Distractor Type (Singleton Distractor and normal Distractor) and Display Size (4 and 6 items). A main effect of First Fixation to Distractor Type was found *F*(1,14) = 25.475, *p* = .001, whereby more first fixations were made to a singleton distractor (*M* = 27) than to a normal Distractor (*M* = 3). Here first fixation numbers represent the average number of first fixations made by all participants out of a total of 160 trials (target absent). In addition there was a significant interaction between First Fixations to Distractor Type x Display Size *F*(1,14) = 27.702, *p* = .0001. Paired *t*-tests demonstrate that on average there were significantly more first fixations made to a normal distractor when there were 4 items in the display (*M* =

5, *SE* = .87) in comparison to 6 items *M* = 2, *SE* = .41, *t*(14) = 6.227, *p* = .0001. However in relation to a singleton distractor there were significantly more first fixations made to the singleton distractor when there were 6 in the display (*M* = 29, SE = 5.12) relative to when there were 4 items (*M* = 24, *SE* = 4.28) (*t*(14) = -3.503, p = .004) (see Figure 3.5).

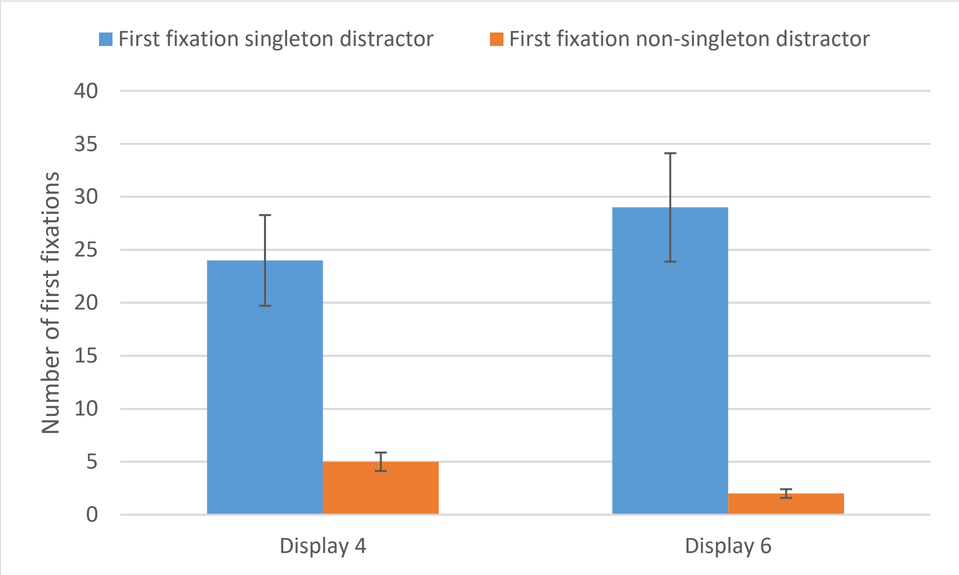


Figure 3.5. Mean number of first fixations to distractor type according to display size when the target was absent and the singleton distractor present (with standard error bars).

Singleton Distractor

Again a repeated measures ANOVA was carried out to examine the singleton distractor data where the target was present (distractor coloured only) and first fixations had been made to the target. The factors were Singleton Presence (present vs. absent) and Display Size (4 and 6 items). A main effect of First fixation was revealed *F*(1,14) = 7.331, *p* = .017, whereby more first fixations were made to the Target (distractor coloured) when the singleton distractor was present *M* = 31, *SE* = 4.73 than when the singleton distractor was absent *M* = 24, *SE* = 3.59. Here first fixation numbers represent the average number of first fixations made to the target by all participants out of a total of 240 trials (target present (distractor colour only)). The was no main effect of Display size $F(1,14) = 3.338$, $p = .089$, and the interaction was also non-significant $F<1$. More fixations being made to the target when the singleton distractor was present suggests that as reported by Geng and DiQuattro (2010) the presence of singleton distractors can facilitate search for a target (see Figure 3.6).

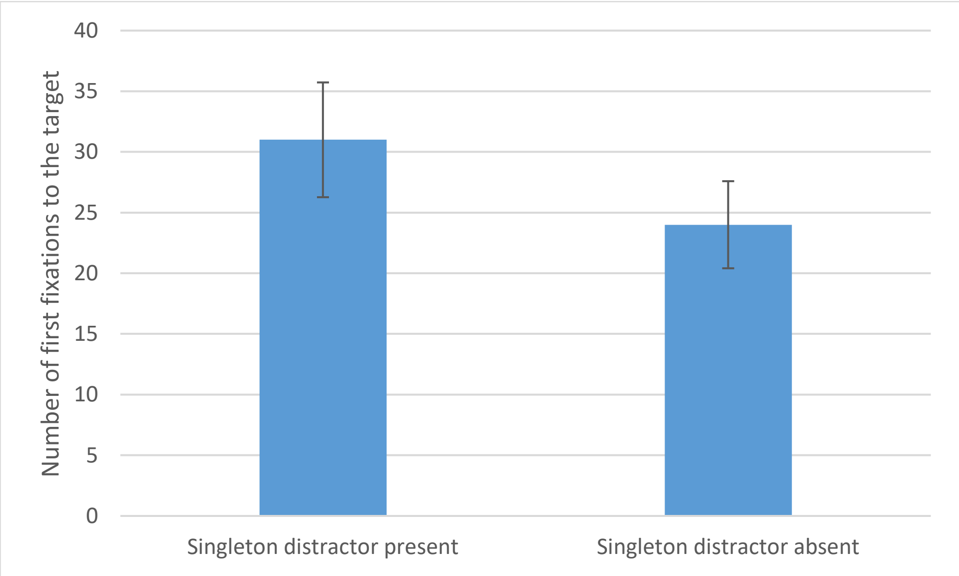


Figure 3.6. Mean number of first fixations to the target according to singleton distractor presence (with standard error bars).

Duration of Fixation

In order to analyse the first fixation data in a fully nested design this analysis examines only the conditions where both the target and the singleton distractor were present were analysed.

A repeated measures ANOVA was carried out to examine whether there were any significant differences in the duration of fixation according to which item within the display was fixated first. The within subject factors were: Target Type (colour singleton or same colour as the distractors); Fixation (target and distractor); and Display Size (four or six items). Significant main effects were revealed for Target Type $F(1,14) = 78.884$, $p = .0001$; First Fixation $F(1,14) = 7.578$, $p = .016$, and Display Size $F(1,14) = 36.917$, $p = .0001$. When the target singleton was the first item fixated the duration of fixation was shorter (M = 273ms) than when the first item fixated was the distractor coloured target (M = 435ms). In relation to the First Fixation main effect, the duration of fixation was shorter when the first item fixated was a distractor (M = 338ms) in comparison to a target (M = 371ms). In relation to the main effect of display size, when there were 4 items in the display the duration of the first fixation was shorter (M = 305ms) than when there were 6 items in the display (M = 403ms).

In addition a two-way interaction was revealed between Target Type x First Fixation $F(1,14) = 10.040$, $p = .007$, indicating when the target was a singleton, the duration of fixation was shorter when the first item fixated was a distractor (M = 234ms, SE = 21.89) in comparison to when the first item fixated was the target (M = 313ms, SE = 14.80), $t(14) = 3.165$, $p = .007$; whereas when the target was the same colour as the distractors the duration of fixation was shorter when the item first fixated was the target (M = 429) in comparison to a distractor (M = 441) ($t(14) = -.1344$, *n.s.*) (see Figure 3.7).

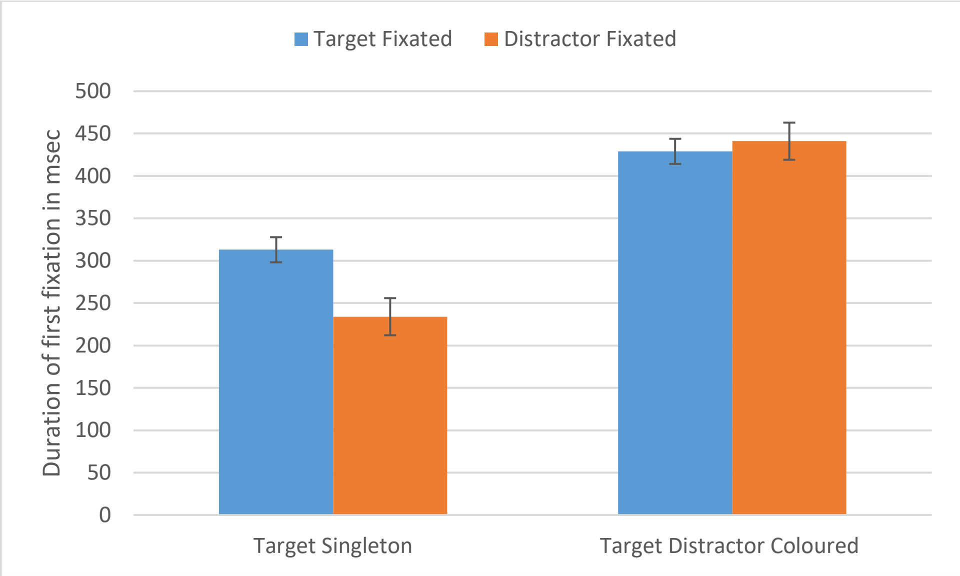


Figure 3.7. Mean duration of first fixation to each item according to Target Type (with standard error bars).

Another two-way interaction was revealed between Target Type and Display Size $F(1,14) = 32.179$, $p = .0001$. Here it seems the duration of fixation is shortest when there are 4 items in the display both when the target is a singleton and when it is the same colour as the distractors. Paired t-tests demonstrate that when the target was the first item fixated both when it was a singleton target and the same colour as the distractors, and there were 4 items in the display duration of fixation was on average significantly shorter (M = 328ms, SE = 12.41) than when there were 6 items (M = 414ms, SE = 18.86), $t(14) = -5.008$, $p = .0001$. These results seem to suggest that duration of fixation is not only related to stimuli salience.

Target Absent

The factors used in this repeated measures ANOVA were Distractor Type as a function of duration of (first) fixation (Singleton Distractor and normal Distractor) and Display Size (4 and 6 items). There were no significant results revealed here (Distractor Type $F(1,14) = .375$, *n.s.*; Display Size ($F(1,14) = 0.15$, *n.s*; Distractor Type x Display Size $F(1,14) = 4.287$, *n.s.*).

Singleton Distractor Present

The factors used here to analyse the target present (distractor colour only) data in this repeated measures ANOVA were Singleton Distractor Presence (present and absent) and Display Size (4 and 6 items). Main effects of Singleton Distractor Presence $F(1,14) = 55.620$, $p = .0001$, and Display Size $F(1,14) = 16.448$, $p = .001$ were revealed. In addition there was a significant interaction between Singleton Distractor Presence x Display Size $F(1,14) = 28.342$, $p = .0001$ (see Figure 3.8). Paired *t*-tests demonstrated that, when the target was present (distractor colour only), the duration of fixation on the target (when it is the first item fixated) was significantly shorter when the singleton distractor was present and there were 6 items in the display (M = 289ms, SE = 15.76) than when there were 4 items (M = 325ms, SE = 13.79), $t(14) = 2.682$, $p = .018$. However when the singleton distractor was absent the duration of fixation to the target (first item fixated) was on average significantly shorter when there were 4 items in the display (M = 339ms, SE = 15.72) than 6 items (M = 519ms, SE = 30.29), $t(14) = -5.041$, $p = .0001$.

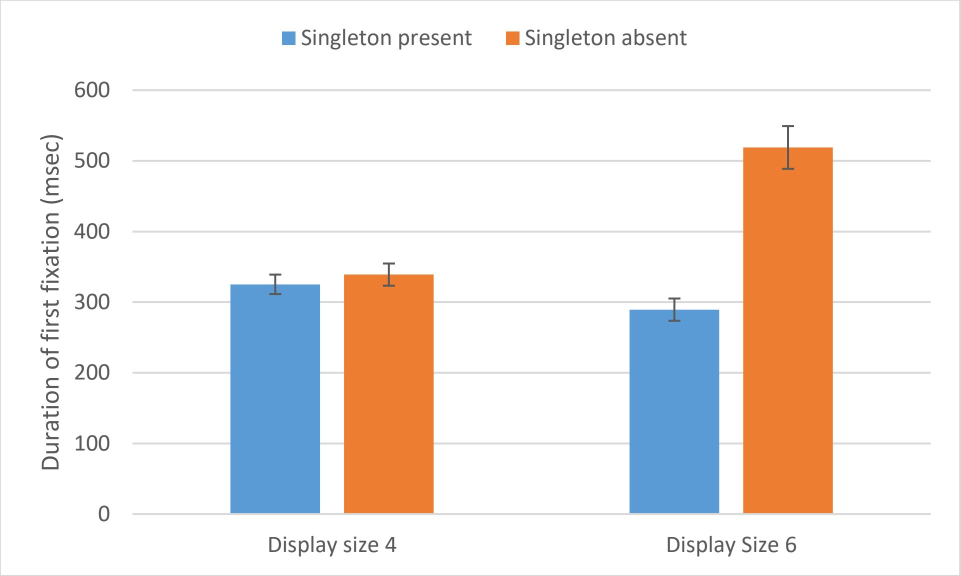


Figure 3.8. Mean duration of first fixation to the Target according to singleton presence and display size (with standard error bars).

3.2.3 Discussion

There has been much debate as to whether or not an irrelevant salient singleton captures attention during parallel search with Theeuwes (1991) positing that it is not possible to ignore such an item in a display because during parallel search attention is captured in a bottom-up manner. However other researchers such as Bacon and Egeth (1994) have argued not only that top-down processing is possible during parallel search, but that it is indeed possible to ignore a salient singleton during parallel search. Furthermore Chen and Zelinsky (2006) reported their eye tracking experiments demonstrated top-down processing can over-ride bottom-up attentional capture when the two are in competition.

The results of Experiment 3.1 show that in terms of first fixations to each type of stimulus whilst singletons (*M* = 32, *SE* = 9.97) attracted more attention than non-singleton distractors (*M* = 7, *SE* = 1.76), it would seem that they did not distract from detecting the target (*M* = 67, *SE* = 10.77). Thus the eye-tracking data as predicted demonstrates that attention is not always captured by an irrelevant singleton distractor as Theeuwes claimed (1991), and thus the experimental hypothesis for this experiment (3.1) is accepted. However the results also suggest the relationship between salience and attentional capture is not straight forward, as it is also shown that when the target was absent the singleton attracted more attention than the non-singleton distractors. Whereas when the singleton was absent the target attracted more attention than the non-singleton distractors. These findings do seem to suggest that salience and thus bottom-up processing does guide attention as posited by Theeuwes (1991), but not in all conditions. In relation to duration of fixation there were few significant findings however it is interesting that the duration of fixation was significantly shorter to a non-singleton distractor (244ms) than to the target (340ms) when the singleton distractor was absent, suggesting when attention was incorrectly deployed this was quickly realised and corrective action taken, as was reported by Geng and DiQuattro (2010).

The results of Experiment 3.2 where the target was sometimes the singleton in terms of colour and shape, there is evidence to suggest that the effect of a singleton may be moderated by experimental conditions, in that there were more first fixations to the target (distractor coloured) when the singleton distractor was present. This finding is in line with Chen and Zelinsky's (2006) finding that a greater number of initial eye-movements were made to the target, and their conclusion was that when there is previous knowledge of the target top-down processing prevails over bottom-up processing. Furthermore the results of Experiment 3.2 whereby when the target was a singleton more first fixations where made to the target than distractors, whereas when the target was distractor coloured more first fixations were made to the distractors, indicate as predicted by the hypothesis that there was an effect of the target being a colour singleton. In addition it was once again found that there was a singleton distractor effect when the target was absent.

These results to some extent, provide support for Theeuwes (1991) e.g. when the target is a singleton, and when the target is absent and then there is a singleton distractor effect, as here salience is capturing attention. However where these results demonstrate that a singleton distractor facilitates target identification it seems that salience does not always capture attention and so hinders search for a target, thus it is not the case that parallel search is, in every condition, a bottom-up process. Therefore these results further corroborate Bacon and Egeth's (1994) findings that show it is possible to ignore a salient singleton during parallel search if the feature search mode is employed.

It is interesting that the error rates in the eye tracking experiments were distinctly lower than in the behavioural versions of the same experiments (Experiments 2.1 and 2.2 in Chapter 2). This of course could be a result of demand characteristics which may be enhanced by the presence of cameras or the close proximity and interactions involved in the researcher setting the participant up for such an experiment. It is difficult to see how this could be avoided but might be worth considering when conducting future eye tracking experiments.

3.3 Conclusion

Taken together, there can be no doubt that the present results indicate the presence of a singleton impacts on search for a target, whereby the presence of a singleton distractor captures attention (as reported by Theeuwes, 1991) and thus impacts on the item first fixated when the target is absent. However when the target is present the evidence here demonstrates that it is possible to ignore an irrelevant salient singleton during parallel search. In fact these results seem to provide support for Bacon and Egeth's (1994) claim that top-down processing is possible during parallel search, and perhaps even that as posited by Chen and Zelinsky's (2006) that parallel search is guided using a combination of bottom-up and top-down processes with different combinations being used in different situations. Moreover support is also found here for Geng and DiQuattro's (2010) findings that in some conditions the presence of a singleton distractor can facilitate detection of a target.

CHAPTER 4

THE EFFECT OF STORED KNOWLEDGE AND STRONG COLOUR ASSOCIATIONS ON SINGLETON SEARCH: A COMPARISON BETWEEN OLDER AND YOUNGER ADULTS

4.0 Introduction

This chapter aims to investigate whether younger and older adults are differentially impacted by stored knowledge and strong colour associations of an object during a singleton search task. This is deemed to be of interest because whilst older adults are less able to ignore irrelevant distractors (Pratt & Bellomo, 2009) they nonetheless seem to benefit from stored knowledge (Badham & Maylor, 2015; McGillivray & Castel, 2010). Olivers et al. (2011) demonstrated that objects activated by working memory i.e. those we are familiar with and thus have stored knowledge of, work as an attentional template and thus have a direct impact on our attentional set. Bacon and Egeth (1994) reported that attentional set determines whether an irrelevant singleton captures attention, thus stored knowledge may impact on a singleton search task.

As mentioned above, evidence suggests that older adults may gain particular benefit from stored knowledge on some tasks. For example, McGillivray and Castel (2010) carried out an associative memory task which compared younger and older adults' ability to correctly recall ages of unfamiliar faces. All participants were required to carry out two tasks, the order of which were counterbalanced between participants, so that half of the participants were asked to first study the faces they were presented with and were subsequently informed of the age i.e. they simply read the age of the face being shown. Whilst the other half of participants were asked to study the faces presented and subsequently guess i.e. they were asked to generate an age for the face being shown, before then being shown the correct age. All participants were later given a cued-recall test whereby they were asked to recall the age of the face shown.

Results indicated that whilst older adults correctly recalled fewer ages overall for the faces presented relative to younger adults, older adults were able to recall the age information for the faces equally as well as the younger adults. However, although older adults demonstrated greater difficulty in correctly recalling specific age-face associations, this deficit was reduced by using their prior knowledge i.e. older adults benefitted more relative to younger adults from first guessing the age correctly when later recalling the age of the face.

Furthermore Badham and Maylor (2015) examined the impact of prior knowledge on stimuli identification where stimuli could be congruent or incongruent in order to examine whether prior knowledge would benefit older adults' associative memory to a greater extent than younger adults'. The task involved participants associating two very famous names with a variety of non-famous faces. The non-famous faces differed in similarity levels to the famous people whose names were being used, with two of the non-famous faces being particularly similar to the two famous people whose names were being used. The non-famous faces were presented together with the famous names, and participants were instructed to try to remember which of the famous names was presented with which (of the non-famous) faces. Following this, participants were asked to answer a simple mathematical sum, and were then shown the non-famous faces again together with both famous names, and were given the task of indicating which of the (famous) names had originally been presented with each of the non-famous faces. Congruent and incongruent responses were analysed i.e. correctly remembering that the famous name was presented initially with the non-famous face which was highly similar to the correct famous person would be categorised as congruent; whereas remembering that the famous name was initially presented with the non-famous face which was highly similar to the incorrect (other) famous name was categorised as incongruent. Results indicated that older adults relative to younger adults demonstrated a greater difference in accuracy between congruent and incongruent. Badham and Maylor (2015) reported that the results show older adults relative to younger adults can better remember stimuli which has greater congruency with prior knowledge in comparison to stimuli which is incongruent with prior knowledge.

Whilst both the McGillivray and Castel (2010) and the Badham and Maylor (2015) studies were used to examine stored knowledge in terms of memory in older adults, it seems that as stored knowledge can influence attentional set (Olivers et al., 2011), and attentional set can determine whether a salient distractor captures attention (Bacon and Egeth, 1994), it is possible that stored knowledge associations may influence older adults' performance to a greater extent than younger adults on a singleton search task where stimuli have strong colour associations and this stored knowledge associations. Examining whether there are any differences between younger and older adults here will provide further understanding of how older adults' visual search performance may be effected in real life situations, which in turn could enable development of methods to ameliorate any deficits, or control for differences.

Search efficiency has been shown to be affected by a number of stimulus properties. In particular it has been demonstrated that stored knowledge can impact on search efficiency, for example Belke et al. (2008) reported distractors in the same semantic category as the target influence search, i.e. RTs were slower when a distractor which was categorically related to the target was present relative to when such a distractor was absent, for example where the target was a bird and the distractor was a fish (both are animals). Thus demonstrating not only that stored associations influence search but also that this type of top-down guidance operates in a parallel manner. It has also been reported that when targets have a strong colour association search is facilitated when the target is correctly coloured relative to when it is incorrectly coloured, and that search for the target is further facilitated when the target is correctly coloured but the distractors incorrectly coloured. For instance, Rappaport et al. (2013) used a search task involving colour manipulation of the target i.e. a corn (presented in yellow for the correctly coloured condition, and in orange and purple for the incorrectly coloured conditions). Distractor items consisted of carrots, aubergines and lemons which were also presented as correctly and incorrectly coloured. In experiment 1 all items in the display were presented as correctly coloured or incorrectly coloured simultaneously. Results of this experiment indicated that search for a correctly coloured target was faster than for an incorrectly coloured target. In a further experiment by Rappaport et al. (2013) correctly and incorrectly coloured targets and distractors were randomly assigned, so that both correctly and incorrectly coloured targets were presented with correctly coloured distractors in half of the trials and with incorrectly coloured distractors in the other half. Results of this experiment revealed once again that RTs were faster when the target was correctly coloured, but also that search was more efficient when the target was correctly coloured and the distractors were incorrectly coloured relative to when the distractors were correctly coloured.

The critical role of colour association was also demonstrated in a recent study by Wildegger et al. (2015) using a similar search task, but which manipulated the way in which the colour and shape were presented – the object could appear in the colour typically associated with that object on the surface or, on the local background of the objects. When the colour was on the background the actual object would be presented as coloured grey. Results revealed search was more efficient when the target was presented as correctly coloured, and with the colour on the surface relative to the background. This benefit held even when the target was less likely to appear, and regardless of display size and exposure duration. This finding suggests that it is the actual colour of the target which facilitates its identification rather than display colour making search for such a target efficient. In addition Anderson and Humphreys (2015) carried out a similar search task with eye-tracking and found that more first fixations were made to the target when it was presented as correctly coloured (compared to incorrectly coloured). Moreover duration of first fixation was shorter when the target was incorrectly coloured relative to correctly coloured, which is posited as indicating that correctness of colour helps to guide attention across trial blocks. The authors conclude the data indicate effects of both bottom-up and top-down guidance of attention to correctly coloured targets. The effects of bottom-up guidance are reported as being evident in the bias of attention to a target in its familiar colour, and the effects of top-down guidance (as indicated by priming) are reported as being evident in the increased top-down weighting to the familiar target colour over trials.

When considering older adults' performance in relation to stored knowledge, an interesting finding in the ageing literature points to intact crystallised intelligence (fact related knowledge) in ageing (Horn & Cattell, 1967). For instance, Maylor (1994) compared older adults' performance to younger adults' in answering general knowledge, and specialised questions of previous contestants from the television quiz show 'Mastermind'. On this quiz show, contestants are required to answer as many questions as they can in a timed condition, the questions are based on general knowledge and on a chosen specialist subject. The results of this investigation demonstrated that, whilst there was no difference in performance on the specialised question, on the general knowledge questions older adults out-performed younger adults. Maylor (1994) suggested this could be due to older adults' having superior levels of crystallised intelligence relative to the younger adults. Therefore whilst older adults may have difficulty ignoring irrelevant information (Hasher, Zacks & May, 1999; Pratt & Bellomo, 2009) and may exhibit decline in executive control (Kramer, Hahn & Gopher, 1999), crystallised intelligence remains relatively in-tact and may be utilised to offset the relative declines. This would suggest that declines in fluid intelligence (Salthouse, 1985) and executive control (Kramer et al., 1999) may be overcome if reliance on stored knowledge and its retrieval plays a role in a task.

Taken together, the evidence above and the findings of Madden et al. (2004) and Christ et al. (2008) (see Chapter 1 for study details) suggests performance difference based on age will be diminished when the task requires identification of a correctly coloured target corresponding with participants' prior knowledge (and which has strong colour associations (Tanaka & Presnell, 1999)). However when the target is incorrectly coloured, and therefore incongruent with stored knowledge representations, age effects may re-emerge. In the context of a singleton search task, when the target is incongruent with stored knowledge it is likely top-down processing will be reduced for the target and thus there could be a greater effect of correctly coloured singleton distractor for the older adults who are likely to be more influenced by the correctness of the singleton distractor resulting in the correctly coloured singleton capturing attention. Therefore findings of these current experiments will demonstrate whether an object which is correctly coloured is easier to identify, and in terms of ageing they will inform us whether older adults are equal to younger adults in their ability to use top-down processing to identify a correctly coloured target of which they have prior knowledge. In addition they will also demonstrate that older adults relative to younger adults are more hindered by targets being presented as incongruent to their stored knowledge, which in turn results in greater disruption by an irrelevant singleton distractor which is presented as correctly coloured.

Given the evidence outlined above the experimental hypothesis for Experiment 4.1 (where the target and is always incorrectly coloured) is: older adults will demonstrate a greater level of interference from a correctly coloured singleton distractor relative to younger adults. For Experiment 4.2 (where the target could be correctly or incorrectly coloured) the experimental hypotheses are:

1. Search will be more efficient when the target is correctly coloured relative to incorrectly coloured irrespective of age.
2. Older adults will demonstrate search for a correctly coloured target to be less hindered by a correctly coloured singleton distractor than search for an incorrectly coloured target.
3. As was reported by Rappaport et al. (2013) for the younger adults search for the correctly coloured target will be facilitated when the singleton distractor is incorrectly coloured.

4.1 Singleton search, stored knowledge and colour association (incorrectly coloured target): A comparison between older and younger adults (Experiment 4.1).

4.1.1 Method

Participants

Participants were 18 (11 females) younger adult participants aged between 18 and 27 years (mean age = 22.02, SD = 2.65) and 20 (12 females) older adults aged between 55 and 80 years old (mean age = 66.3, SD = 4.34). The young participants were University of Birmingham undergraduate students who participated to fulfil course requirement. The older adults were recruited from a data base of older adult volunteers held by the Psychology department at the University of Birmingham. These participants were paid a small fee (£6) to compensate for their time. A prerequisite to participation in this study was that it was necessary to be in good health (self-assessed), and to have normal or corrected to normal vision with no colour blindness. The experiment was carried out in accordance with the ethical guidelines of the University of Birmingham and the BPS (2009). Each participant provided informed consent before taking part.

Stimuli and Apparatus

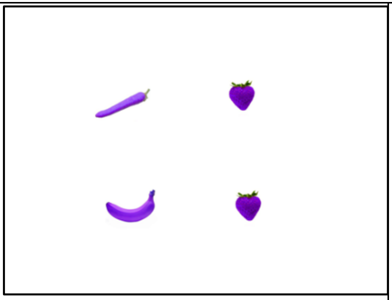
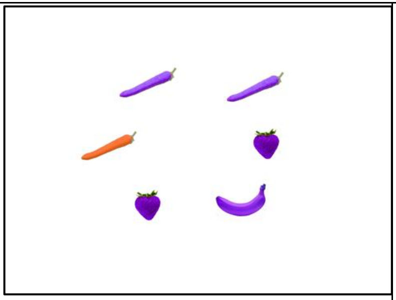
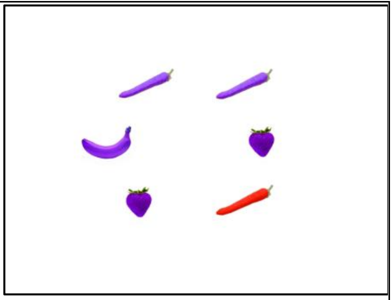
		
Target present and incorrectly coloured, singleton distractor absent, display size 4	Target present and incorrectly coloured, singleton distractor present and correctly coloured (carrot = orange), display size 6	Target present and incorrectly coloured, singleton distractor present and incorrectly coloured (carrot = red), display size 6.

Figure 4.1. Trial conditions showing all three singleton distractor conditions when the target is present.

Participants sat in a dimly lit room approximately 60 cm from a 17-inch computer screen (so that each cm represented .95 degrees of visual angle). The stimuli consisted of a target which was a banana (3cm x 4.2cm) and was the odd object out, set amongst a display of distractor items which consisted of strawberries (3.3cm x 3.4cm) and carrots (1cm x 4.2cm). All stimuli were filled with colour, the target (banana) and normal distractors (strawberries and carrots) were presented in purple, and the singleton distractor (strawberry or carrot) was presented on one third of the trials (160) in red (correct for the strawberry and incorrect for the carrot) and on one third of the trials (160) in orange (incorrect for the strawberry and correct for the carrot), on a white background. On the remaining one third of trials the singleton distractor was absent. The banana and strawberries were presented as standing upright, whereas the carrots were presented at an angle of 45 degrees with the top in the air. The trial conditions were (1) target present and incorrectly coloured (purple); (2) target absent and distractors coloured purple. Thus the target and the distractors were all always incorrectly coloured. In respect of the singleton distractor, the conditions were: (1) correctly coloured (red) strawberry; (2) an incorrectly coloured (orange) strawberry; (3) a correctly coloured (orange) carrot; (4) an incorrectly coloured (red) carrot. There were two display sizes: four and six. In the four item displays one item was placed in each quadrant of the screen (at 45˚, 135˚, 225˚, and 315˚ angles), whereas with the six item displays the items were placed as if around a clock face at approximately 1 o'clock, 3 o'clock, 5 o'clock, 7 o'clock, 9 o'clock and 11 o'clock (see Figure 4.1). There were a total of 24 display configurations which were each presented 20 times, creating a total of 480 trials. In order to allow for rest periods, the trials were divided in to four blocks of 120 trials.

Design and procedure

The incorrectly coloured (purple) target was either present (on half of all trials) or absent (on half of all trials) and within these conditions the singleton distractor was: present and correctly coloured red strawberry (on one sixth of all trials i.e. 80) or orange carrot (on one sixth of all trials i.e. 80)); present and incorrectly coloured orange strawberry (on one sixth of all trials i.e. 80) or red carrot (on one sixth of all trials i.e. 80)), or absent (each of these singleton conditions occurred equally i.e. on one third of all trials). Arrays consisted of 4 items of stimuli on half of all trials or 6 items of stimuli (half of all trials). Age of the participant was a between-subjects factor. Participants completed the experiment at their own speed having been advised that they were required to indicate whether a banana was present or absent on each screen whilst responding as quickly and accurately as they could. They were instructed to press the ‘1’ key using their index finger to indicate the presence of the banana and the ‘2’ key using their middle finger for absent. The number pad or the keyboard numbers could be used in order to allow for left and right handedness. On average the experiment took approximately 25 minutes to complete.

The participant initiated the start of the experiment by pressing the space bar to begin. Each display was preceded by a central fixation cross which appeared for 250ms and followed by a blank screen for 500ms (see Figure 4.2). The display of stimuli remained on the screen until a response was recorded. At the end of each block the participant was instructed to have a rest and press the space bar to continue when they were ready. Eprime was programmed to display the stimuli in random order.

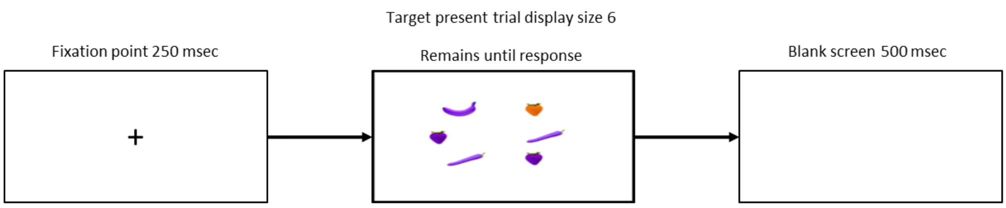


Figure 4.2. Trial sequence

4.1.2 Results

Accuracy

The average error rate for younger adults was 2.4%, and the average error rate for older adults was 1.3%. As the error rates were low no further analysis was carried out. There were no exclusions of participants due to high error rates.

Response time

Before analysing response times (RTs), trials with extreme RTs (±2.5 SD) were deleted. This resulted in an average of 1 trial per participant being excluded; the maximum number of trials excluded for one participant was 7 trials, and the minimum was 0. The trials excluded for exceeding ±2.5 SD thus represented 0.1% of trials.

The RT data were examined first by analysing trials where the singleton distractor was absent and then separately analysing trials where the singleton distractor was present (to examine whether there was an effect of the singleton distractor being the correct colour) as opposed to simply comparing singleton present (as both correctly and incorrectly coloured) to singleton absent in a fully nested design.

Singleton distractor absent

Here the data were analysed using a mixed design ANOVA with Target Presence (present vs. absent) and Display Size (4 vs. 6) as within factors and Group as the between subjects factor (see Table 4.1. for results of ANOVA, and Table 4.2. for Means and Standard Deviations).

Table 4.1. *Results of ANOVA for singleton distractor absent Experiment 4.1*.

	F(1,36)	*p*
Group	33.46	0.0001
Target Presence	70.184	0.0001
Target Presence x Group	13.42	0.001
Display Size	28.658	0.0001
Display Size x Group	<1	0.812
Target Presence x Display Size	9.151	0.005
Target Presence x Display Size x Group	1.538	0.223

Table 4.2. *Means (and SD) for singleton distractor absent for Experiment 4.1*.

	Target Present		Target Absent	
	4 items	6 items	4 items	6 items
Younger adults	527.45 (79.58)	552.87 (121.66)	555.94 (78.96)	606.44 (117.50)
Older adults	697.84 (112.39)	709.40 (109.31)	772.67 (113.48)	844.15 (143.24)

The significant difference between groups revealed that older adults' RTs were slower (*M* = 756.01ms, *SE* = 23.24) than younger adults (*M* = 560.68ms, *SE* = 24.50). The main effect of Target Presence indicated RTs were faster to target present (*M* = 621.49ms, *SE* = 16.80) relative to target absent (*M* = 694.80ms, *SE* = 18.05). The main effect of Display Size indicated once again RTs were faster when there were 4 items in the display (*M* = 638.48ms, *SE* = 15.03) relative to 6 (*M* = 678.21ms, *SE* = 19.28).

Furthermore the significant two way interaction between Target Presence and Group indicated RTs for both groups were faster to target present (younger adults *M* = 540.16ms, *SE* = 24.38; older adults *M* = 703.62ms, *SE* = 23.12) than to target absent (younger adults *M* = 581.19ms, *SE* = 26.19: older adults *M* = 808.41ms, *SE* = 24.85). However, the advantage for present trials was significantly bigger ($t(29.83) = -3.663$, $p = .001$) for the older participants (*M* = 104.79, *SE* = 14.68) than for the younger participants (*M* = 41.98, *SE* = 8.37; see Figure 4.3).

The significant interaction between Target Presence and Display Size indicated the set size effect was larger for absent relative to present trials: Target present: 4 items *M* = 612.64ms, *SE* = 15.96; 6 items *M* = 631.13ms, *SE* = 18.73, $t(37) = -2.021$, $p = .051$; Target absent: 4 items *M* = 664.31ms, *SE* = 16.03; 6 items *M* = 725.29ms, *SE* = 21.40, $t(37) = -6.208$, $p = .0001$ (Figure 4.4).

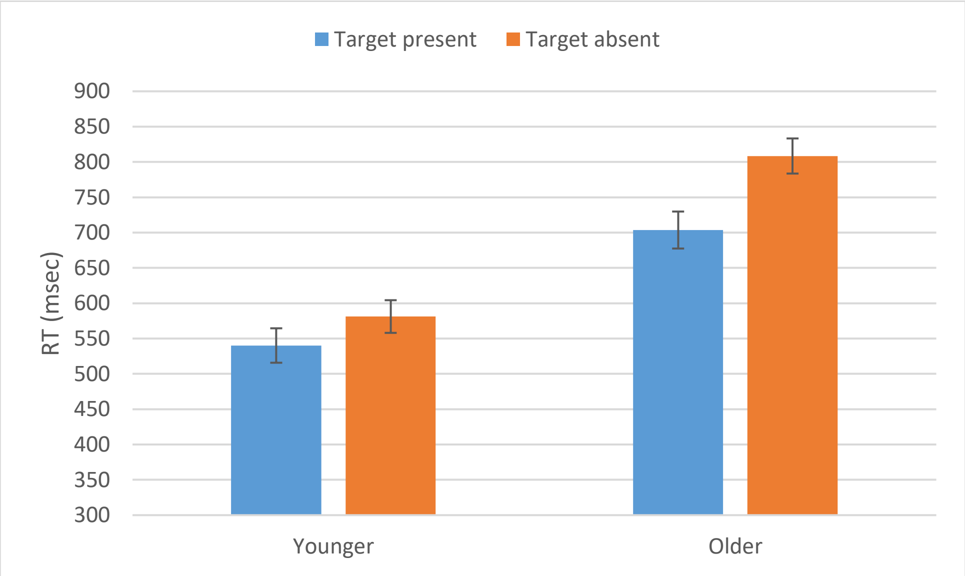


Figure 4.3. Mean RTs for both groups according to target presence when the singleton distractor is absent (with standard error bars).

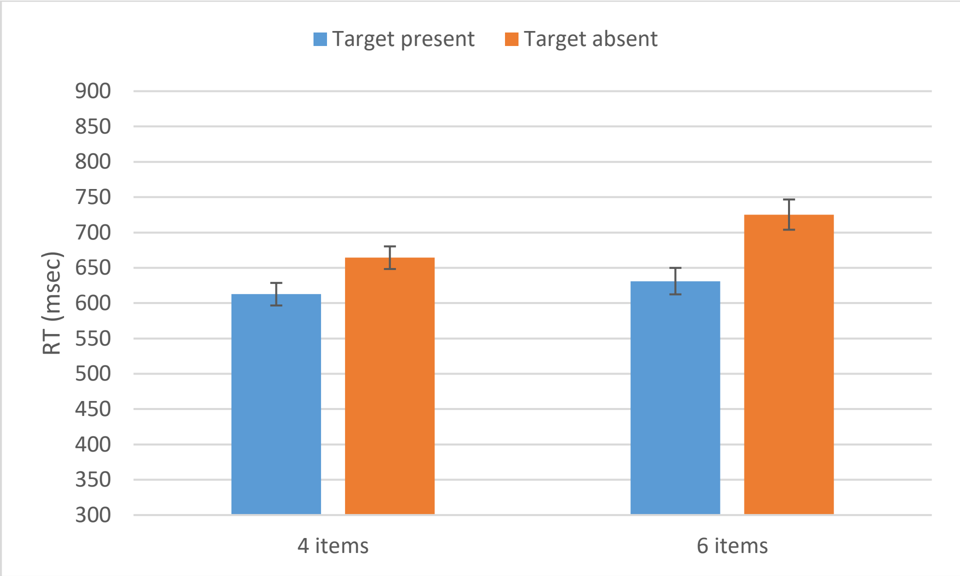


Figure 4.4. Mean RTs for both display sizes according to target presence when the singleton distractor is absent (with standard error bars).

These results show the only difference in the patterns of behaviour between older and younger participants is that for the older adults the difference between target absent and target present is bigger than for the younger adults. This finding corroborates those of Plude and Doussard-Roosevelt (1989), where it was reported that older adults seem to be more cautious than younger adults in responding to the target being ‘absent’ relative to ‘present’.

Singleton distractor present

A mixed design ANOVA was carried out with Target Presence (present vs. absent), Singleton Correctness (correct vs. incorrect), and Display Size (4 vs. 6) as within factors and Group as the between subjects factor (see Table 4.3. for results of the ANOVA, and Table 4.4. for Mean and Standard Deviation for Target present trials and Table 4.5. for Mean and Standard Deviation for Target absent trials).

Table 4.3. *Results of ANOVA for Singleton distractor present for Experiment 4.1*.

	F(1,36)	*p*
Group	35.313	0.0001
Target Presence	83.484	0.0001
Target Presence x Group	19.071	0.0001
Singleton Correctness	<1	0.371
Singleton Correctness x Group	<1	0.939
Display Size	28.211	0.0001
Display Size x Group	5.467	0.025
Target Presence x Singleton Correctness	1.32	0.258
Target Presence x Singleton Correctness x Group	<1	0.756
Target Presence x Display Size	7.6	0.009
Target Presence x Display Size x Group	<1	0.965
Singleton Correctness x Display Size	<1	0.956
Singleton Correctness x Display Size x Group	<1	0.704
Target Presence x Singleton Correctness x Display Size	<1	0.343
Target Presence x Singleton Correctness x Display Size x Group	<1	0.881

Table 4.4. *Means (and SD) for singleton distractor present when the target is present for Experiment 4.1*.

	Target Present			
	Singleton Correct		Singleton Incorrect	
	4 items	6 items	4 items	6 items
Younger adults	530.45 (96.12)	532.01 (82.43)	536.02 (79.74)	526.75 (78.06)
Older adults	689.78 (103.07)	714.77 (138.55)	701.17 (124.71)	711.34 (112.29)

Table 4.5. *Means (and SD) for singleton distractor present when the target is absent for Experiment 4.1*.

	Target Absent			
	Singleton Correct		Singleton Incorrect	
	4 items	6 items	4 items	6 items
Younger adults	567.09 (123.34)	588.75 (135.80)	550.00 (105.15)	589.19 (144.79)
Older adults	805.95 (138.38)	853.80 (146.74)	792.16 (145.70)	845.85 (117.08)

The significant difference between the groups indicated younger adults' RTs (*M* = 552.53, *SE* = 25.86) were faster than older adults' (*M* = 764.35, *SE* = 24.53). The main effect of Target Presence indicated once again RTs were faster to target present (*M* = 617.79ms, *SE* = 15.54) than to target absent (*M* = 699.10ms, *SE* = 20.82). In addition the main effect of Display Size demonstrated RTs were faster when there were 4 items in the display (*M* = 646.58ms, *SE* = 17.83) relative to 6 (*M* = 670.31ms, *SE* = 18.10).

Both groups had significantly faster RTs when the target was present (younger adults *M* = 531.31ms, *SE* = 22.55; and older adults *M* = 704.27ms, *SE* = 21.40) relative to when it was absent: younger adults *M* = 573.76, *SE* = 30.20, $t(17) = -3.754$, $p = .002$; and older adults *M* = 824.44ms, *SE* = 28.65, $t(19) = -8.924$, $p = .0001$), with the contrast being greater for the older adults. This was confirmed by calculating the difference between RTs for target present trials and target absent trials and conducting an Independent t-test to compare between the groups $t(36) = -4.420$, p = 0001 (younger adults *M* = 42.45, *SE* = 11.31, and older adults *M* = 120.18, *SE* = 13.47).

Both groups had faster RTs when there were 4 items in the display compared with 6 items; younger adults $t(17) = 2.836$, p = 011 (display size 4: M = 545.89ms, SE = 23.39; display size 6: M = 559.17ms, SE = 26.26); and older adults $t(19) = 2.804$, p = 011 (display size 4: M = 747.27ms, SE = 26.46; display size 6: M = 781.44ms, SE = 24.91). Although the contrast was greater for older adults (see Figure 4.5) an Independent t-test indicated the differences between the groups in RTs according to display size was not significant $t(27.07) = -1.263$, $p = .215$, *n.s.*.

RTs were faster when there were 4 items in the display relative to 6 regardless of whether the target was present or absent. However the effect of display size was greater when the target was absent relative to target present and a Paired t-test indicated this difference was significant $t(37) = -3.072$, $p = .004$ (target present M = 18.13, SE = 9.02; target absent M = 61.54, p = 11.20).

Brinley plots are increasingly used to determine what proportion of the variance in performance of older adults is explained by comparing it to younger adults (Perfect, 1994). According to Brinley (1965) because older adults have proportionally slower RTs than younger adults by using an interaction and comparing performances (plotting mean RTs of younger adults against those of older adults and using a regression to fit the plot) across conditions it is possible to determine whether the slower RTs are due to the natural generalised slowing associated with ageing (when an interaction is found) or (where no interaction is found) that the differences are more modular. A Brinley plot was performed here and indicated that the older adults' performance was somewhat explained by that of the younger adults', thus differences between groups in this experiment seem to be related to the slowing which is associated with the ageing process (see Figure 4.6).

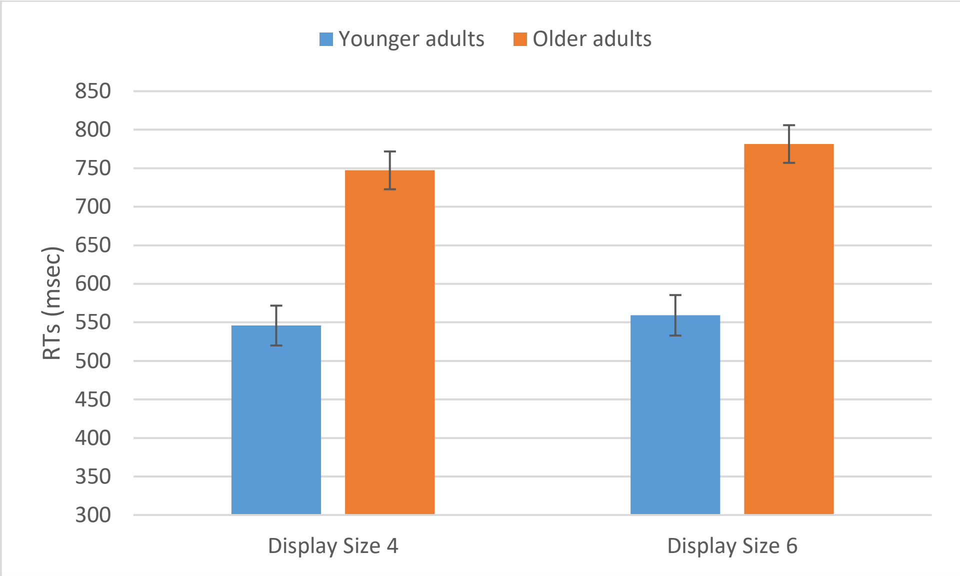


Figure 4.5. RTs for both groups according to display size when the singleton distractor is present (with standard error bars).

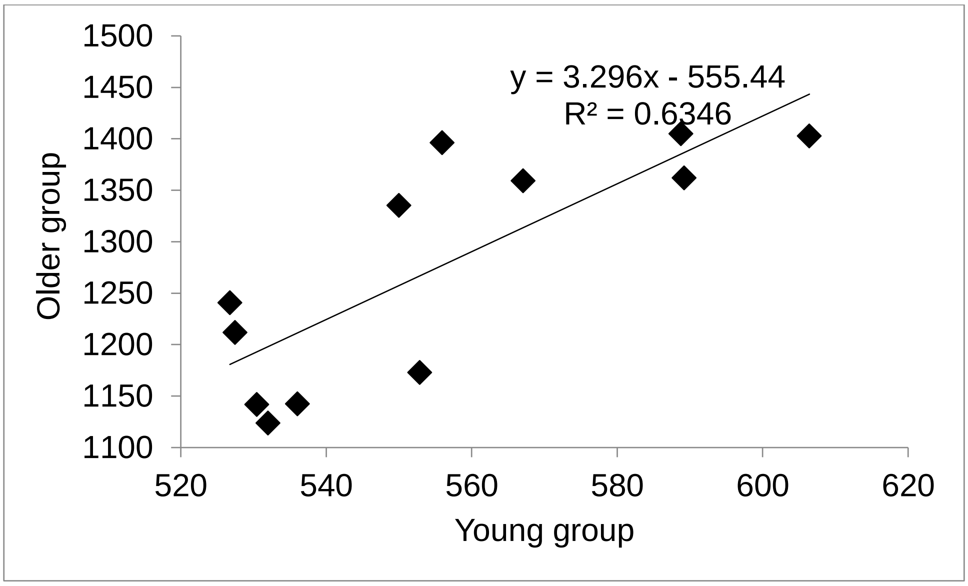


Figure 4.6. Brinley plot for all conditions for Experiment 4.1.

4.1.3 Discussion

The results of Experiment 4.1 demonstrated the typical finding of visual search tasks with faster target present trials than target absent trials (e.g., Chun & Wolfe 1996). RTs were also faster for smaller display size (Atkinson, Holmgren & Juola, 1969). With regards to group differences older adults were as expected slower than younger adults (Salthouse, 1996). While the target presence and display size effects seemed larger for the older adults (Plude & Doussard-Roosevelt, 1989), the Brinley plot demonstrated that these larger effects are to some extent predicted by the younger adults RTs suggesting that age related slowing accounted for these differences.

More interestingly, we found no evidence for the singleton being correctly or incorrectly coloured, affecting performance across the age groups. Thus, it seems that when the target was (purple) incorrectly coloured (and hence incongruent with existing stored knowledge) there was no impact of stored knowledge on older or younger adults' performance. In neither younger nor older adults was there a greater difficulty to identify the presence of the target when the singleton distractor was correctly coloured relative to when it was incorrectly coloured. The findings which show a greater RT difference between target present and target absent for the older adults relative to the younger adults provide further support for previous research (Plude & Doussard-Roosevelt, 1989) which reported similar findings and concluded it was likely that the differences were possibly due to the general slowing associated with the ageing process.

It is possible the findings here that indicate no evidence for the singleton being correctly or incorrectly coloured affecting performance across the age groups can be explained in terms of the heterogeneous distractors promoting a feature search mode (Lamy & Egeth, 2003). Such that when the target is incorrectly coloured (so stored knowledge cannot be used for target identification) but there are multiple shapes in the display feature search mode is utilized and thus reduces the effects of the singleton distractor being correctly or incorrectly coloured. However the 4 item displays more often than not contain a singleton even when the singleton distractor is absent, as the target is then a singleton (shape), and when the singleton distractor is present it is a singleton based on two dimensions (shape and colour). As such this could promote a singleton search mode. Therefore for the 4 item displays participants might be utilizing a singleton search mode whereas for the 6 item displays this would be less efficient and therefore a feature search mode is adopted. This suggests that search strategy is dynamic and is adapted to the circumstances of the search. This raises the question of whether if the target is presented as correctly coloured whether a feature search mode would be adopted.

4.2 Singleton search, stored knowledge and colour association (target correct and incorrectly coloured): a comparison between older and younger adults (Experiment 4.2).

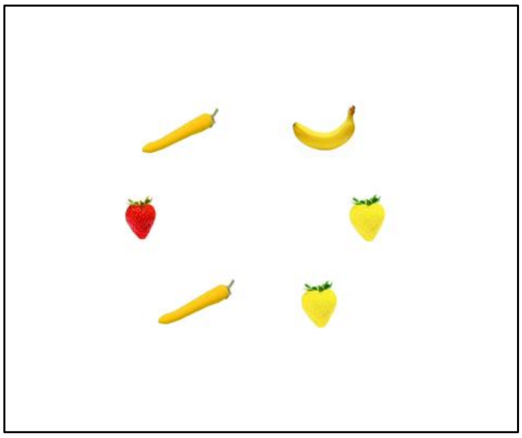
In this next experiment the target is presented as correctly coloured as well as incorrectly coloured. As mentioned above the aim of this experiment is to examine whether an object which is correctly coloured is easier to identify, and whether older adults are equal to younger adults in their ability to use top-down processing to identify a correctly coloured target of which they have prior knowledge. Furthermore it aims to also demonstrate whether older adults relative to younger adults are more hindered by objects being presented as incongruent to their stored knowledge, and whether this then results in greater disruption by an irrelevant singleton distractor which is presented as correctly coloured.

4.2.1 Method

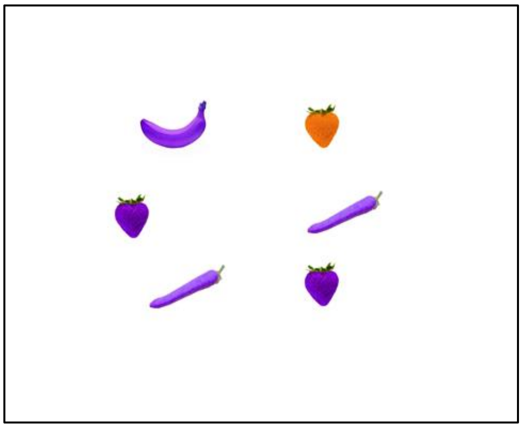
Participants

Participants were 18 (12 females) younger adults aged between 18 and 25 years (mean = 20.88, SD = 1.28), and 18 (10 females) older adults aged between 55 and 82 years old (mean = 68.06, SD = 4.57). The younger adults were University of Birmingham undergraduate students who participated to fulfil course requirement. The older adults were recruited from a data base of older adult volunteers held by the Psychology department at the university and were paid for their time (£6). They were living independently in their own homes at the time of participation. A prerequisite of participation in this study was that it was necessary to be in good health (self-assessed), and to have normal or corrected to normal vision with no colour blindness. The experiment was carried out in accordance with the ethical guidelines of the University of Birmingham and the BPS (2009). Each participant provided informed consent before taking part.

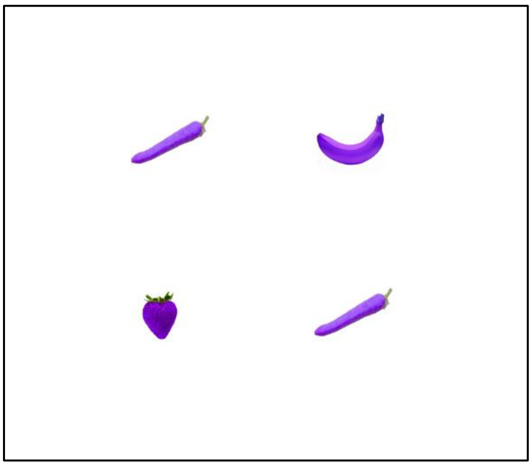
Stimuli and Apparatus



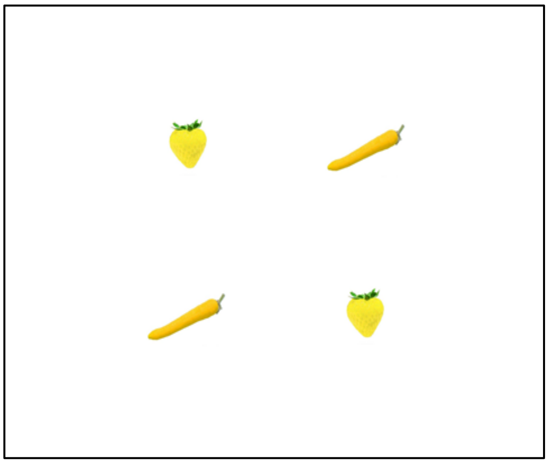
Target present and correctly coloured with singleton distractor present and correctly coloured, display size 6 (above)



Target present and incorrectly coloured with singleton distractor present and incorrectly coloured, display size 6 (above)



Target present incorrectly coloured, singleton distractor absent, display size 4 (above).



Target absent, distractor colour correct (yellow), singleton distractor absent, display size 4 (above)

Figure 4.7. Trial conditions for Experiment 4.2 showing target and singleton distractors when present and absent, and correctly and incorrectly coloured.

This was the same as that used in Experiment 4.1 (above) in respect of the singleton distractor conditions, the size, colour, and manner of presentation of the stimuli. However this time on half of the target present trials (one quarter of all trials) the target was (yellow) correctly coloured (banana) and on the other half (one quarter of all trials) it was (purple) incorrectly coloured (see Figure 4.7). When the target was absent the distractors (with the exception of the singleton) were presented on half of all trials as all yellow (correctly coloured for the target), and on the other half of all trials all purple (incorrectly coloured for the target). The conditions were: two colour conditions (equally likely to occur) for the target which were either correct (yellow) or (purple) incorrect (participants were not informed of this). The singleton distractor had three conditions (all equally likely to occur): correctly coloured (red strawberry or orange carrot) and incorrectly coloured (orange strawberry or red carrot), or absent. The conditions when the target was present and correct (yellow) were: i) target present, singleton (red) correctly coloured strawberry); ii) target present, singleton (orange) correctly coloured carrot; iii) target present, singleton (orange) incorrectly coloured strawberry; iv) target present, singleton (red) incorrectly coloured carrot; v) target present, singleton absent. These conditions occurred as both a four item display and a six item display. These conditions were then all repeated but with the display colour being purple (the incorrect colour for the target). All other aspects and conditions were the same as in Experiment 4.1; however there were 960 trials in total which were split in to four blocks (240 trials per block). On average this experiment took 45 minutes to complete.

Design and procedure

The target was a banana which was (yellow) correctly or incorrectly (purple) coloured (equally likely to occur). The target was also either present or absent (equally likely to occur) and the singleton distractor was a correctly or incorrectly coloured strawberry and carrot, or absent (equally likely to occur). Each condition was presented as a four item display and a six item display (equally likely to occur). Performance was compared within factors according to experimental conditions and between subjects according to age group.

The procedure was the same as in the previous experiment (4.1 above).

4.2.2 Results

Accuracy

The average error rate for younger adults was 2.3% and for older adults it was 0.9%. As the error rates were low no further analyses with these data was conducted.

Response time

Before analysing response times (RT), trials with extreme RTs (±2.5 SD) were deleted. This resulted in an average of 12 trials per participant being excluded; the maximum number of trials excluded for one participant was 46 trials, and the minimum was 5. The trials excluded for exceeding ±2.5 SD thus represented 2.01% of trials.

The data were separately analysed in two sections. First, when the singleton distractor was absent, in order to give a picture of performance uncontaminated by the presence of the singleton distractor, and then when the singleton was present (correctly or incorrectly coloured).

Singleton distractor absent

The singleton absent RT data were examined by using a mixed design ANOVA for this analysis, the within subject factors were Target Presence (present or absent), Target/Distractor Colour (correct/yellow or incorrect/purple) and Display Size (6 or 4 items), Group was the between subjects factor (see Table 4.6 for results for this ANOVA, and Table 4.7 for the Mean and Standard deviation for both).

Table 4.6. *Results of ANOVA for Experiment 4.2 for Singleton distractor absent analysis.*

	F(1,34)	*p*
Group	14.252	0.001
Target Presence	57.213	0.0001
Target Presence x Group	18.673	0.0001
Target/Distractor Colour	<1	0.694
Target/Distractor Colour x Group	3.242	0.081
Display Size	16.603	0.0001
Display Size x Group	11.63	0.002
Target Presence x Target/Distractor Colour	2.784	0.104
Target Presence x Display Size	49.195	0.0001
Target Presence x Display Size x Group	12.464	0.001
Target/Distractor Colour x Display Size	3.864	0.058
Target/Distractor Colour x Display Size x Group	<1	0.392
Target Presence x Target/Distractor Colour x Display Size	<1	0.654
Target Presence x Target/Distractor Colour x Display Size x Group	<1	0.356

Table 4.7. *Mean (and SD) for both groups for all conditions when the singleton distractor is absent for Experiment 4.2*.

	Target/display correctly coloured				Target/display incorrectly coloured			
	Target present		Target absent		Target present		Target absent	
	4 items	6 items	4 items	6 items	4 items	6 items	4 items	6 items
Younger adults	575.08 (93.91)	556.46 (117.31)	585.65 (102.51)	600.02 (121.61)	549.76 (98.60)	545.89 (91.43)	580.40 (132.64)	599.45 (126.11)
Older adults	682.01 (122.84)	665.17 (131.33)	765.34 (174.92)	818.64 (201.85)	675.03 (137.80)	668.77 (135.33)	760.59 (162.94)	853.40 (180.63)

The significant difference between Groups indicated as would be expected younger adults (*M* = 574.09, *SE* = 30.35) had faster RTs than older adults (*M* = 736.12, *SE* = 30.35). The significant main effect for Target Presence indicated RTs were faster when the target was present (*M* = 614.77, *SE* = 19.97) relative to target absent (*M* = 695.44, *SE* = 24.86). The main effect of Display Size showed RTs to 4 items as faster (*M* = 646.73, *SE* = 21.01) than to 6 items (*M* = 663.47, *SE* = 22.09).

The significant three-way interaction between Target Presence, Display Size and Group (see Figure 4.8) subsumed the two-way interactions (Target Presence x Group; Display Size x Group; Target Presence x Display Size). This three-way interaction was decomposed by carrying out separate two-way repeated measures ANOVAs for Target presence (present and absent), with Display Size (4 vs. 6) as the within subject factors and Groups as the between subjects factor (younger adults vs. older adults) (see Table 4.8).

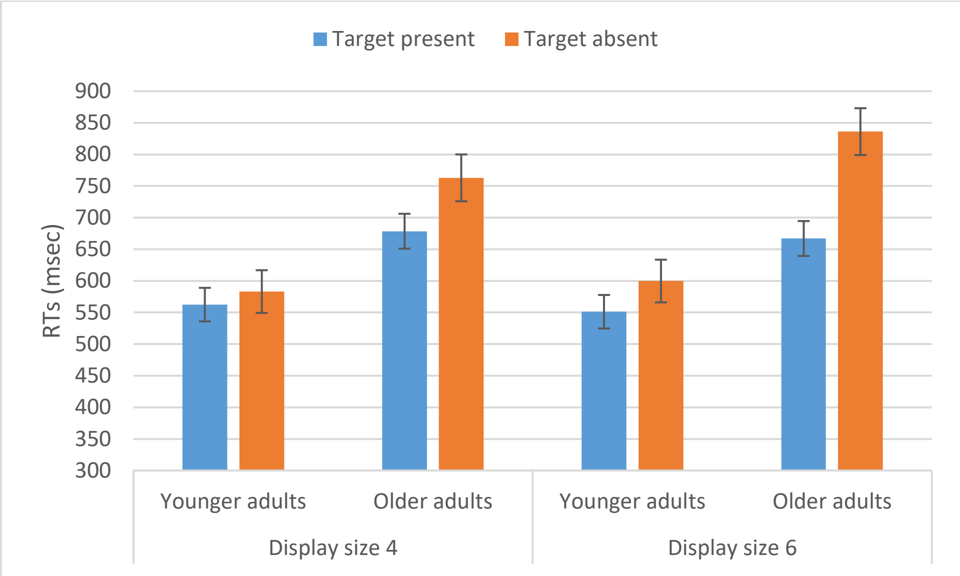


Figure 4.8. Mean RTs when the singleton distractor is absent for both groups for target present and target absent according to display size for Experiment 4.2 (with standard error bars).

Table 4.8. *Significant results for split ANOVA for Experiment 4.2 singleton absent analysis*.

	Target present		Target absent	
	F(1,34)	*p*	*F*(1,34)	*p*
Group	9.338	0.004	17.521	0.0001
Display Size	5.082	0.032	49.884	0.0001
Display Size x Group	<1	0.976	19.659	0.0001

The significant interaction was investigated further by calculating the difference in RTs between display size 6 and display size 4 and conducting an independent t-test to compare the groups. This independent t-test indicated the difference was significant *t*(22.37) = 2.629, *p* = .015 (younger adults *M* = 14.24, *SE* = 2.74, and older adults *M* = 30.98, *SE* = 5.75). This demonstrates that when the target is absent older adults experience a greater display size effect relative to younger adults. Relative to the younger adults the older adults were more hindered by the absence of the target and the larger display size.

Singleton distractor present data

Here only the trials where the singleton distractor was present were analysed using a mixed design ANOVA with Target Presence (present vs. absent), Target/Distractor Colour (yellow vs. purple), Singleton Correctness (incorrect vs. correct) and Display Size (4 vs.6 items) as within-subject factors and Group as between subject factors (see Table 4.9 for results of this ANOVA; Table 4.10 for the Mean and Standard Deviation for both groups when the target/distractor colour is correct/yellow; Table 4.11 for the Mean and Standard Deviation for both groups when the target/distractor colour is incorrect/purple).

Table 4.9. *All results for ANOVA for Experiment 4.2. Singleton distractor present analysis.*

	F(1,34)	*p*
Group	14.075	0.001
Target/Distractor Colour	36.685	0.0001
Target/Distractor Colour x Group	<1	0.943
Target Presence	38.065	0.0001
Target Presence x Group	20.801	0.0001
Singleton Correctness	8.364	0.007
Singleton Correctness x Group	<1	0.569
Display Size	41.292	0.0001
Display Size x Group	3.62	0.066
Target/Distractor Colour x Target Presence	<1	0.577
Target/Distractor Colour x Target Presence x Group	1.646	0.208
Target/Distractor Colour x Singleton Correctness	19.03	0.0001
Target/Distractor Colour x Singleton Correctness x Group	<1	0.392
Target Presence x Singleton Correctness	2.929	0.096
Target Presence x Singleton Correctness x Group	<1	0.695
Target Presence x Target/Distractor Colour x Singleton Correctness	10.636	0.003
Target Presence x Target/Distractor Colour x Singleton Correctness x Group	<1	0.934
Target/Distractor Colour x Display Size	3.955	0.055
Target/Distractor Colour x Display Size x Group	<1	0.686
Target Presence x Display Size	7.601	0.009
Target Presence x Display Size x Group	9.802	0.004
Target/Distractor Colour x Target Presence x Display Size	<1	0.663
Target/Distractor Colour x Target Presence x Display Size x Group	<1	0.791
Singleton Correctness x Display Size	17.522	0.0001
Singleton Correctness x Display Size x Group	<1	0.887
Target/Distractor Colour x Singleton Correctness x Display Size	51.188	0.0001
Target/Distractor Colour x Singleton Correctness x Display Size x Group	4.315	0.045
Target Presence x Singleton Correctness x Display Size	<1	0.879
Target Presence x Singleton Correctness x Display Size x Group	<1	0.746
Target/Distractor Colour x Target Presence x Singleton Correctness x Display Size	3.857	0.058
Target/Distractor Colour x Target Presence x Singleton Correctness x Display Size x Group	1.119	0.298

Table 4.10. *Mean and (Standard Deviation) for both groups for all conditions when the singleton distractor is present and the target/distractor colour is correct/yellow for Experiment 4.2*.

	Target Present				Target Absent			
	Singleton Correct		Singleton Incorrect		Singleton Correct		Singleton Incorrect	
	4 items	6 items	4 items	6 items	4 items	6 items	4 items	6 items
Younger adults	561.11 (91.94)	563.37 (108.23)	566.62 (102.71)	628.42 (140.60)	589.45 (112.60)	590.69 (114.85)	564.64 (117.50)	620.47 (128.04)
Older adults	674.65 (139.64)	673.14 (145.85)	685.23 (153.77)	747.16 (121.03)	771.32 (146.50)	826.30 (196.09)	775.18 (181.61)	850.88 (220.87)

Table 4.11. *Mean and (Standard Deviation) for both groups for all conditions when the singleton distractor is present and the target/distractor colour is incorrect/purple for Experiment 4.2*.

	Target Present				Target Absent			
	Singleton Correct		Singleton Incorrect		Singleton Correct		Singleton Incorrect	
	4 items	6 items	4 items	6 items	4 items	6 items	4 items	6 items
Younger adults	540.07 (81.30)	570.36 (102.36)	548.73 (89.99)	553.48 (90.49)	565.48 (116.62)	584.72 (121.93)	567.29 (120.69)	580.11 (121.60)
Older adults	667.21 (122.09)	692.87 (147.13)	666.91 (142.57)	675.67 (139.79)	757.37 (158.13)	807.53 (186.65)	747.53 (162.06)	818.42 (224.64)

The ANOVA revealed significant main effects for all four factors as well as a number of interactions in various hierarchies. However, here we are specifically interested in singleton distractor colour effect as well as differences between the groups. Thus, and for the sake of simplicity, I have further investigated only the higher order interactions here. Again there was a significant difference between Groups

F(1,34)=14.075, p = .001, and as would be expected younger adults had on average faster RTs (M = 574.69ms, SE = 31.13) than older adults (M = 739.84ms, SE = 31.13). Target Presence F(1,34) = 38.065, p = .0001, on average RTs were faster when the target was present (M = 625.94ms, SE = 19.53) relative to target absent (M = 688.57ms, SE = 25.28): Target/Distractor Colour F(1,34) = 35.685, p = .0001, here RTs were on average significantly faster when the target/distractor was incorrect (for the target when present) (M = 646.49ms, SE = 21.77) in comparison to when the target/distractor colour was correct (M = 668.04ms, SE = 22.39): Singleton Correctness F(1,34) = 8.364, p = .007, RTs were faster when the singleton distractor was correctly coloured (M = 652.23ms, SE = 21.28) in comparison to when it was incorrectly coloured (M = 662.27ms, SE = 22.85):

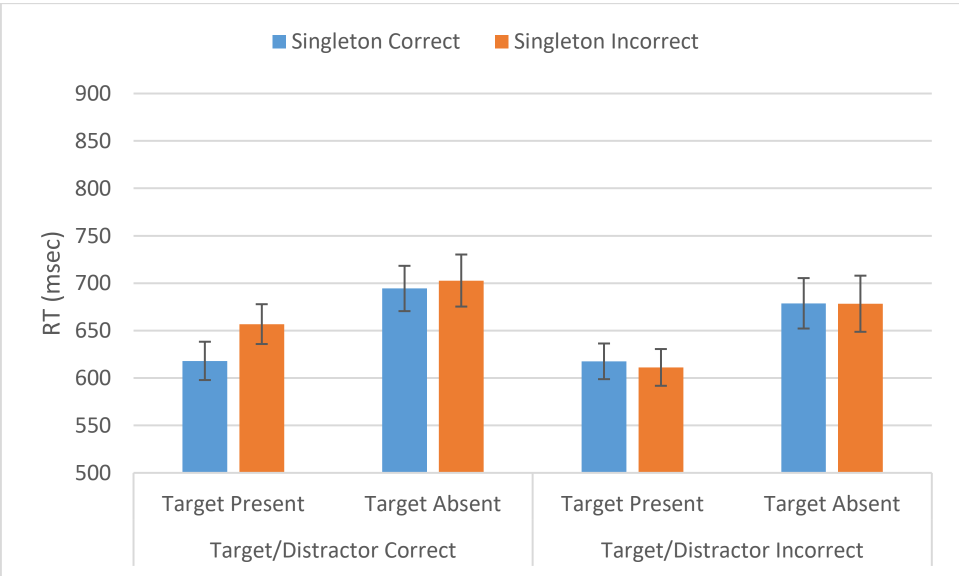


Figure 4.9. Mean RTs according to Target/Distractor Correctness, Target Presence and Singleton Correctness (with standard error bars).

As can be seen in Table 4.9 the mixed ANOVA (above) also revealed a significant three-way interaction between Target Presence, Target/Distractor Colour, and Singleton Correctness $F(1,35) = 10.636$, $p = .003$ (Figure 4.9). In order to examine the effect of colour and of the singleton correctness this interaction was investigated further by calculating the difference between singleton incorrectly and correctly coloured (i.e. RTs of singleton incorrectly coloured minus correctly coloured). We then analysed this effect using an ANOVA with Target Present (present vs. absent) and Target/Distractor Colour (yellow vs. purple) as within subjects factors. The analysis revealed a two-way interaction (see table 4.12) between Target presence and Target/distractor colour.

Table 4.12. *Results of repeated measures ANOVA using singleton difference RTs.*

	F(1,35)	*P*
Target Presence	3.158	0.084
Target/Distractor Colour	18.634	0.0001
Target Presence x Target/Distractor Colour	11.72	0.002

For target present trials, a *benefit* was evident for a correctly coloured singleton when the target was also correctly coloured ($M = 38.79$, $SE = 7.10$) but not when the target was incorrectly coloured ($M = -6.43$, $SE = 3.89$; $t(35) = 5.352$, $p = .0001$). However when the target was absent there was no difference in the effect of singleton correctness between the target/distractor colour being yellow (correct for the target $M = 7.64$, $SE = 8.44$) or purple (incorrect for the target $M = -.44$, $SE = 5.36$) $t(35) = 1.012$, p .318, n.s.. Thus, the results show that the colour of the singleton distractor only had an effect on performance when the correctly coloured target was present in the display, in which case a correctly coloured singleton facilitated performance compared to an incorrectly coloured one. As such, both in this experiment and in the previous one (which only featured incorrectly coloured targets), incorrectly coloured targets prevented an effect of the singleton colour.

The three-way interaction between Target Presence x Display Size x Group (see Figure 4.10) was decomposed by calculating the difference in RTs between target present and target absent (target presence effect) and using these scores (i.e. RTs of target absent minus target present). We then analysed this effect using an ANOVA with Display Size (4 vs. 6) as within subjects factors and group as the between subjects factor. The analysis revealed a two-way interaction (see table 4.13) between Display Size and Group.

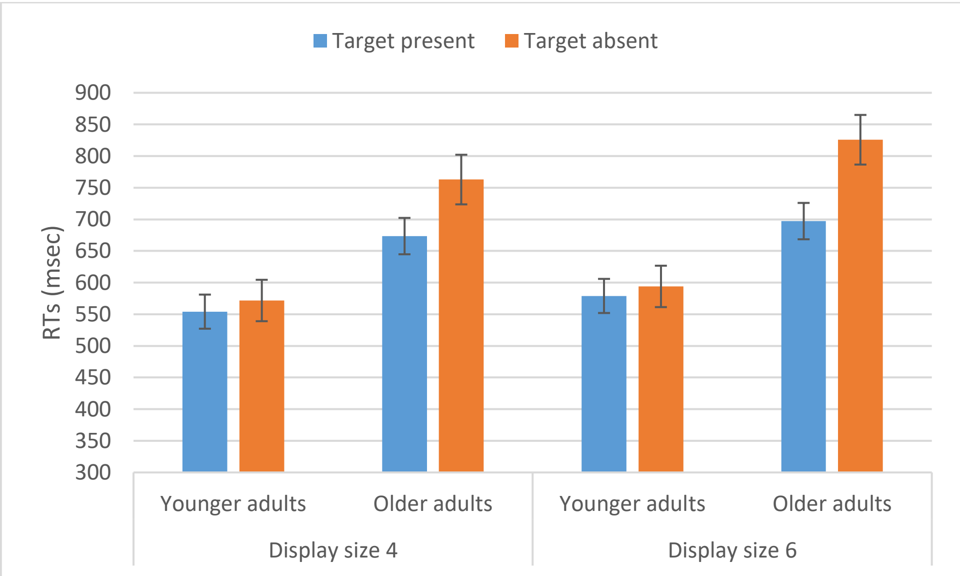


Figure 4.10. RTs when the singleton distractor is absent for both groups to target present and target absent according to display size for Experiment 4.2 (with standard error bars).

Table 4.13. *Results of repeated measures ANOVA using target presence effect RTs.*

	F(1,34)	*p*
Group	20.801	0.001
Display Size	7.601	0.009
Display Size x Group	9.803	0.004

This interaction was investigated further by carrying out Independent t-tests which revealed the effect of target presence was greater for the older adults when there were 4 items in the display $t(34) = -4.001$, $p = .0001$ (younger adults $M = 17.58$, $SE = 9.51$, and older adults $M = 89.35$, $SE = 15.21$), and when there were 6 items in the display $t(34) = (20.432) = -4.664$, $p = .0001$ (younger adults $M = 15.09$, $SE = 7.40$, and older adults $M = 128.57$, $SE = 23.18$). Thus it appears that the effect of target presence in the older adults increases according to display size whereas for the younger adults it remains stable.

The initial mixed ANOVA (see Table 4.9) also revealed a significant three-way interaction of Target/Distractor Colour x Singleton Correctness x Display Size $F(1,34) = 51.188$, $p = .0001$ which was subsumed by a four-way interaction (below).

The significant four-way interaction between Target/Distractor Colour x Singleton Correctness x Display size x Group (see Table 4.9 above) $F(1,34) = 4.315$, $p = .045$ (see Figures 4.11 and 4.12) was examined further by once again calculating the difference in RTs when the singleton distractor was incorrectly coloured relative to correctly coloured and carrying out a mixed ANOVA with the within subjects factors being Target/Distractor Colour (yellow vs. purple), Display Size (4 vs. 6), and Group as the between subjects factor (see Table 4.14 for results).

Table 4.14. *Results for mixed ANOVA using singleton effect RTs to investigate 4-way interaction*.

	F(1,35)	p
Group	0.273	0.605
Target/Distractor Colour	18.449	0.0001
Target/Distractor Colour x Group	0.653	0.425
Display Size	16.804	0.0001
Display Size x Group	0.005	0.942
Target/Distractor Colour x Display Size	50.535	0.0001
Target/Distractor Colour x Display Size x Group	4.756	0.036

The main effect of Target/distractor colour indicated when the singleton distractor was incorrectly coloured it was a benefit when the Target/Distractor Colour was correct (*M* = 23.22, *SE* = 5.60) whereas when the Target/Distractor Colour was incorrectly coloured there was a cost (M = -3.45, SE = 3.51). This analysis revealed the expected 3-way interaction indicating that the singleton colour had a different effect on performance based on Target/Distractor Colour, Display size and the age of the participants. We further investigated these effects by splitting the data according to display size and conducting two separate mixed ANOVAs – one for display size 4, and the other for display size 6. The within subjects factor was Target/Distractor Colour (yellow vs. purple), and the between subject factor was Group. In respect of display size 4 there was no effect of Group $F(1,34) = <1$, and the main effect of Target/Distractor Colour was non-significant $F(1,34) = <1$. However the interaction Target/Distractor Colour x Group was significant $F(1,34) = 4.749$, $p = .036$. Paired t-tests indicated that for the younger adults there was a significant difference in the effect of singleton correctness between the target/distractor colour being yellow (correct for the target) and purple (incorrect for the target) $t(17) = -2.660$, $p = .017$ (yellow *M* = -

9.65, $SE = 4.28$; purple $M = 5.23$, $SE = 3.79$); whereas for the older adults there was no significant difference $t(1,17) = 1.103$, $p = .285$ (yellow $M = 7.22$, $SE = 13.88$; purple $M = -5.07$, $SE = 7.76$) (see Figure 4.13). It is hard to interpret these differences as the singleton colour effect here is relatively small (smaller than 10 ms in all conditions) but it seems that overall younger participants are more sensitive to these colour differences.

In respect of display size 6 the mixed ANOVA revealed again no effect of Group $F(1,34) = <1$. However here the main effect of Target/Distractor Colour was significant $F(1,34) = 43.176$, $p = .0001$, as a correctly coloured singleton benefited performance for the correctly coloured (yellow) target/distractor (benefit $M = 47.65$, $SE = 6.32$) but not for the incorrectly coloured (purple) target/distractor (benefit $M = -6.95$, $SE = 4.18$). The interaction Target/Distractor Colour x Group was non-significant $F(1,34) = <1$.

The results of these ANOVAs (split for display size) show there is no difference between the groups in the larger display size. Here, when the target was incorrectly coloured both groups were insensitive to the colour of the singleton. In contrast, when the target was correctly coloured sensitivity to the singleton distractor emerged in both groups so that a correctly coloured singleton benefited performance. While the results for the smaller display size are harder to interpret, they suggest that younger adults were more sensitive to the singleton colour than older participants and this sensitivity was modulated by the target colour.

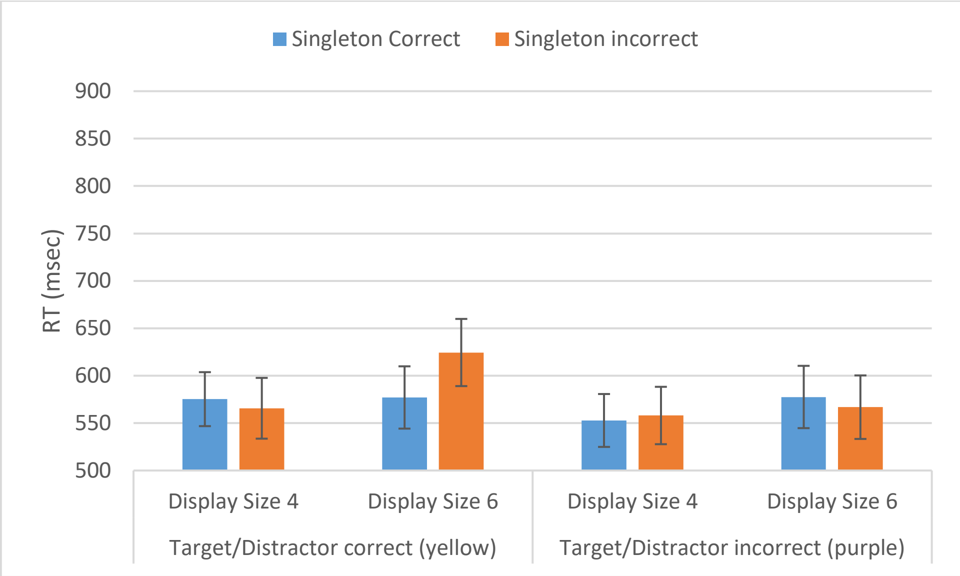


Figure 4.11. Mean RTs for younger adults according to Target/Distractor Colour, Singleton Correctness and Display Size (with standard error bars).

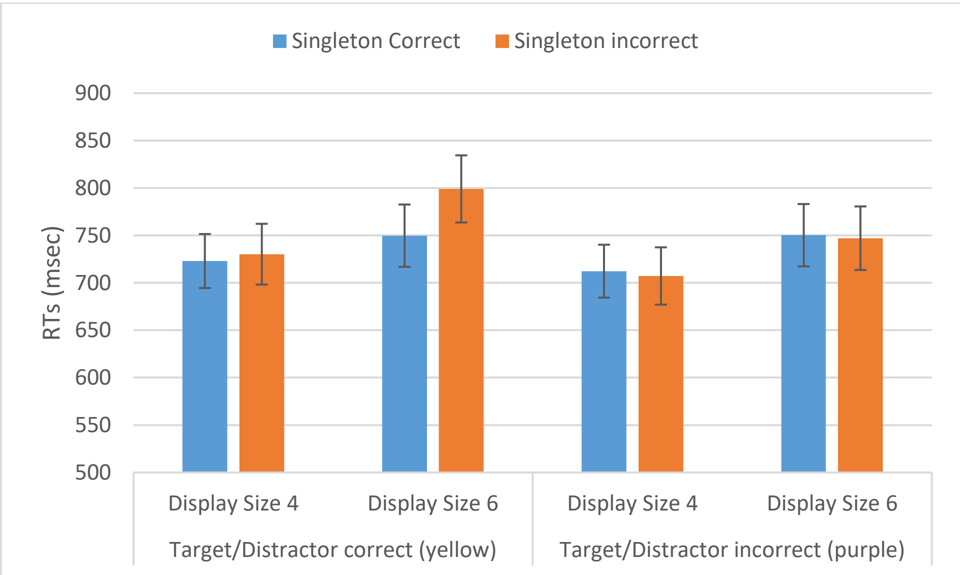


Figure 4.12. Mean RTs for older adults according to Target/Distractor Colour, Singleton Correctness and Display Size (with standard error bars).

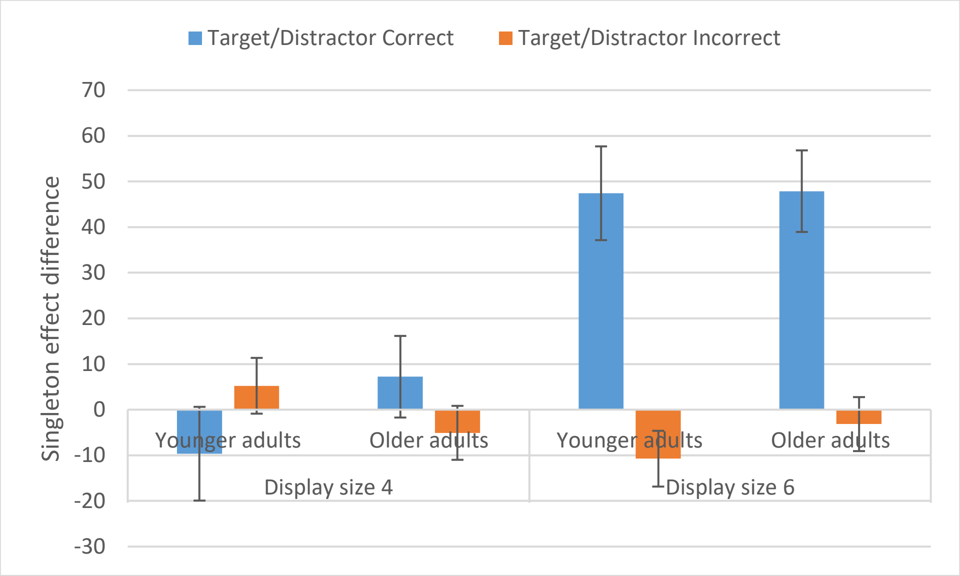


Figure 4.13. Singleton effect difference for both groups when the singleton distractor is absent according to target/distractor colour for both display sizes 4 and 6 (with standard error bars) for Experiment 4.2.

In order to assess whether the apparent differences in the older adults' performance relative to the younger adults were due to the general slowing process associated with ageing the data were entered on to a Brinley Plot (see Figure 4.14).

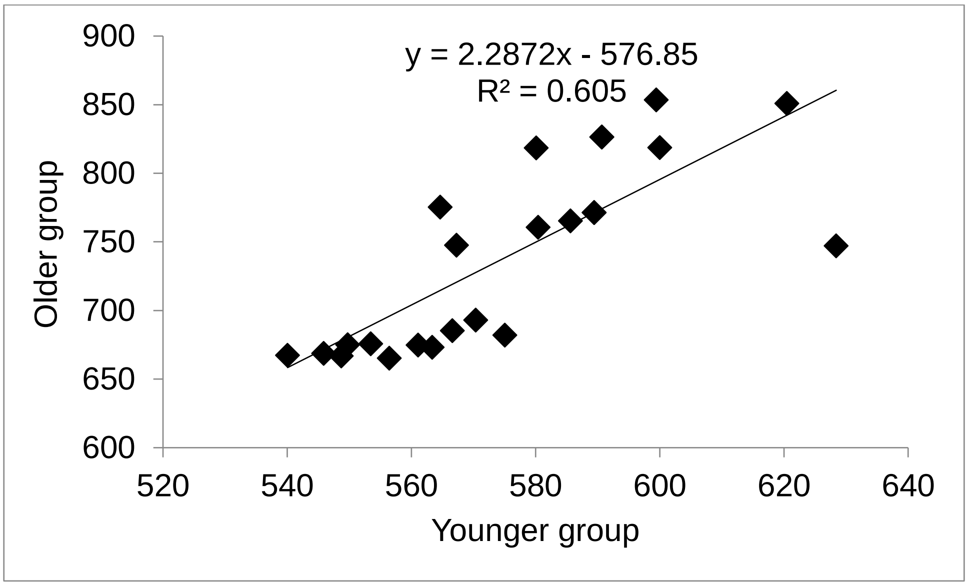


Figure 4.14. Brinley Plot showing RTs for both groups for all conditions in Experiment 4.2.

The results of the Brinley Plot indicates that the difference in performance between older and younger groups in this experiment is somewhat accounted for by general slowing only. The Brinley plot shows that when all conditions are plotted the younger adults' RTs predict the older adults' performance to some extent (61% of the variance is explained). This suggests therefore that the difference between the groups can largely be explained by the generalised slowing which is associated with ageing.

4.2.3 Discussion

There were several findings of note in this experiment. Interestingly, performance tended to be better for targets that were incorrectly compared to correctly coloured. This contradicted our prediction that targets that match representations in stored knowledge will be easier and quicker to detect. It seemed however, that this effect was not apparent in all conditions and critically interacted with the colour of the singleton distractor.

Another interesting finding in this experiment (again contradicting our initial predictions) is the benefit in performance that a correctly coloured singleton distractor may have in certain conditions. Correctly coloured singleton distractors tended to be easier to ignore (yielded quicker RTs) compared to incorrectly coloured ones. Thus, it appears that when a singleton distractor matched a template in stored knowledge participants were more efficient in ignoring it.

The main finding is therefore the interesting interaction involving both the target and the singleton colour. The colour of the target (whether it is correctly or incorrectly coloured) seemed to have had a direct impact on whether participants were sensitive to the colour of the singleton. In particular, when the target was incorrectly coloured (and therefore was not in accordance with stored knowledge) both younger and older participants were less affected by the colour of the singleton. In contrast, when the target was correctly coloured (and therefore in accord with stored knowledge) both younger and older participants became more susceptible to colour effects in the singleton. Furthermore, while performance in both groups seemed equivalent (overall RT differences apart) for the larger set size, it appears that for smaller set sizes group differences start to emerge. However, the Brinley plot analysis indicates any apparent differences are somewhat attributable to the ageing process. We discuss these finding further in the general discussion below.

4.3 General discussion

The results of Experiment 4.1. indicated when the target (which in this experiment was always a purple banana) was incorrectly coloured (and thus incongruent with existing stored knowledge) there was no impact of stored knowledge on older adults' performance relative to younger adults i.e. in neither younger nor older adults was there a greater effect of singleton distractor when that singleton distractor was correctly coloured relative to when it was incorrectly coloured. The findings therefore provide further support for previous research and conclusions that the differences were possibly due to the general slowing associated with the ageing process (Plude & Doussard-Roosevelt, 1989).

The results of Experiment 4.2 indicate that there was an effect of singleton distractor. This finding suggests that knowing exactly what you are looking for (a banana in this case) does not mean that top-down guidance prevents attention capture by an irrelevant singleton distractor as was posited by Lamy and Tsal (1999), and Theeuwes and Burger (1998). It is possible the finding of Experiment (4.2) differs from previous singleton search evidence because stored knowledge relating to colour associations has had an impact on this search task by increasing the likelihood of top-down guidance, and that this additional factor makes search more complex. This in turn would suggest that search perhaps differs according to the conditions of each task.

There was an effect of the target being correctly coloured, however search was more efficient when the target was incorrectly coloured relative to correctly coloured. Furthermore when the target was incorrectly coloured there was no effect of singleton distractor correctness which was not the case when the target was correctly coloured, therefore the experimental hypothesis (1) that search will be more efficient when the target is correctly coloured relative to incorrectly coloured irrespective of age is rejected for this experiment.

It was predicted here that older adults would demonstrate search for a correctly coloured target to be less hindered by a correctly coloured singleton distractor than search for an incorrectly coloured target. Younger adults were found to benefit from the singleton distractor being incorrectly coloured when the target and distractors were correctly coloured (at display size 4), whereas older adults demonstrated no effect of singleton correctness in relation to target correctness. Therefore although a difference was revealed between the groups there is no direct support for the experimental hypothesis (2) that older adults will demonstrate search for a correctly coloured target to be less hindered by a correctly coloured singleton distractor than search for an incorrectly coloured target.

An interesting finding in Experiment 4.2 is that participants across both age groups benefited (but only when the correctly coloured target was present in the display) from a correctly coloured singleton distractor (compared to an incorrectly coloured one). While this finding is somewhat puzzling as we would expect the correctly coloured singleton to be more salient and to capture attention more, there are previous reports that go against this conjecture and that could fit with the finding we report here. For instance, a salient distractor has been shown to facilitate search performance to a low salient target (DiQuattro & Geng, 2011; Geng & DiQuattro, 2010). Furthermore, Geng & DiQuattro (2010) suggested that this benefit is a product of rapid rejection of the salient distractor. In other words, participants are more efficient in rejecting the salient distractor compared to a non-salient one which might require more scrutiny before it can be rejected. It was also argued that such rejection of distractors may rely on a reactive suppression mechanism (see Braver, 2012 for a review on proactive and re-active suppression) that is triggered late in the search task (Geng, 2014). Interestingly, it is also argued that reactive suppression is intact in old age (Braver, Satpute, Rush & Barch, 2005) which would fit with the lack of group difference we see in this effect here. Thus, we would argue that the benefit participants showed in our experiments from a correctly coloured (relative to incorrectly coloured) singleton, is attributable to the need for more scrutiny in order to reject the incorrectly coloured singleton.

As mentioned above whilst there was a benefit from a correctly coloured singleton it was limited to those scenarios where a correctly coloured target was searched for and present in the display. Indeed, no effect of singleton colour was evident when searching for an incorrectly coloured target. This may suggest that when the search target does not correspond with stored knowledge a more controlled search process may take place (similar to a feature search mode) which precludes sensitivity to the stored knowledge reference of other non-target items. It may therefore be the case, that searching for a target that corresponds to stored knowledge facilitates the processing of other non-target items that also corresponds with stored knowledge. And furthermore, such non-target items are more easily rejected than non-target items that are similarly physically salient but do not correspond with stored knowledge and may therefore need further processing to be rejected. In this sense, it may reflect the notion that looking for a banana is less affected by another known fruit/vegetable (which might be expected given the context) than a 'new' unknown item/fruit which might therefore capture attention more and demand more processing before it can be rejected. To some extent this corresponds with the findings of Henderson, Brockmole, Castelhano and Mack (2007) where it was reported that when searching a real-life scene, the theory that saliency guides attention is not well supported. They posited that cognitive factors such as stored knowledge are dominant in guiding search of real-life scenes.

Interestingly, while performance across age groups was fairly similar in terms of the singleton colour effects, some differences emerged for the smaller set size of 4 items. In this condition, we found young participants to be more sensitive to correct or incorrect coloured singleton than the old participants. However these differences were fairly small, and the Brinley plot analysis supported the notion that these differences are somewhat attributable to the overall difference in RTs between the groups. It is noteworthy that the experimental design we have utilised here meant that in the 4 items set size the singleton distractor could have also been a singleton shape in target present trials (for instance when a strawberry appeared with two carrots, see Figure 4.7). As such, this may have changed the dynamics and the strategy that was utilised in this search task and the difference which seemed apparent between the groups may be attributed to such a change. Further investigation, is therefore needed to examine this possibility.

It is also worth noting that in this chapter the distractors are heterogeneous (whereas in Chapters 2 and 3 they are homogeneous) and therefore promote a feature search mode rather than a singleton search one (Bacon & Egeth, 1994). In feature search mode, the effect of a singleton distractor is attenuated (e.g., Bacon & Egeth, 1994). In our experiments, especially when the target was incorrectly coloured, participants showed less sensitivity to the singleton colour. This therefore, fits with the idea that in such conditions participants in both age groups relied on a feature search mode. Thus, our data suggest that old participants are equally adequate as young participants in utilising feature search mode and this, in turn, reduces the attention capture exerted by singleton distractors for old participants too.

Another group difference we reported in the second Experiment (4.2) of this chapter occurred when the singleton distractor was absent. Older adults showed a greater target presence effect than younger adults and this effect was modulated by set size for them (but not for young participants). These results seem to corroborate previous findings which have reported that older adults seem to be more cautious than younger adults in responding to the target being ‘absent’ relative to ‘present’ (Plude and Doussard-Roosevelt,1989; Hommel, Li & Li, 2004; Scialfa, Esau & Joffe, 1998). These previous studies posited that it was likely that these differences were due to the general slowing which is associated with ageing. When the singleton distractor was present there was further evidence of older adults being more cautious to respond to target ‘absent’.

Taken together these findings suggest that older adults were able to utilise stored knowledge in a similar fashion to younger adults. This finding would then extend previous research findings which have reported that older adults’ performance on memory tasks can benefit from stored knowledge (Badham & Maylor, 2015; McGillivray & Castel, 2010), by demonstrating that older adults’ performance can also benefit from stored knowledge associations on a singleton search task. In addition the findings of the current study also corroborate the findings of previous studies which show that older adults are not less able than younger adults to utilize top-down processing in search (Madden et al, 2004).

A limitation of this experiment is that although it uses stimuli which are real life objects, it is still an artificial situation, as images are set on a plain background, whereas in real life scenes tend to have a lot of detail in the background. As such it may be beneficial for future research to use images with a realistic ‘busy’ background. In addition the data collected here are only behavioural and it would be beneficial to have collected some additional more informative data such as eye-tracking. Furthermore it would also be interesting to examine what happens to visual search when fruit and vegetables which have more than one natural associated colour are used as stimuli.

CHAPTER 5

A COGNITIVE INTERVENTION WITH OLDER ADULTS: IMPROVING ATTENTION AND WORKING MEMORY

5.0 Introduction

Cognitive control is a fundamental aspect of cognition. This ability is essential to enable successful adaptation and flexibility in an ever changing environment, particularly when irrelevant distractions or habitual responses need to be overcome in order to achieve a goal. Evidence demonstrates that cognitive control declines with age, specifically, in tasks when attention must be endogenously and intensively focused, especially when detractions and interferences are present, and where cognitive functions require a great deal of attentional resources (Craik & Byrd, 1982). Indeed, attention deficits are strongly associated with executive dysfunctions such as response inhibition, vigilance, working memory and planning (Willcutt, Doyle, Nigg, Farone, & Pennington, 2005), which are likely to have a detrimental impact on daily living. Specific attention related skills which are impaired in ageing include reasoning (fluid intelligence) and memory (Salthouse, 2004), selective attention (Glisky 2007), and the ability to switch or divide attention (Nobre and Kastner, 2013). Overcoming all of these declines as we age (e.g., Kramer, Hahn & Gopher, 1999), is a major challenge for an ageing population (United Nations, 2009). Thus, exploring ways in which to limit the detrimental cognitive effects of ageing is called for.

Whilst cognitive interventions have been used to try to improve cognitive functions, they are not always fully successful as was demonstrated by a cognitive intervention carried out by Owen et al. (2010). This study looked at whether any transferable skills were gained through cognitive training for six weeks in over 11000 participants in an on-line study involving tasks targeting reasoning, memory, planning and visuospatial skills and attention. The results indicated that whilst participants did improve on each of the tasks on which training was given, this was not the case for closely related cognitive tasks. As such it was concluded that cognitive training per se. did not transfer (at least in this particular case) in to a general improvement in cognitive performance, as gains were only seen on tasks where training had been given. It is possible though that this intervention was not completely successful because it was carried out on-line and thus there is little experimental control over the conditions of training.

Nonetheless there is evidence which suggests that maintaining frequent cognitive stimulation throughout life and continuing into older adulthood is not only associated with a lower risk of developing dementia (Wilson et al., 2002), but also with improved performance on tasks measuring perceptual speed and visuospatial ability (Wilson et al., 2002). In attempts to slow these areas of decline, and even to postpone the onset of mild cognitive impairment, many cognitive interventions have been carried out with the older adult population with varying levels of success. A systematic review of ten studies was carried out by Papp, Walsh and Snyder (2009) examining randomized controlled trials of cognitive interventions in healthy older adults. Whilst they found that most of the cognitive interventions on healthy older adults did seem to show a small benefit, the benefits gained were mostly on tasks on which training had been given (that is, limited transfer of the training to non-trained tasks and processes). They concluded that the existing literature is limited, with limitations relating to insufficient follow up times, a lack of matched active controls, and few outcome measures demonstrating transferable skills which benefit daily cognitive functioning.

Another systematic review was carried out in 2013 by Reijnders, van Heugten, and van Boxtel which examined thirty-five studies to assess the effectiveness of cognitive interventions for healthy older adults and those with MCI (mild cognitive impairment). The evaluation outcome was that, generally, the quality of the studies had been low and this was linked to poor randomisation methods, and again a lack of clear transferable benefits gained from training. In addition it was felt that future interventions should include subjective outcome measures. Despite the fact that it remained unclear as to whether gains transferred in to improvement in everyday activities, evidence was found for improved task performance in relation to memory, attention, executive functioning, information processing and fluid intelligence in healthy older adults. This provides some evidence for the efficacy of cognitive interventions aimed at ameliorating the cognitive declines associated with age.

More recently a meta-analysis was carried out by Toril, Reales and Ballesteros (2014) on twenty studies using video game training to assess the effectiveness of such technology-based interventions in enhancing cognitive functions of healthy older adults. It is important to note here that the authors of this meta-analysis did not use transfer benefits (i.e. evidence of improvement on tasks on which no training was given) as a selection criterion. Therefore improvements here in some cases relate to cognitive functions on which training was received. Results indicated that the interventions were associated with significant positive changes in healthy older adults in terms of speed of processing (measured by RTs), memory, attention, and overall cognitive function, but not executive functions. In addition the authors report that variables which influence the effectiveness of the interventions include the age of participants whereby older adults (71-80 years) benefit more than younger participants (60-70- years). The length of the intervention was another variable which seemed to influence effectiveness whereby those interventions which had fewer sessions and thus were shorter in duration (1-6 weeks) were more effective than those which were longer in duration (7-12 weeks). It was concluded that video game training has beneficial outcomes for healthy older adults' cognitive functioning, and although the benefits do not transfer to all cognitive functions training did improve performance on several untrained tasks. It was recommended that future research should look at ways of improving executive functioning in older adults, as well as improving transfer effects of training – and it is suggested that this could be done by providing training for certain processes on tasks whilst evaluating performance on another.

A recent study carried out by Anguera et al. (2013) is illustrative of a successful cognitive intervention which addressed many of the shortcomings of previous interventions. Training was computer based and was carried out at home (without a researcher present). The training sessions lasted for one hour, three times a week for four weeks, after which outcome measures were taken, with follow up measures taken after six months. The results indicated that participants in the multitasking group showed improvements at outcome that were comparable to performance of 20-year-old participants (at baseline), and according to EEG results on untrained tasks of cognitive control (measured by sustained attention, working memory and speed of processing), any age-related deficits were corrected. Furthermore at the six month follow up improvements remained in sustained attention (untrained task) and on the multitasking games, on which training was given, again demonstrating that cognitive interventions can be beneficial to older adults. It is important to note, however, that the performance measures taken in this study to indicate improvements in working memory and sustained attention were ultimately dependent on overall RTs rather than the more specific measures typically associated with working memory and sustained attention (e.g., standard deviation of RTs or omission errors). As such, it could still be contemplated that these documented improvements represented a general improvement in speed of processing rather than in specific attention mechanisms or executive control.

Another example of a successful cognitive intervention (attention training) which targeted a specific population and which identified the specific cognitive mechanisms underlying improved cognitive performance is that carried out by Shalev et al. (2007). This intervention used a program called CPAT (Computerised Progressive Attentional Training) which was designed to improve specific aspects of attention in children with attention deficit/hyperactivity disorder (ADHD). The CPAT program training tasks targeted sustained attention, selective attention, orienting attention and executive attention. Each of the tasks began at a simple level and increased in difficulty as proficiency improved. Improvement in each task was aided by a tight schedule of feedbacks tuned to individual performance. Results revealed a significant transfer effect in reading comprehension and passage copying for the experimental group (even when controlling for individual differences in initial performance). Behavioural symptoms of inattention and hyperactivity were also shown to reduce following the intervention in the experimental group.

The efficacy of CPAT has also been demonstrated with stroke survivors (Sampanis, 2014). In this study eight sub-acute stroke patients (mean age of 56 years) were compared to both healthy age-matched (no activity) controls as well as patients (who did not receive the CPAT intervention but who took part in cognitive testing in the laboratory). The stroke survivors received ten one-hour training sessions over a two-week period. Results indicated a specific improvement in sustained attention (reduced standard deviations following training) as well a more general improvement in performance of attention tasks (reduced RT). Moreover, the patients who carried out the intervention also significantly improved performance in a non-trained neuropsychological cognitive screen, including in cognitive domains such as language, memory, number processing and praxis (Sampanis, 2014).

These studies demonstrate that CPAT is an effective intervention program not only in directly improving attention performance per se. but also as a potential domain general approach to cognitive impairments. Across both studies, participants who received the CPAT intervention improved in non-trained academic tasks as well as in cognitive domains outside attention. Furthermore, it is also appropriate to use with both young children (Shalev et al., 2007) and with older adults (Sampanis, 2014) albeit with brain injury. As such, the CPAT program seems a plausible candidate as an intervention that may have the potential to improve core attention processes that can be affected by age, and has the potential to demonstrate transfer effects to a wide range of non-trained cognitive domains.

In the present study we tested the efficacy of CPAT as an intervention program for healthy older adults. We ask whether attention performance in older adults can be improved following CPAT, over and above improvement that can be achieved following the use of standard (off the shelf) computer games. In addition, we aimed to address one of the limitations in the previous studies using CPAT. In both Shalev et al. (2007) and Sampanis, (2014) there was no follow-up testing to assess the long-term effect of the program. Therefore in the current study we included a follow-up assessment not only to adhere to good practice (van Tulder, Furlan, Bombardier & Bouter, 2003) but also to establish the extent to which the CPAT program can benefit participants on a longer-term basis.

5.1 Computerised Progressive Attention Training (CPAT) with older adults: a comparison between the intervention group and control group.

The present study aimed to assess the effectiveness of attention training (CPAT) as a domain-general approach to intervention in old age and its potential to yield transfer effects to non-trained cognitive tasks and behaviour. Some of the shortcomings of previous studies are also addressed here. Specifically randomisation of participants before they arrive to take part–based on age and sex, the inclusion of an active control group–playing computerised games in a similar manner to the CPAT group, and keeping participants blind to the group assignment (single blind design). The training tasks within CPAT were designed to target specific underlying attention mechanisms (sustained attention, selective attention and executive attention). Moreover, we have also included different tasks for assessing attention mechanisms from the ones used in CPAT so that tasks on which no training was given were used to evaluate the outcome of the intervention. In addition subjective measures were taken so that participants had the opportunity to personally assess the effectiveness of the intervention.

The outcome measures consist of a continual performance task (CPT), a peripheral cueing task, a stroop-like task, a visual search task, a singleton search task, and a motor task. Whilst CPT and visual search tasks are used in the training they differ from those on which the outcome measures are taken. All other outcome measures are non-trained tasks. As cognitive rather than motor training was given, the motor task here assesses for transferrable effects of learning. The motor task has been selected for this purpose as pointing and reaching tasks are common types of motor tasks used to examine movement slowing associated with ageing (Rossit &

Harvey, 2008). It should be noted also that slower motor movements may more generally relate to slower information processing (Salthouse & Coon, 1993). It has been claimed that age related declines in motor function make independent living more challenging, and therefore interventions aiming to slow this decline are essential in order to ensure the safety of older adults in tasks ranging from driving to carrying out housework (Seidler et al., 2010). According to Song and Nakayama (2009), reaching movements require the unified parallel processing of perception, cognition and action. As such this type of motor task would be likely to highlight any improvement in performance, resulting from cognitive/attention training such as that given in the CPAT intervention.

5.1.1 Method

Participants

Participants were 24 older adults, 12 formed the intervention group and the other 12 formed the control group, and for both groups 6 were female. Ages ranged from 61 years and 82 years across both groups (CPAT mean age = 71.6, SD = 7.23, Controls mean age = 72.5, SD = 5.68). Participants were respondents to a poster created by the researcher asking for healthy older adult volunteers, which was placed in health centres and public halls around the central Birmingham area. A pre-requisite to participation was that volunteers were living independently, healthy (self-assessed), and had normal or corrected to normal vision with no colour blindness. Participants' occupations were categorised according to the International standard classification of occupations (ISCO -08) (2008), this revealed that the majority of participants for both groups had been managers or professionals during their working lives (see Table 5.1). Participants were paid (£6 per hour) for their time and commitment at the end of the intervention – following the outcome measures session. No participants withdrew from this intervention. The experiment was carried out in accordance with the ethical guidelines of the University of Birmingham and the BPS (2009). Each participant provided informed consent before taking part.

Table 5.1 *Categories of participants' occupation for each group according to the ISCO -08.*

Occupation	CPAT	Controls
Managers	3	
Professionals	6	8
Technicians	2	1
Clerical	1	1
Services and Sales		1
Armed forces		1

Design

A between groups design was used to examine the effectiveness of the CPAT program to improve the performance on the outcome measures in comparison to that of the control group.

A randomised controlled design was employed, with participants being assigned to either the intervention or control group before they arrived for the baseline measures session. Randomisation was based on sex and age i.e. as participants came forward they were allocated to either the CPAT or Control group based on age and sex to ensure the groups were matched for these two factors.

Stimuli

*Baseline/outcome and follow up measures***.** The baseline measures (Time 1) consisted of five behavioural experiments, one motor task, and two subjective measures. These tasks were also the outcome (Time 2) and follow up (Time 3) measures. All tasks except for the subjective measures were run on a PC which controlled the presentation of the stimuli and data collection in the form of RTs in milliseconds, and accuracy.

The following four experiments were designed to use as baseline, outcome and follow up measures for the CPAT intervention (Tsal, Shalev & Mevorach, 2005) and were also used in the Sampanis (2014) study. These four tasks differed from the training tasks and were developed along with the four functions of attention model proposed by Tsal et al. (2005). The theoretical framework of this model is derived from Posner and Petersen's (1990) theory of attention networks. The four functions of attention model refers to four distinct functions within the attention regime: (i) sustained attention - the ability to maintain focused attention on a tedious task over time; (ii) selective (spatial) attention - the ability to focus attention on a relevant target while ignoring distracters; (iii) orienting of attention - the ability to direct attention over the visual field according to sensory input, and to disengage and reorient efficiently; (iv) executive attention - the ability to resolve conflicts of information and/or responses. For all four tasks stimuli were presented on a black screen and all began with practice trials which provided an auditory indication of an incorrect response (negative feedback). In addition, for all practice trials where too many incorrect responses were made (20% of trials) participants were presented with an on screen message advising this and informing them that they were required to repeat that particular practice trial until correct response rates reached a minimum of 80%. No feedback was provided during the full experiment.

Behavioural experiments:

A Continuous Performance Task (CPT).

This task by Shalev, Ben-Simon, Mevorach, Cohen, and Tsal (2011) measured sustained attention i.e. the ability to maintain on-going and unbroken focus on a continuous task. Participants were presented with stimuli which consisted of a sequence of geometric colour shapes appearing in the centre of the screen (Figure 5.1). The size of each stimulus ranged from 2.5 to 2.7cm in height and from 2.6 to 3.0cm in width. There were 16 possible stimuli resulting from the factorial combinations of square, circle, triangle, or star appearing in red, blue, green or yellow. Participants were instructed to indicate the presence of the target (red square) by pressing the space bar with their preferred index finger, as quickly as possible and to avoid responses to all other stimuli. The target appeared on 30% of the trials. Having a low rate of target present stimuli (30%) and varying the inter-stimulus interval (ISI), this task maintains a high demand on sustained attention but minimizes the involvement of other cognitive factors (Shalev et al., 2011; Stern & Shalev, 2013). On 17.5% of the trials a differently coloured square appeared, on 17.5% of the trials a red non-square geometric shape appeared, and on 35% of the trials a non-target shape appeared, that shared neither identity nor colour with the target. Each stimulus was presented for 100msec and was separated from the next by an interval of 1000, 1500, 2000, or 2500msec. The various stimulus types and inter-stimulus intervals were randomly mixed. The task began with 15 practice trials which were followed by a single block of 320 trials and took approximately 12 minutes to complete.

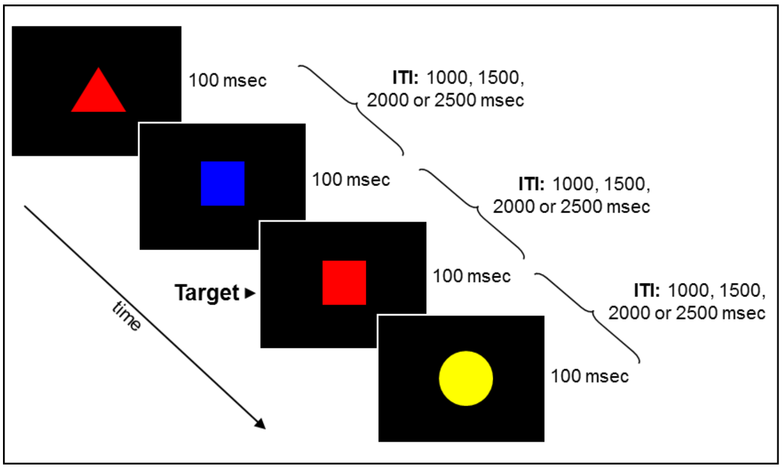


Figure 5.1. Sustained attention outcome measure.

Peripheral Cueing Task.

This task was used to measure attentional orientation and was based on Posner Snyder, and Davidson (1980) which was designed to examine attentional shifts following exogenous cues (Jonides & Irwin, 1981). Participants were instructed to respond to the identity of a stimulus (circle or triangle), which appeared in a cued or an un-cued location (Figure 5.2). A discrimination task in which participants had to indicate whether the target was a circle or triangle was used. The fixation display consisted of a white cross at the center of the screen (0.6cm in width and height) and two white rectangles, subtending 4cm in width and 3cm in height, and centered at 6 cm to the right and to the left of fixation. The cueing display was identical to the fixation display except that one of the rectangles briefly brightened (200ms). The target display consisted of either a white-perimeter circle (subtending 1.4cm in diameter) or a white-perimeter triangle (subtending 1.4cm in length and in height) superimposed on the fixation display and centered inside one of the two rectangles. On each trial, the fixation display appeared for 1000msec, followed by the cueing display that appeared for 100 msec. The fixation display then appeared again for a 100msec following which the target was displayed for 100 msec. The time for response was unlimited. The Inter-trial interval (ITI) was 1500 msec. 80% of trials were valid trials (in which the target appeared at the same location as the bright rectangle) and 20% were invalid trials (in which the target appeared at the location of the other rectangle), randomly mixed within a block. Participants were instructed to respond with their right index finger to the circle and with their left index finger to the triangle. The task began with 10 practice trials which were followed by three blocks of 60 trials each.

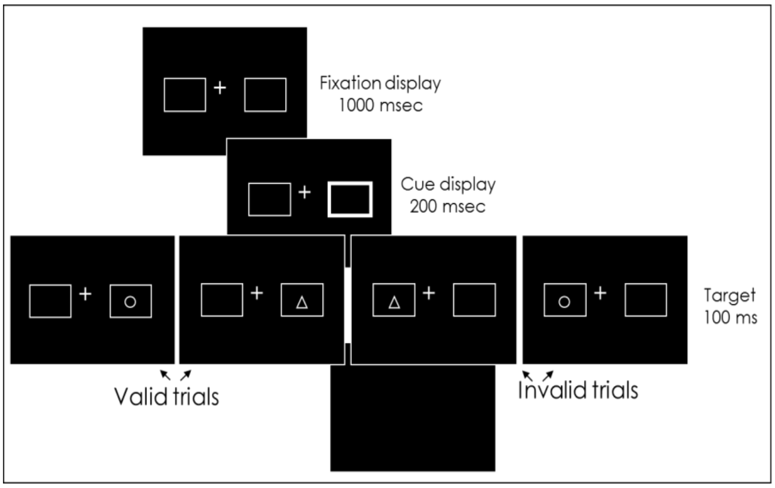


Figure 5.2. Orientation attention outcome measure.

Stroop-like task

Measuring executive attention, and based on the Stroop test (1935), this task was designed to measure the interference caused by conflicting stimuli. Again this task is the same as described in the Sampanis (2014) study. Participants were presented with a single stimulus varying along two dimensions which could elicit conflicting responses. A white arrow subtending 1.5cm in height and 0.6cm in width, pointing either up or down, appeared either 1.2cm above or below fixation along the vertical meridian (Figure 5.3). Participants responded “up” with their right index finger and “down” with their left index finger. The task was composed of two subtasks: Location judgments and direction judgments. In the location subtask participants were required to respond “up” or “down” according to the location of the arrow (above or below fixation) ignoring its direction. In the direction subtask participants were required to respond “up” or “down” according to the direction in which the arrow is pointing ignoring its location. On 50% of the trials within each block the condition was congruent (e.g. an arrow above fixation pointing upward) and 50% were incongruent (e.g. an arrow above fixation pointing downward). These two types of trials were randomly presented within each block. Each display was preceded by a 1000msec white central fixation cross. The stimulus was presented for 150msec. The time for response was unlimited. The ITI was 1500msec. Participants began the task with 10 practice trials following which they were presented with two 40-trial "location" blocks followed by two 40-trial "direction" blocks.

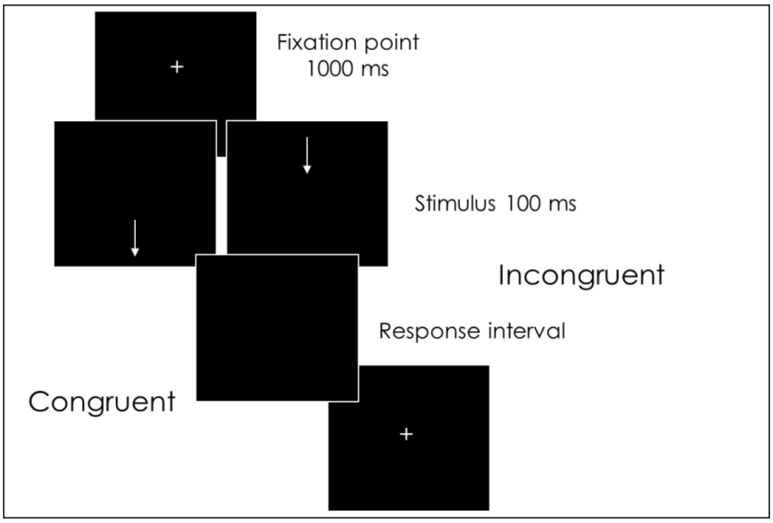


Figure 5.3. Executive attention outcome measure.

Visual Search Task

Measuring selective attention, this task measured the ability to identify a target item set amongst different numbers of distractor items which varied in their similarity to the target. More specifically the procedure was based on a conjunctive search task used by Treisman and Gelade (1980). Participants were required to search for a target defined as a specific conjunction of colour and shape. The target was a blue square (1.1cm in width and height) appearing among an equal number of red squares (1.1cm in width and height) and blue circles (1.1cm in diameter; Figure 5.4). There were four display sizes of 4, 8, 16 or 32 items, which were equally frequent and randomly intermixed within a block. The items were randomly positioned within a 7 x 6 matrix subtending 9.5cm in width and 8cm in height. The target was present on 50% of the displays. Each trial began with the presentation of a small white central cross (0.6cm in width and height) for 1000msec which was immediately followed by the onset of the search display which remained on until response. The ITI, from response to the presentation of the fixation point, was 500 msec. Participants were required to respond with their right index finger to the presence of the target and with their left index finger to its absence. There were 10 practice trials prior to four 40 trial blocks.

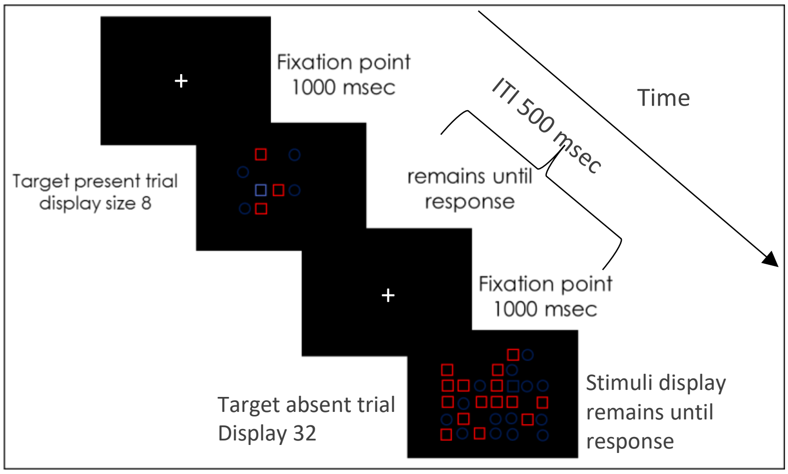


Figure 5.4. Selective attention outcome measure

Singleton search task

Measuring visual selection, this task is a variation of that designed by Theeuwes (1991) to examine top-down and bottom-up processing using stimuli with stored knowledge associations (Figure 5.5). This experiment was used in Chapter 4 of this thesis where full details of this task can be found.

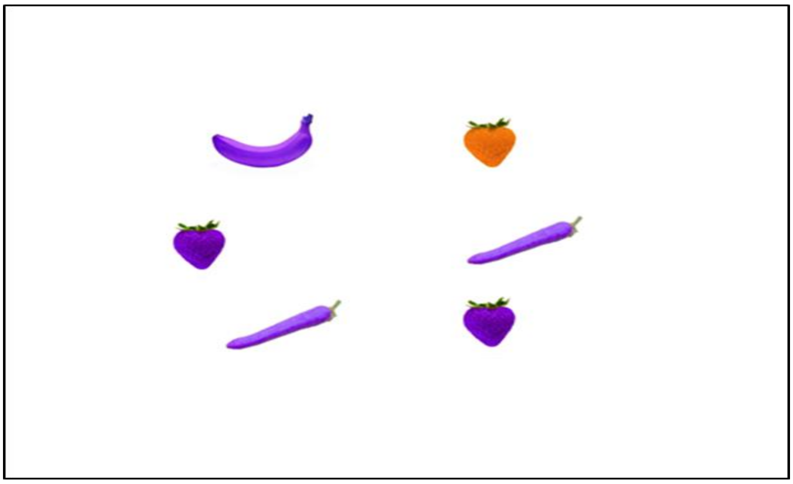


Figure 5.5. Selective attention outcome measure 2

Motor task (selection of pop-out).

A simple pointing task (based on Fitts's Law, 1954) was used to measure the deployment of focal attention, with both the latency (ms) and trajectory/maximum deviation of movement recorded (millimetres). Participants were required to use their right index finger (regardless of handedness) to point to the odd-colour-out square in a display of three items as quickly as possible (the location of the target square (which was either green or red) changed according to streak). The length of the streaks varied between 1 and 6. For example, in a streak of 4 the colour pattern may be 'green', 'green', 'green', 'green', 'red', where the first green and first red presentations are 'switch' trials where the colour changes after a run of repetitions. Thus streak 1 actually measures a switch. The second, third, and fourth red presentations are referred to as streak 2, streak 3, and streak 4. The colour of the target was random however the number of streaks for each was equal. The stimuli were presented on a black screen and all three squares measured 3.8cms across. There were two blocks of 96 trials and on half of the trials there were two red squares with the target (third) being green (Figure 5.6), whilst on the other half of all trials two squares were green and the target (third) was red. The distance between each was approximately 60cms. According to Maljkovic and Nakayama (1994) discrimination of a target feature relies upon the deployment of focal attention to the target item, therefore improvements on this task, as a result of the training will be evident if the CPAT group show a reduced effect of streak. The experiment was programmed and run in Matlab with Qualisys ProReflex MCU240, 60Hz motion detection cameras capturing data which were generated by placing an infra-red passive reflective 4mm marker on the index finger of the right hand of each participant. Motion was recorded in each trial from the point at which the button (that initiated recording) was depressed for a 4000ms period – allowing enough time for the participant to complete the reach.

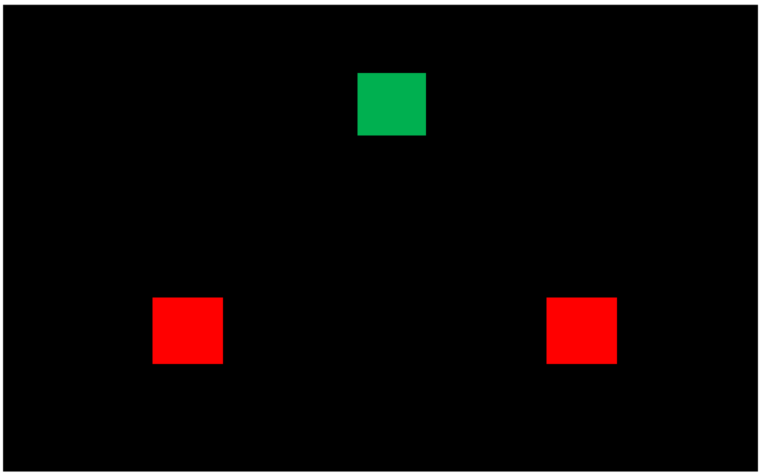


Figure 5.6. Motor task measuring focal attention (Target = green square)

Subjective measures.

The Cognitive Failures Questionnaire (Broadbent, Cooper, FitzGerald, & Parkes, 1982). On this measure 25 questions were asked about daily performance relating to memory and attention (permission to use this questionnaire for this study was granted by Copyright Clearance Center's RightsLink service on 25/04/2012).

Responses were given on a 5 point Likert scale ranging from 4 which represents ‘Very often’ to 0 representing ‘Never’. Thus high scores on this questionnaire are representative of experiencing more episodes of forgetfulness, confusion and inattention. In addition a semi-structured interview was designed and carried out. However due to a shortage of space it is not reported here but can be seen in Appendix B.

Training Tasks

CPAT group.

Participants in this group were trained on three attention tasks – Global local, CPT and Search (these are the training tasks which were used in the Shalev et al. (2007), and the Sampanis (2014) studies). These tasks were selected as they are widely accepted to target specific aspects of attention. Each of the three tasks began with the easiest condition and as proficiency at each level improved the level of difficulty increased, and at the end of each block (six levels in each) the participant would be informed that they would be going on to the next block. For each task the increase in difficulty had been deliberately designed to require a substantial increase in attainment in order to progress on to the next level, and had been tested to ensure that progression to each new level resulted in an increase in RTs and higher error rates (Shalev et al., 2007). Proficiency was assessed according to measurements taken during the practice round for each new level of each task; it was based on average RTs during the practice trials together with a fixed accuracy rate. At the beginning of each new block the participant would receive instructions on the screen and from the researcher as to what was now required. During each task (not for CPT) feedback was provided on each trial, indicating how performance on each trial compared to performance in the practice trials. At the end of each block (on all three tasks) participants received feedback on performance, informing them of how many correct and incorrect responses they made and whether this overall performance was better or worse than previous performances. Performance was translated in to points for each session.

The Global local task (Figure 5.7) is based on Navon's (1977) task and includes elements of the Stroop task (Stroop, 1935). This task was designed to improve executive attention by encouraging inhibition of incorrect responses, efficient switching of focus and dividing attention. Each block consisted of 40 trials. At the beginning participants were asked to indicate whether any global smiling face (made up of small smiley faces, small hearts or small cubes) was present or absent on each trial throughout the whole block (L key for present and A key for absent) and as difficultly increased participants were asked to identify randomly changing specific global or local aspects of the stimuli (always a smiley face), as instructed by a simple depiction at the start of each trial.

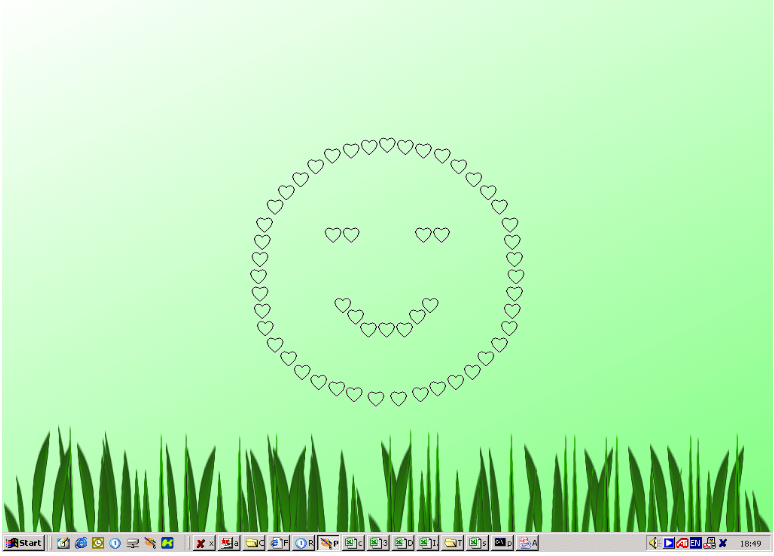


Figure 5.7. Executive attention training - the global configuration of the hierarchical figure forms a smiley face (a target at level 1). As difficulty level increases elements of working memory and task switching are inserted to the task making it extremely challenging and involving different aspects of executive functions.

This CPT task (Figure 5.8) differed to that used for the baseline (outcome and follow-up) measures in that it was more complex e.g. the background was not plain, the target was not one dimensional and it changed position across trials. The task was based on that of Rosvold, Mirsky, Sarason, Bransome and Beck, et al. (1956) and was designed to improve sustained attention by requiring attention to be continuously maintained whilst inhibiting incorrect responses to stimuli. Blocks for this task began with 80 trials (easier stage) with 30% of the stimuli being the target, and increased to 160 trials (harder stage) with only 20% of the stimuli being the target. At the beginning participants were asked to respond (by pressing the space bar) only when the target appeared on the screen, and as difficulty increased (in addition to the increase in the number of trials) they were asked to respond when the target appeared in one of two boxes, with distractors appearing simultaneously next to the boxes or in the boxes (as seen below in Figure 5.8). On this task the standard deviation of RTs were used as the measure determining progression of difficulty, this is because it provides a measure of variability thus consistently good performance is identified and participants are consequently moved up to a more difficult level.

Figure 5.8. Sustained attention training - target (red car) is present but not in one of the two target boxes thus response must be inhibited. This is a higher difficulty level with distractors present in the target location (one of the boxes).

The conjunctive search task (Figure 5.9) differed from the baseline search task in that the background was not simply one solid colour and the target and distractors jittered on the screen. This task was designed to improve selective attention by encouraging the ability to ignore irrelevant information. Each block consisted of 40 trials and began with a white background and with only six simple items (simple smiley faces) on each display which remained still, and the distractors (red smiley boys and green smiley girls) were relatively dissimilar to the target (green smiley boy). However as the difficulty increased the background was no longer one solid colour, stimuli were randomly situated, and jittered, and the number of items increased from 6, going on to 12 and eventually up to 24. In addition the distractors were made progressively more similar to the target (as shown below). Participants were required to indicate whether the target was present or absent on each screen by pressing the L key for present and the A key for absent.

Figure 5.9. Selective attention training - here the target is present (orange quiditch on a broom with open arms in the centre of the display), and the visual load is high (many items presented on a noisy background) placing a high demand on selective attention.

Control group.

Participants in this group played three different computer games – Minesweeper, Solitaire and Mahjong. All three games had a time element i.e. each game has a timer on the screen, the purpose of which was to decrease the time taken to succeed at each game. The games were selected because all required engagement of executive attention.

Minesweeper

The aim of this game was to uncover all of the squares whilst avoiding uncovering the 10 bombs (as doing so would cause the game to restart). This is done using the numbers revealed in each square (in the absence of a bomb) as an indication of how many bombs surrounded each square. During the game a timer displayed the length of time taken (Figure 5.10).

Figure 5.10. Minesweeper game – showing at the start of the game that there are 10 hidden bombs, and a timer.

Solitaire

The aim of this game was to uncover all cards and place them in numerical order in the correct suits. This was achieved by strategically selecting and moving cards according to several rules. During the game a timer displayed the length of time taken and number of moves made (Figure 5.11).

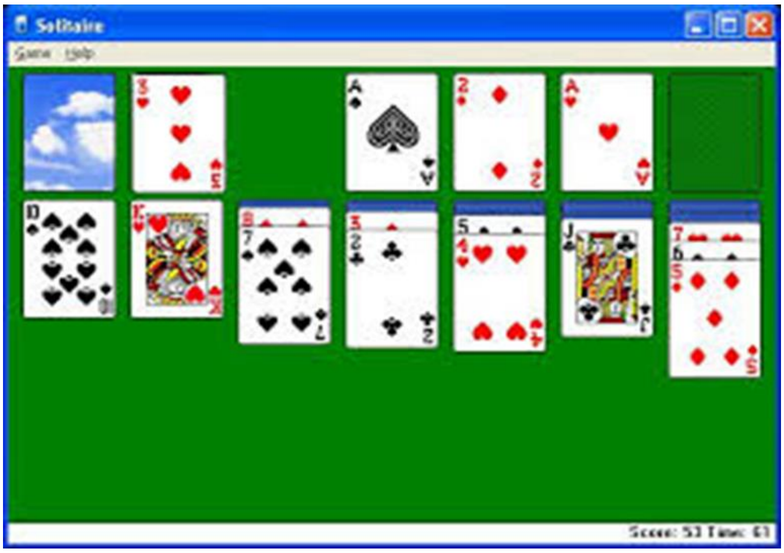


Figure 5.11. Solitaire game – here the card just played cannot be placed and so another card must be turned over from the pile (top left). The timer and number of moves are shown in the bottom right hand corner.

Mahjong

The aim of this game was to clear the screen of all tiles; this was done by matching pairs (according to several rules) which caused the matched pairs to disappear from the screen. Once again there was a display showing the length of time and number of moves taken (Figure 5.12).

Figure 5.12. Mahjong game – tiles must be paired but only the tiles on the outsides can be used. Timer and number of moves made and shown across the top.

Procedure

Participants were healthy volunteers who had responded to a recruitment poster placed in local public places e.g. community centre etc. Participants were made aware that they were taking part in an intervention study but were blinded to the fact that there were two groups – CPAT and control, thus this was a single blind design. Participants were booked where possible to begin their participation at 10am for all three sessions (baseline, outcome and follow up). If it was not logistically possible to make this time, all three sessions were booked for similar times. For all participants the procedure for the baseline, outcome and follow up measures were the same, regardless of whether individuals were assigned to the experimental or control group. The whole process took approximately three hours for each session, depending on how quickly participants got through the tasks and how long each individual took for breaks. The follow up measures took slightly less time as no semi-structured interview was carried out. As an incentive to complete the full intervention participants were advised before they began that they would receive payment for their time and commitment at the end of the outcome measures session.

The session began with the pointing task in a darkened room; participants had a passive marker placed on the index finger nail of their right hand (regardless of handedness) and were asked to remove any jewellery which could interfere with camera capture. Participants were informed to follow the instructions on the screen which asked them to hold their index finger on the button on the table in front of them until the stimuli appeared on the screen. When the stimuli appeared they were requested to point to the odd square out as quickly as possible and hold there until the stimuli disappeared from the screen, after which they would place their finger back on the button. Participants were given a short break between the two blocks of 96 trials. Each block began with 3 practice trials. Following completion of the pointing task, participants were taken to a different room in the same building where all other baseline measures were taken.

All experiments were carried out in the same order for all participants and each of the behavioural experiments had practice trials. The first of the behavioural experiments was the CPT experiment. This task was conducted early in the session because in the pilot study the participants had indicated that they felt this task was the most tedious task and when conducted at the end of the session it made them feel lethargic thus continuous concentration was extremely difficult at this point. Participants were warned that this task had no breaks as it was a continuous task and that it would last for approximately 12 minutes. Once again participants were given a practice run, this time of 15 trials with auditory negative feedback, and more than 20%

incorrect responses to the practice trials necessitated repetition of the practice trials. When the practice trials had been successfully completed the full task of 320 trials followed, without any feedback.

The next task was the Peripheral cueing task. There were 10 practice trials at the start of each of the three blocks; once again these trials gave auditory negative feedback and 20% or more incorrect responses necessitated repetition of these trials. Successful completion of the practice trials was followed by the full experiment, with 60 trials on each of the three blocks.

The next task was the Cognitive Failures Questionnaire (Broadbent et al., 1982). Participants were asked to answer all questions as honestly and quickly as they could. Following completion of this task participants were taken down stairs for a 10-minute comfort break and were offered a drink and an opportunity to rest or chat as they preferred.

Upon returning to the experimental room the Stroop-like task was carried out. Again there were 10 practice trials providing auditory negative feedback and if there were too many mistakes, participants were required to repeat the practice trials. These trials were followed immediately by the full experiment. There were four blocks in total, each consisting of 40 trials. After two consecutive blocks of indicating the location of the arrow the aim of the experiment changed and participants were requested to indicate which direction the arrow was pointing in. Instructions were presented on the screen advising the participant of the change in task and 10 practice trials preceded the two direction blocks, still using the A key to indicate down and the L key to indicate up.

The next task was a conjunctive search task Participants had 10 practice trials with auditory negative feedback and were required to repeat this if they made too many mistakes. The full experiment followed which consisted of four blocks of 40 trials.

In order to allow participants to break from the screen and to avoid having 2 consecutive search tasks the semi-structured interview was conducted next. The final task was a singleton search task which had previously been used to examine the effects of a singleton distractor when real life items were used in place of the usual shapes (see chapter 4).

The training sessions began the week after the baseline measures had been taken. There were three one-hour training sessions given for three consecutive weeks. Availability for this had been a pre-requisite of participation. Participants were generally asked to come in to the University of Birmingham for these sessions on a Monday, Wednesday and Friday and were asked where possible to maintain a particular time slot for all training sessions. This was the case for both the experimental group and the control group; also all sessions for both groups took part in the same room using the same computer. Whilst no official break was given in the sessions, participants were encouraged to briefly relax and chat between tasks.

For the CPAT group, training began with the search task, followed by the global local task and then the CPT task. Each task lasts only a few minutes and so typically a participant would get through at least two blocks of each task in one session, however once again this was dependant on the ability and speed of the participant and the time taken between each task.

For the control group, sessions began with Minesweeper, then Mahjong and finally Solitaire. Each game was played for approximately 17 minutes, and the number of games completed in this time depended on the ability of the participant and the length of time they took between games.

Following training participants were asked to come in the following week for the outcome measures. After this no further training was given, and then approximately four months later (depending on availability) participants were asked to return for the follow up measure session.

5.1.2 Results

Behavioural Experiments

The results were analysed initially as Time 1 vs. Time 2 in order to assess for any immediate changes in performance, and then separately as Time 2 vs. Time 3 to assess for stability in the changes over a 4-month period. All participants completed all tasks at all three time points.

Continuous performance task: comparison of performance at Time 2 relative to Time 1

Average error rates for this task were very low for both groups at Time 1 (CPAT *M* = 4% and Control *M* = 3.5%) and at Time 2 (CPAT *M* = 3.5% and Control *M* = 4%). A Paired t-test comparing the omission error rates at Time 2 to Time 1 indicated there were no significant differences for either group (CPAT *t*(11) = 1.000, *p* = .339 *n.s.*, Control *t*(11) = <1, *p* = .586 *n.s.*). Paired t-tests on the commission errors also revealed no differences between Time 1 and Time 2 for either group (CPAT *t*(11) = <1, *p* = .749 *n.s.*, Controls *t*(11) = <1, *p* = .995. *n.s.* No participants were excluded as a result of high error rates for this task.

A mixed design ANOVA was conducted on RTs with Time (1 and 2) as the within subject factor and Group as the between subjects factor. No significant differences were revealed between the Groups *F*(1,22) = <1, (CPAT *M* = 444.40, *SE* = 12.61, Control *M* = 452.82, *SE* = 12.61), as was the case for the main effect of Time *F*(1,22) = <1 (CPAT *M* = 447.47, *SE* = 10.75, Control *M* = 449.74, *SE* = 10.16) and the interaction Time x Group *F*(1,22) = 2.577, *p* = .123 *n.s.* (see Figure 5.13).

As this was a continuous performance task standard deviations scores are important to examine as these scores demonstrate the extent to which the behaviour was maintained over the whole task (as there are no breaks). As such a mixed design ANOVA was carried out using the standard deviations data. The within subjects factor was Time (1 and 2) and the between subjects factor was Group. No significant results were revealed (Time *F*(1,22) = 1.067, *p* = .313, and Time x Group *F*(1,22) = 1.440, *p* = .243) (see Figure 5.14).

Continuous performance task: comparison of performance at Time 3 relative to Time 2

Error rates on this task at Time 3 were very low for both groups (CPAT group = .3% and Control group = .6%). Paired t-test comparing the omission error rates at

Time 3 to Time 2 indicated there were no significant differences for either group (CPAT $t(11) = <1$, $p = .998$ *n.s.*, Control $t(11) = <1$, $p = .588$ *n.s.*). Paired t-tests on the commission errors also revealed no differences between Time 3 and Time 2 for either group (CPAT $t(11) = <1$, $p = .477$ *n.s.*, Controls $t(11) = -2.161$, $p = .061$ *n.s.*). No participants were excluded for high error rates. No further investigation of the error rates was required.

A mixed design ANOVA was conducted on RTs with Time (2 and 3) as the within subjects factor and Group as the between subjects factor. The results revealed no significant differences between the Groups $F(1,22) = 3.117$, $p = .091$ *n.s.*, as well as no significant main effect of Time $F(2,44) = <1$, and a non-significant interaction $F(2,44) = <1$. (see Figure 5.13).

However once again because this is a continued performance task standard deviation of RTs is an important measure which indexes the participant's ability to sustain attention over the course of the task (i.e., how stable performance is throughout the course of the task), thus a further mixed design ANOVA was conducted here using standard deviations, again with Time as the within subjects factor and Group as the between subjects factor. The results still indicated no significant differences between the Groups $F(1,22) = 2.358$, $p = .139$ *n.s.*, and no main effect of Time $F(1,22) = <1$, and again the interaction was non-significant $F(1,22) = <1$ (see Figure 5.14). Whilst there was not a significant improvement from Time 2 to Time 3, there was not a significant decline in performance either thus suggesting that performance remained stable from Time 2 to Time 3 for both groups.

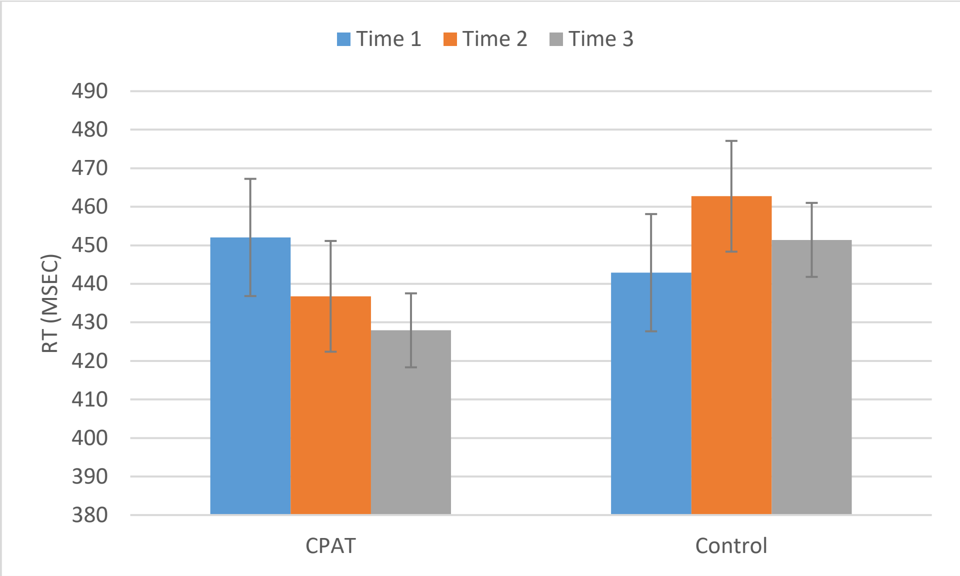


Figure 5.13. RTs on the Continuous performance task for both groups at Times 1 – 3 (with standard error bars).

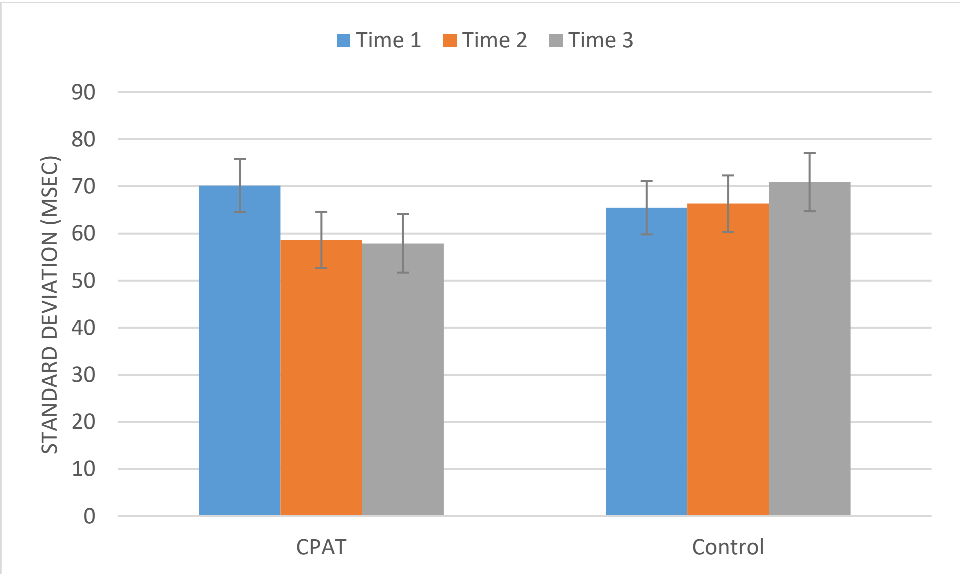


Figure 5.14. Standard deviations on the Continuous performance task for both groups at Times 1 – 3 (with standard error bars).

Peripheral cueing task: comparison of performance at Time 2 relative to Time 1

The average error rate for the CPAT group at Time 1 was 4.5% and for the Control group it was 3.5%. At Time 2 the average error rate for the CPAT group was 4% and for the control group it remained at 3.5%. No participants were excluded as a result of high error rates for this task. A mixed design ANOVA was carried out with Cue (Valid and Invalid) and Time (Time 1 and Time 2) as within factors and Group as the between factor. The only significant result was a main effect of Time $F(1,22) = 5.228$, $p = .032$ whereby more errors were made at Time 2 ($M = .046$, $SE = .008$) relative to Time 1 ($M = .031$, $SE = .002$). As such no further investigation of error was required here.

A mixed design ANOVA was carried out with Cue (Valid and Invalid) and Time (Time 1 and Time 2) as within factors and Group as the between factor. Significant main effects were revealed for Cue $F(1, 22) = 70.911$, $p = .0001$; and Time $F(1, 22) = 4.663$, $p = .042$. In addition a significant two-way interaction was revealed for Time x Group $F(1, 22) = 5.607$, $p = .027$ (see Figure 5.15). This interaction revealed that there was a greater gain in overall latencies for the CPAT group $t(11) = 3.094$, $p = .010$ (overall RT at time 1: $M = 611.90$, $SE = 24.53$, and at time 2: $M = 558.27$, $SE = 29.43$) relative to the control group $t(11) = <1$ (overall RT at time 1: $M = 635.61$, $SE = 24.53$, and at time 2: $M = 638.08$, $SE = 25.09$). However the magnitude of the validity effect was the same across the groups and the validity effects did not differ as a function of training (Time 1 vs. Time 2).

Peripheral cueing task: comparison of performance at Time 3 relative to Time 2

The error rates for this task were low for both groups at Time 3 (CPAT group = 4%, and the Control group = 3%). No participants were excluded for high error rates. A mixed design ANOVA was carried out with Cue (Valid and Invalid) and Time (Time 1 and Time 2) as within factors and Group as the between factor. There were no significant results revealed thus no further investigation of error was required here.

A mixed design ANOVA with Cue (Valid and Invalid) and Time (Time 2 and Time 3) as within subjects factors and Group as the between subjects factor revealed a significant main effect of Cue $F(1, 22) = 53.382$, $p = .0001$. All other results were non-significant (Group = $F(1,22) = 2.304$, $p = .143$; Time $F(1,22) = <1$; Cue x Group $F(1,22) = <1$; Time x Group $F(1,22) = 3.567$, $p = .072$; Cue x Time $F(1,22) = <1$; Cue x Time x Group $F(1,22) = <1$) (see Figure 5.15). However because the Time x Group interaction was nearing significance Paired t-tests were carried out and indicated no significant differences between Time 2 and Time 3 for either group (CPAT $t(11) = -1.518$, $p = .157$; Control $t(11) = 1.291$, $p = .223$. Thus the benefits of faster RTs at Time 2 in the CPAT group did not develop further over time, however once again as there is also no evidence of a significant decline in performance in either group it seems performance therefore remained stable over time.

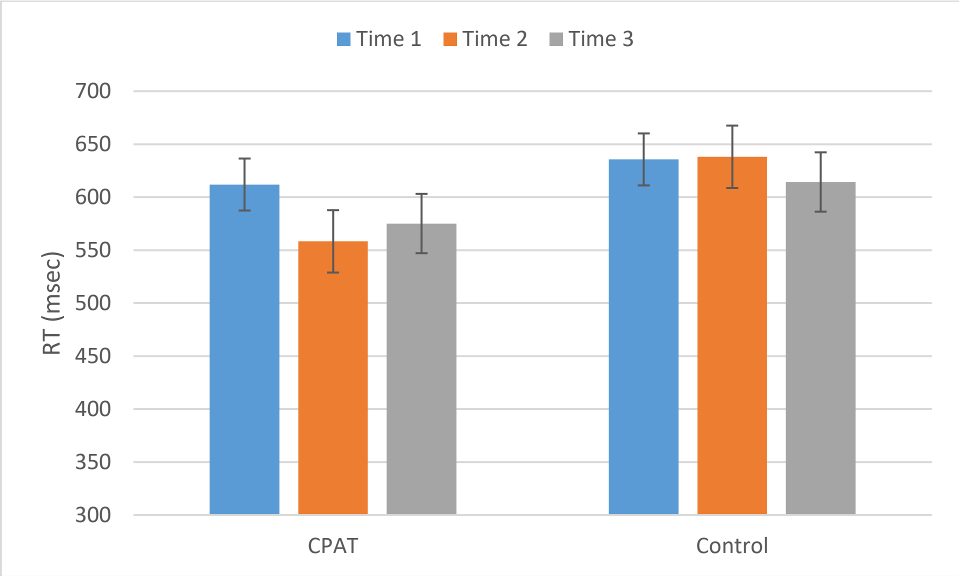


Figure 5.15. Mean RTs on the Peripheral cueing task for both groups at Times 1, 2, and 3 (with standard error bars).

Stroop-like task: comparison of performance at Time 1 relative to Time 2

Error rates at Time 1 were very similar for both groups (CPAT M = 2.25%, and Control M = 2%), at Time 2 the average error rate for the CPAT group was 1.5% (SE = .005), for the Control group it was 3.75% (SE = .022). No participants were excluded for high error rates in this experiment. A mixed design ANOVA was carried out on the Time 1 and Time 2 data to examine these differences between the groups. The within subject factors were Dimension (Location and Direction), and Congruency (Congruent and Incongruent), and the between subject factor was Group. The ANOVA revealed only one significant result, for the 2-way interaction Dimension x Congruency $F(1,22) = 4.609$, $p = .043$. Paired t-tests indicate a significant difference in errors between congruent and incongruent when responses were made to the direction of the arrow $t(23) = 5.919$, $p = .0001$ (direction congruent M = .98, SE = .01; direction incongruent M = .96, SE = .01). Whereas when the responses were made to the location of the arrow there was no difference according to congruency (location congruent *M* = .98, *SE* = .01; location incongruent *M* = .98, *SE* = .01). All other results were non-significant thus importantly indicating no differences between the groups as such no further examination was required (Group *F*(1,22) = <1; Time *F*(1,22) = <1; Time x Group *F*(1,22) = <1; Dimension *F*(1,22) = <1; Dimension x Group *F*(1,22) = <1; Congruency *F*(1,22) = 3.756, *p* = .066, *n.s;* Congruency x Group *F*(1,22) = 2.309, *p* = .143 *n.s.*; Time x Dimension *F*(1,22) = 1.228, *p* = .280 *n.s.*; Time x Dimension x Group *F*(1,22) = 3.187, *p* = .088 *n.s.*; Time x Congruency *F*(1,22) = <1; Time x Congruency x Group *F*(1,22) = 1.170, *p* = .291 *n.s.*; Dimension x Congruency x Group *F*(1,22) = 1.927, p = .179 *n.s.*; Time x Dimension x Congruency *F*(1,22) = 2.075, *p* = .164 *n.s.*; Time x Dimension x Congruency x Group *F*(1,22) = <1).

A mixed design ANOVA was carried out on RT data with Dimension (Location and Direction), Congruency (Congruent and Incongruent) and Time (1 and 2) as within subject factors and Group (CPAT and control) as between subject factor. Significant main effects were revealed for all three within factors: Dimension *F*(1, 22) = 64.180, *p* = .0001; Congruency *F*(1, 22) = 59.630, *p* = .0001; and Time *F*(1, 22) = 4.361, *p* = .049. In addition significant two-way interactions were revealed for Congruency x Group *F*(1, 22) = 6.433, *p* = .019; Time x Group *F*(1, 22) = 7.505, *p* = .012; and Dimension x Congruency *F*(1, 22) = 14.385, *p* = .001. Moreover a significant four way interaction was revealed Dimension x Congruency x Time x Group *F*(1, 22) = 4.828, *p* = .039.

The significant 4-way interaction was decomposed by running further separate ANOVAS according to group. The within subject factors were Dimension (Location and Direction), Congruency (Congruent and Incongruent) and Time (1 and 2). In relation to the CPAT group (see Figure 5.16) there was a significant main effect of Dimension $F(1,11) = 84.613$, $p = .0001$, and Congruency $F(1,11) = 50.863$, $p = .0001$, as well as of Time $F(1,11) = 10.287$, $p = .008$. In addition there was a significant interaction between Dimension x Congruency $F(1,11) = 21.134$, $p = .001$. All other results for this group were non-significant (Dimension x Time: $F(1,11) = 2.002$, $p = .185$, *n.s.*). In respect of the Control group (see Figure 5.17) there was a significant main effect of Dimension $F(1,11) = 15.740$, $p = .002$, and Congruency $F(1,11) = 30.316$, $p = .0001$, but not of Time. There were no significant interactions for this group however there was a near significant interaction between Dimension x Congruency x Time $F(1,11) = 4.323$, $p = .062$. (Dimension x Congruency $F(1,11) = 3.540$, $p = .087$, *n.s.*). Importantly these results indicate that at Time 2 relative to Time 1 the CPAT group had significantly improved RTs (Time 1: $M = 614.67$ms, $SE = 39.88$, Time 2: $M = 548.65$ms, $SE = 25.67$), whereas this was not the case for the Control group (Time 1: $M = 643.60$ms, $SE = 28.22$, Time 2: $M = 652.51$ms, $SE = 31.64$). As the source of the 4-way interaction seemed to be the near significant 3-way interaction for the Control group, the 4-way interaction was investigated further by carrying out separate repeated ANOVAs according to Time for the Control group. The within subject factors for both ANOVAs were Dimension (Location and Direction) and Congruency (Congruent and Incongruent). The Time 1 ANOVA revealed a main effect of Dimension $F(1,11) = 9.836$, $p = .009$, and of Congruency $F(1,11) = 36.306$, $p = .0001$, however the interaction was non-significant $F(1,11) = 1.082$, $p = .321$ *n.s.*. Whereas the Time 2 ANOVA revealed Main effects of Dimension $F(1,11) = 13.257$, $p = .004$, and Congruency $F(1,11) = 19.945$, $p = .001$, as well as a significant interaction Dimension x Congruency $F(1,11) = 5.339$, $p = .041$. Paired t-tests indicated a significant difference between congruent and incongruent when responses were made to the direction of the arrow *t*(11) = -6.904, *p* = .0001 (Congruent *M* = 624.40, *SE* = 26.44; Incongruent *M* = 753.38, *SE* = 36.93), but not when responses were made to the location of the arrow *t*(11) = -1.883, *p* = .086 (Congruent *M* = 586.44, *SE* = 33.09; Incongruent *M* = 645.82, *SE* = 43.80). This results indicates that at Time 2 the Control group were demonstrating a greater effect of congruency in the direction condition relative to the location condition which had not been the case at Time 1. With regards to the performance of the CPAT group these findings indicate that their performance had improved in respect of faster RTs at Time 2 relative to Time 1.

Stroop-like task: comparison of performance at Time 3 relative to Time 2

The error rates for this task at Time 3 were even lower than they had been at Time 1 and Time 2 for both groups (CPAT = 1.25%, and Control = 1.40%). No participants were excluded for high error rates on this task. A mixed design ANOVA was carried on the Time 2 and Time 3 data to examine the error rates further. The within subject factors were Dimension (Location and Direction), and Congruency (Congruent and Incongruent), and the between subject factor was Group. The Congruency x Time interaction was significant *F*(1,22) = 9.306, *p* = .006. Paired t-tests indicated that at Time 2 there was no significant difference in errors between congruent and incongruent *t*(23) = 1.030, *p* =.314, whereas at Time 3 the difference was significant *t*(23) = 3.069, *p* = .005 (Congruent *M* = .07, *SE* = .01; Incongruent *M* = .12, *SE* = .02), suggesting that at Time 3 errors reflected a greater congruency effect. No further investigation of error rates was required.

A mixed design ANOVA was carried out on RT data with Dimension (Location and Direction), Congruency (Congruent and Incongruent), and Time (Time 2, and Time 3) as within subject factors and Group as the between subjects factor. Significant main effects were revealed for Dimension $F(1, 22) = 99.471$, $p = .0001$, and Congruency $F(1, 22) = 44.634$, $p = .0001$. The effect of Group was nearing significance $F(1,22) = 4.014$, $p = .058$, here the CPAT group had faster RTs ($M = 558.86$, $SE = 28.81$) relative to the Control group ($M = 640.48$, $SE = 28.81$). However the main effect of Time was non-significant $F(1,22) = <1$. A near significant two-way interaction was revealed for Time x Group $F(1,22) = 4.069$, $p = .056$. In addition a 2-way interaction was revealed between Dimension x Congruency $F(1, 22) = 21.364$, $p = .0001$.

Independent t-tests were carried out to investigate the data further and results revealed that, whilst RTs at Time 2 were significantly different between the groups $t(22) = -2.549$, $p = .019$ (CPAT $M = 548.65$, $SE = 25.67$; Control $M = 625.51$, $SE = 31.64$) at Time 3 the difference was non-significant $t(22) = -1.362$, $p = .187$ (CPAT $M = 569.07$, $p = 31.83$; Control $M = 628.45$, $SE = 29.81$). Here we can see that whereas the performance of the CPAT group declined from Time 2 to Time 3 the performance of the Control group improved. Therefore it seems that the benefits gained from the CPAT training on this task at Time 2 (faster RTs) were not further developed at Time 3 but nonetheless remained faster (RTs) than the Control group (as evidenced by the near significant effect of Group) and thus to some extent remained stable over a 4-month period (see Figures 5.16 and 5.17).

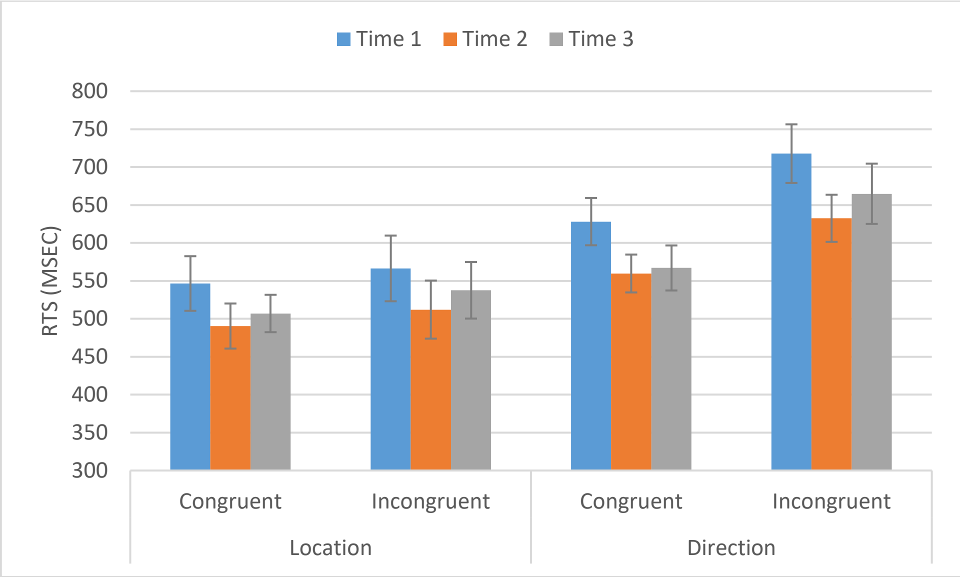


Figure 5.16. RTs on the Stroop-like task for the CPAT group in all four conditions at Times 1, 2 and 3 (with standard error bars).

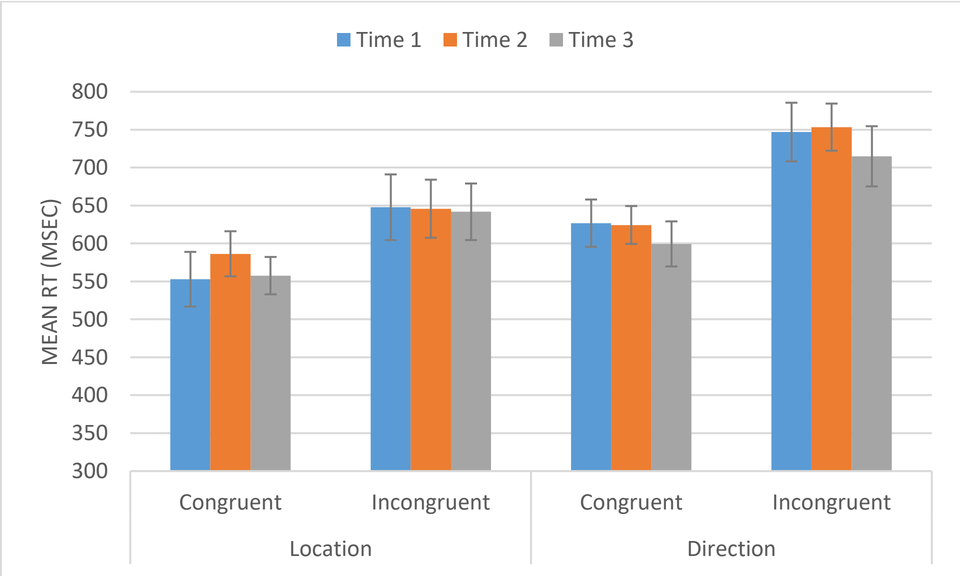


Figure 5.17. RTs on the Stroop-like task for the Control group in all four conditions at Times 1, 2 and 3 (with standard error bars).

Visual search task: comparison of performance at Time 1 relative to Time 2

Error rates for the CPAT group at Time 1 *M* = 3.2%, *SE* = .01, and for the Control group *M* = 5.3%, *SE* = .01. At Time 2 the CPAT group error rate average *M* = 4.1%, *SE* = .01, and for the Control group *M* = 2.5%, *SE* = .01. A mixed design ANOVA was carried out to examine these differences further whereby the within subjects factors were Time (1 and 2) and Display size (4, 8, 16 and 32). However the only significant result was a main effect of Display size $F(3,66) = 20.192$, $p = .0001$. Paired t-tests indicated that display size 32 had significantly more errors than all the other display sizes: display size 32 (*M* = 1.88, *SE* = .40) vs. display size 4 (*M* = .12, *SE* = .04) $t(23) = 4.583$, $p = .0001$; display size 32 vs. display size 8 (*M* = .06, *SE* = .03) $t(23) = 4.519$, $p = .0001$; display size 32 vs. display size 16 (*M* = .18, *SE* = .05) $t(23) = 4.551$, $p = .0001$. As mentioned above all other results from the ANOVA were non-significant (Group $F(1,22) = 1.331$, $p = .261$ *n.s.*; Time $F(1,22) = 1.423$, $p = .246$ *n.s.*; Time x Group $F(1,22) = 3.578$, $p = .072$ *n.s.*; Display size x Group $F(3,66) = <1$; Time x Display size $F(3,66) = 1.323$, $p = .725$ *n.s.*; Time x Display size x Group $F(3,66) = 2.970$, $p = .097$ *n.s.*). No participants were excluded as a result of high error rates for this experiment.

A mixed design ANOVA was also carried out on the RT data with Display size (4, 8, 16 and 32) and Time (1 and 2) as within factors and Group as the between factor. Significant main effects were revealed for both Display size $F(3, 66) = 202.245$, $p = .0001$ and Time $F(1, 22) = 13.580$, $p = .001$. In addition a significant interaction was revealed for Time x Group $F(1, 22) = 17.623$, $p = .0001$. This interaction indicated that there was an overall gain in RTs for the CPAT group $t(11) = 6.233$, $p = .0001$ (overall RTs at Time 1 *M* = 920.32ms and those at Time 2 *M* = 789.33ms) which was greater than for the control group *t*(11) = <1 (overall RT at Time 1 *M* =866.97ms and at Time 2 *M* = 875.49ms). However, the slope of the search functions (the effects of the number of items) did not differ as a function of the group or of training (see Figure 5.18).

Visual search task: comparison of performance at Time 3 relative to Time 2

Error rates for this task were low at Time 3 and relatively similar for both groups (CPAT = 3.2%, and Control = 2.5%). No participants were excluded for high error rates. A mixed design ANOVA was carried out to examine these differences further whereby the within subjects factors being Time (2 and 3) and Display size (4, 8, 16 and 32) and Group as the between subjects factor. As would be expected there was a significant main effect of Display size *F*(3,66) = 16.785, *p* = 0001, whereby more errors occurred when there were more items in the display (four items *M* = .12, *SE* = .04; eight items *M* = .14, *SE* = .1; sixteen items *M* = .19, *SE* = .04; thirty-two items *M* = 1.03, *SE* = .18). However the only significant difference in the increase in errors was between Display size 16 and 32 *t*(23) = -4.676, *p* = .0001 (16 items *M* = .19, *SE* = .041; 32 items *M* = 1.03, *SE* = .17). In addition there was a significant interaction between Time x Display size *F*(3,66) = 3.983, *p* = .011. Paired t-tests indicated that when there were thirty-two items in the display there was a significant difference between the error rate at Time 3 (*M* = .67, *SE* = .16) relative to Time 2 (*M* = 1.40, *SE* = .32) *t*(23) = 2.159, *p* = .042. All other results were non-significant (Group *F*(1,22) = <1; Time *F*(1,22) = 1.365, *p* = .255; Time x Group *F*(1,22) = <1; Display size x Group *F*(3,66) = 2.296, *p* = .86; Time x Display size x Group *F*(3,66) = <1; four items Time 3 vs. Time 2 *t*(23) = <1;

eight items Time 3 vs. Time 2 *t*(23) = <1; sixteen items Time 3 vs. Time 2 *t*(23) = -1.163, *p* = .257).

A mixed design ANOVA was carried out on RTs with Display size (4, 8, 16 and 32) and Time (Time 2, and Time 3) as within subjects factors and Group as the between subjects factor. A significant main effect was revealed for Display size *F*(3, 66) = 177.286, *p* = .0001 (see Figure 5.18). All other results were non-significant (Group *F*(1,22) = 1.412, *p* = .247; Time *F*(1,22) = <1; Time x Group *F*(1,22) = 2.643, *p* = .118; Display size x Group *F*(3,66) = <1; Time x Display size *F*(3,66) = <1; Time x Display size x Group *F*(3,66) = <1.) (see Figure 5.18). As the Time x Group interaction was not far from significance paired t-tests were carried out, whilst these were also non-significant (CPAT Time 2 vs. Time 3 *t*(11) = -1.168, *p* = .267 *n.s*.; Control *t*(11) = 1.137, *p* = .280 *n.s*.) we can see that whereas performance in the CPAT group declined from Time 2 to Time 3 (*M* = 789.33, *SE* = 33.20 vs. *M* = 817.25, *SE* = 40.27) the Control group performance improved from Time 2 to Time 3 (*M* = 875.58, *SE* = 37.39 vs. *M* = 847.58, *SE* = 35.66). These findings suggest that the benefits seen in the CPAT group were to some extent maintained over time in that there is no evidence of a significant decline at Time 3.

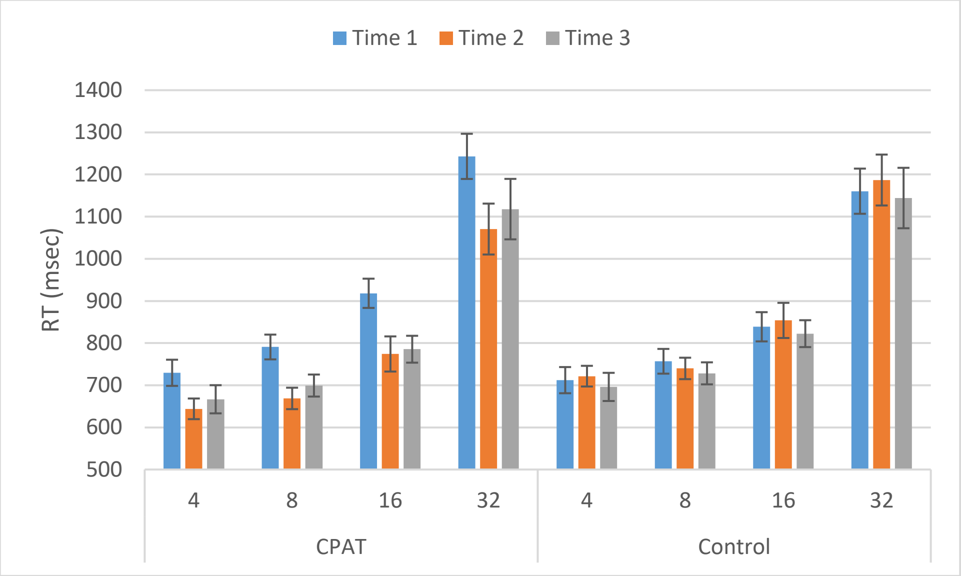


Figure 5.18. Mean RTs on the Visual search task for both groups in all four conditions (display sizes) for Time 1, Time 2 and Time 3 (with standard error bars).

Singleton search: comparison of performance at Time 1 relative to Time 2

Average error rates for both groups were low at Time 1 (CPAT *M* = 1.1, *SE* = .03; Control *M* = 1.8, *SE* = .07) and Time 2 (CPAT *M* = 1.1, *SE* = .06; Control *M* = 1, *SE* = .02), and no participants were excluded for high error rates. A mixed design ANOVA was used to examine the error rates. The within subjects factors were Target Presence (present vs. absent), Singleton (present and correctly coloured, present and incorrectly coloured, and absent), and Time (1 vs. 2). The between subjects factor was group. The results revealed a significant main effect of Target Presence $F(1,22) = 4.853$, $p = .038$ whereby there were more errors when the target was present (*M* = .14, *SE* = .025) relative to the target being absent (*M* = .10, *SE* = .029). All other results of this mixed design ANOVA were non-significant thus no further examination of error was required.

In respect of RTs a mixed design ANOVA with Target Presence (Present vs. Absent), Singleton (Present and correctly coloured, Present and incorrectly coloured, and Absent), and Time (1 vs. 2) were within factors and Group as between factor was carried out. Results revealed a main effect of Target $F(1, 22) = 93.167$, $p = .0001$, whereby RTs were faster when the target was present ($M = 724.49$, $SE = 23.28$) relative to target absent ($M = 830.86$, $SE = 30.66$). In addition a significant interaction was revealed for Target Presence x Time $F(1,22) = 7.098$, $p = .014$, and for Singleton x Time $F(2,44) = 4.403$, $p = .027$, both of which were subsumed by a significant 3-way interaction between Target Presence x Singleton x Time $F(2,44) = 4.269$, $p = .022$. This interaction arose because RTs were always faster at Time 2 relative to Time 1 (see Figure 5.19). Paired t-tests demonstrated that the difference between Time 1 and Time 2 was only significant when the target was absent and the singleton distractor was present both when the singleton was correctly coloured $t(23) = 3.110$, $p = .005$ (Time 1 $M = 875.23$, $SE = 35.69$; Time 2 $M = 769.60$, $SE = 28.27$), and when the singleton was incorrectly coloured $t(23) = 2.273$, $p = .033$ (Time 1 $M = 878.34$, $SE = 42.95$; Time 2 $M = 791.79$, $SE = 33.59$) (see Figure 5.22). These results suggest for both groups search was less hindered by the presence of a singleton distractor whether it was correctly or incorrectly coloured (when the target was absent) at Time 2 relative to Time 1. Thus the training received by the CPAT group had no beneficial impact on their likelihood of being distracted by a singleton distractor when the target was absent relative to the control group.

Singleton search task: comparison of performance at Time 3 relative to Time 2

Error rates at Time 3 were very low for this task for both groups (CPAT *M* = 1.4%, and Control *M* = .6%), no participants were excluded for high error rates. A mixed design ANOVA was used to examine the error rates. The within subjects factors were Target Presence (present vs. absent), Singleton (present and correctly coloured, present and incorrectly coloured, and absent), and Time (2 vs. 3). The between subjects factor was Group. The results revealed as before the only significant result was a main effect of Target Presence $F(1,22) = 11.316$, $p = .004$ whereby there were more errors when the target was present ($M = .14$, $SE = .027$) relative to the target being absent ($M = .09$, $SE = .030$). All other results of this mixed design ANOVA were non-significant thus no further examination of error was required.

A mixed design ANOVA was carried out on RT data with Target Presence (Present vs. Absent), Singleton (Present and correctly coloured, Present and incorrectly coloured, and Absent), and Time (2, and 3) as within subjects factors and Group as the between subjects factor. A significant main effect of Target Presence was revealed $F(1,20) =56.212$, $p = .0001$, whereby RTs were faster when the target was present ($M = 737.975$, SE = 29.84) relative to target absent ($M = 742.762$, SE = 29.94). A significant main effect of Singleton was also revealed $F(2,22) =11.780$, $p = .0001$. Paired t-tests indicated RTs were significantly faster when the singleton was present and correctly coloured ($M = 733.76$, $SE = 19.21$) relative to when the singleton was absent ($M = 753.00$, $SE = 21.79$) $t(23) = -4.376$, $p = .0001$, and that RTs were significantly faster when the singleton was incorrectly coloured ($M = 734.34$, $SE = 21.32$) relative to singleton absent $t(23) = -4.873$, $p = .0001$, however there was no significant difference in RTs between the singleton being correctly coloured relative to incorrectly coloured *t*(23) = <1. There was a significant 3-way interaction between Target Presence x Singleton x Time *F*(4,88) = 7.711, *p* = .001 (see Figure 5.19). Descriptive statistics indicated that at Time 3 relative to Time 2 RTs had improved in all conditions except when the target was absent and the singleton was correctly coloured and here RTs were slower at Time 3 relative to Time 2, however a paired t-test indicated this was not significant *t*(23) <1. Thus CPAT training did not benefit performance on this task over time.

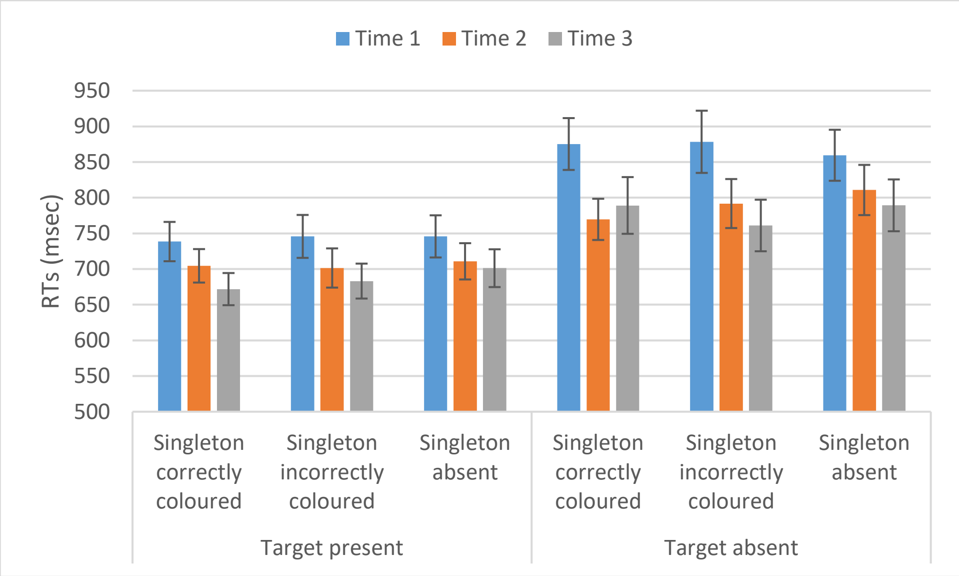


Figure 5.19. RTs for both groups at Time 1, Time 2, and Time 3 according to Target Presence and Singleton condition (with standard error bars).

Motor task: comparison of performance at Time 2 relative to Time 1

Due to missing data (as a result of equipment error), the analysis for this experiment was based on 10 participants in the CPAT group and 9 participants in the Control group. In addition there were fewer trials with valid data in streaks 5 and 6 (where the target colour was repeated on 5 or 6 consecutive trials), and consequently only steaks 1 to 4 are included in this analysis. The measures of interest here were initiation latency as this is believed to indicate speed of deployment of focal attention (Song & Nakayama, 2007). As well as maximum deviation, because as with initiation latency this is believed to represent internal competition, and improvement here could be indicative of improved information processing (Song & Nakayama, 2007). In addition total time for overall movement is also of interest (this consists of time from button release to time when point is fixed) as it is believed that this allows for changes in target identification and motor plans over time (Jeannerod, 1988). Initiation latency is measured in milliseconds and refers to the time between the stimulus being presented on the screen and the movement onset, with onset being classified as movement of the index finger being more than 25 millimetres per second for 15 consecutive frames. Maximum deviation was measured in millimetres and refers to the deviation of the index finger trajectory from a straight line between the start and end of the movement.

Initiation latencies (IL) were assessed using a mixed design ANOVA. The within-subjects factors were Time (Time 1, and Time 2) and Streak (1, 2, 3 and 4) and the between-subjects factor was Group. This revealed a main effect of Streak $F(3, 51) = 5.815$, $p = .002$, as well as a two way interaction for Streak x Group $F(3, 51) = 4.182$, $p = .01$, and a three way interaction for Time x Streak x Group $F(3, 51) = 4.164$, $p = .01$. There were no significant overall differences between the groups ($F(1,17) = .753$, $p = .403$, *n.s.*). The 3-way interaction was investigated further by splitting the data according to Group and carrying out separate ANOVAs for each. The within subjects factors were Streak (1, 2, 3 and 4) and Time (Time 1 vs. Time 2). The ANOVA in respect of the CPAT group revealed a significant main effect of Time $F(1,9) = 5.335$, p

= .046 whereby RTs were faster at Time 2 (M = 500.42, SE = 31.51) relative to Time 1 (M = 589.15, SE = 42.61). All other results were non-significant (Streak $F(3,27)$ = 2.116, p = .122; Time x Streak $F(3,27)$ = <1). The ANOVA in respect of the Control group revealed the main effect of Time to be non-significant $F(1,8)$ = <1. However the main effect of Streak was significant $F(3,24)$ = 6.960, p = .002, as was the interaction Time x Streak $F(3,24)$ = 4.156, p = .033. The main effect of Streak indicated that RTs improved from Streak 1 to Streak 2, remained stable for Streak 3 but improved again from Streak 3 to 4 (Streak 1 M = 599.99, SE = 33.00; Streak 2 M = 583.61, SE = 29.81; Streak 3 M = 583.86, SE = 33.01; Streak 4 M = 566.11, SE = 31.45).

Paired t-tests showed that the CPAT group had significantly reduced their RTs at Time 2 relative to Time 1 in Streak 1 $t(9)$ = 2.272, p = .049 (Time 1 M = 595.28, SE = 43.89; Time 2 M = 507.22, SE = 31.66), and at Streak 4 t(9) = 2.694, p = .025 (Time 1 M = 596.84, SE = 44.82; Time 2 M = 498.05, SE = 35.20), and the other Streaks were nearing significance Streak 2 $t(1,9)$ = 2.095, p = .066, Streak 3 $t(1,9)$ = 2.118, p = .063; whereas the control group had no significant differences in Streak at Time 2 relative to Time 1 $t(1,8)$ = -.457, p = .660; Streak 2 $t(1,8)$ = -.152, p = .883; Steak 3 $t(1,8)$ = .579; p = .578, Streak 4 $t(1,8)$ = -.307, p = .767) (see Figure 5.20). This suggests the control group were experiencing a greater effect of streak change relative to the CPAT group.

In respect of maximum deviation using an ANOVA as above with the same factors results revealed no significant results, thus suggesting CPAT training had no apparent impact here (Streak $F(3, 51)$ = 2.684, p = .071; Time $F(1,17)$ = 1.055, p = .319; Group $F(1,17)$ = .494, p = .492; Time x Group $F(1,17)$ = 2.589, p = .126).

In respect of Total time for the movement (from button release to point fixed) a mixed design ANOVA was carried out with Time (Time 1, and Time 2) and Streak (1, 2, 3 and 4) as within-subjects factors and Group as between-subjects factor. The results revealed a significant main effect Streak $F(3, 51) = 6.385$, $p = .001$, whereby RTs became faster as the number of Streaks increased (see Figure 5.21). In addition there was a significant interaction between Time x Group $F(1,17) = 4.683$, $p = .045$. Paired t-tests indicated that whereas as the CPAT group RTs had significantly improved from Time 1 to Time 2 $t(9) = 2.954$, p = .016 (Time 1: $M = 1275.92$, $SE = 35.26$, Time 2: $M = 1138.28$, $SE = 55.93$), the control groups RTs showed no significant differences from Time 1 to Time 2 $t(8) = <1$ (Time 1 $M = 1281.17$, $SE = 55.53$, Time 2: $M = 1300.79$, $SE = 63.26$). Thus suggesting that the CPAT group's training benefited their ability to make more direct movements. There were no further significant findings (Time $F(1,17) = 2.637$, $p = .123$; Group $F(1,17) = 1.300$, $p = .270$; Streak x Group $F(,3,51) = 1.889$, $p = .143$).

Motor task: Comparison of performance at Time 3 relative to Time 2

Due to missing and invalid data (due to technical difficulties) this analysis was based on 5 participants from the CPAT group and 7 from the Control group. In addition due to the number of invalid trials for Streaks 5 and 6, only Streaks 1 to 4 were analysed. As before the areas of interest with this task were: (i) initiation latency as an indication of speed of deployment of focal attention; (ii) maximum deviation as an indication of speed of information processing; (iii) total time for overall movement as an indication of generalised improvement in information processing and movement. The IL refers to the time between the stimulus being presented on the screen and the movement onset, with onset being classified as movement of the index finger being more than 25 millimetres (ms) per second for 15 consecutive frames. Maximum deviation was measured in ms and refers to the deviation of the index finger trajectory from a straight line between the start and end of the movement.

A mixed design ANOVA was conducted on ILs, with the within-subjects factors being Time (Time 2, and Time 3) and Streak (1, 2, 3 and 4) and with Group as the between-subjects factor. The results revealed a significant difference between the Groups $F(1,12) = 6.402$, $p = .026$, whereby the CPAT group ($M = 457.17$, $SE = 35.92$) had faster RTs relative to the Control group ($M = 577.39$, $SE = 31.11$). There was also a main effect of Streak $F(3,36) = 14.608$, $p = .0001$, whereby RTs improved from Streak1 to 3, but increased from Streak 3 to 4 (see Figure 5.20). This suggests the CPAT training benefits (in respect of faster RTs) were maintained over time.

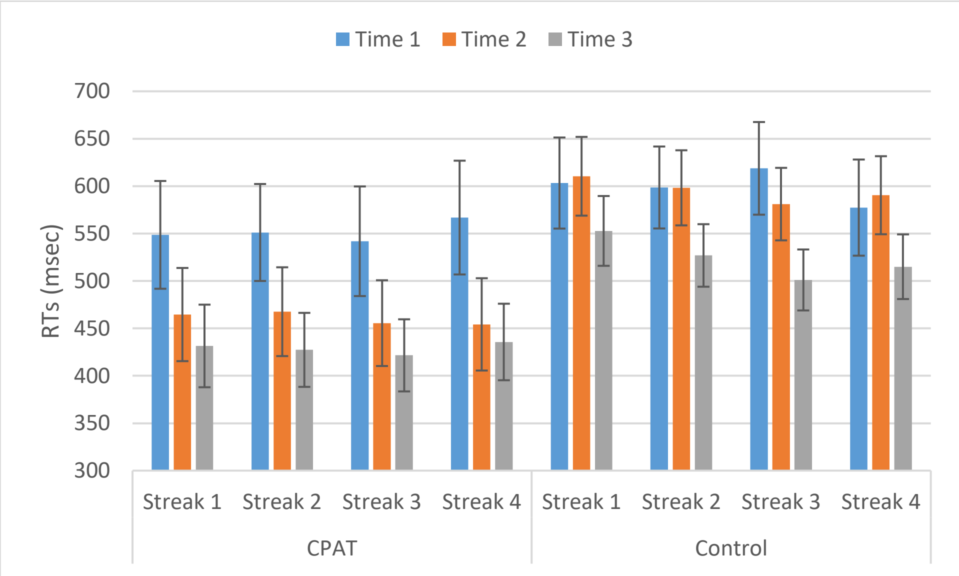


Figure 5.20. Initiation latency for both groups for Streaks 1-4 at Time 1, Time 2, and Time 3 (with standard error bars).

For the Maximum deviation measure, a mixed design ANOVA was conducted with within-subjects factors being Time (Time 2, and Time 3) and Streak (1, 2, 3 and 4), and with Group as the between-subjects factor. The results revealed only a nearing significant main effect of Streak $F(3, 36) = 2.772$, $p = .055$. Maximum deviation decreased with Streak (Streak 1 $M = 55.04$, $SE = 4.48$, Streak 2 $M = 55.03$, $SE = 4.87$, Streak 3 $M = 54.27$, $SE = 4.81$, Streak 4 $M = 52.35$, $SE = 4.61$).

For the Total Movement Time measure, a similar mixed design ANOVA revealed there was no overall significant difference between the Groups $F(1,12) = 1.271$, $p = .282$. There was only a significant main effect of Streak $F(3, 36) = 9.471$, $p = .0001$ and again RTs improved from Streak 1 to 3, but increased from Streak 3 to 4. (see Figure 5.21). This suggests that the benefits seen at Time 2 in the CPAT group were not further improved after a four-month period without training, nonetheless the absence of a significant decrease in their performance suggests stability over this time.

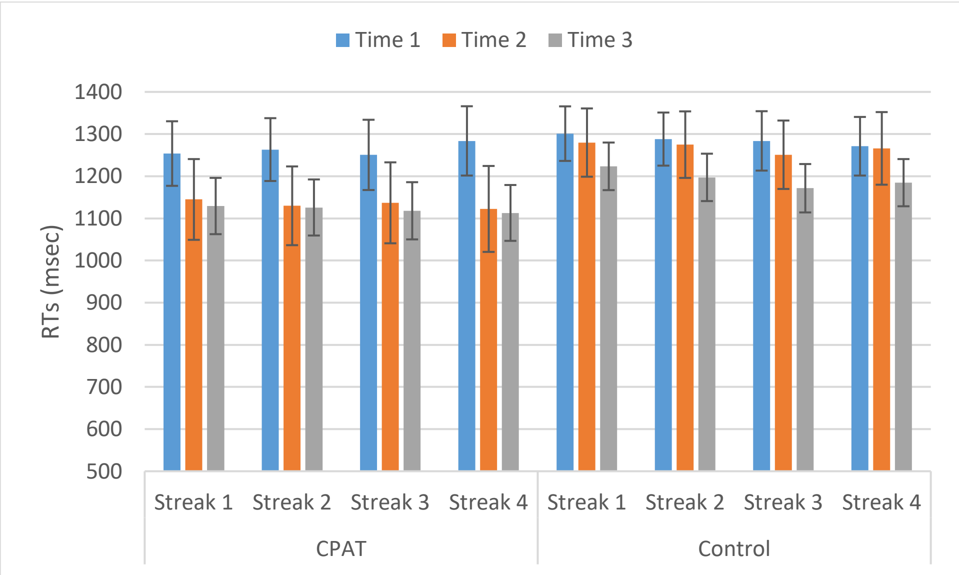


Figure 5.21. RTs in respect of total movement time for both groups for Streaks 1-4 at Times 1, 2 and 3 (with standard error bars).

Cognitive failures questionnaire: comparison of performance at Time 2 relative to Time 1

For the Cognitive Failures Questionnaire (Broadbent et al., 1982) higher scores indicate participants report experiencing more frequent subjective cognitive issues.

A mixed design ANOVA was carried out with Time (1 and 2) as the within subjects factor and Group as the between subjects factor. The results revealed there was no significant difference between the Groups $F(1,22) = .062$, $p = .806$. A significant main effect of Time was revealed $F(1,22) = 7.618$, $p = .011$, whereby cognitive failure scores had reduced at Time 2 ($M = 42.38$, $SE = 2.44$) relative to Time 1 ($M = 46.54$, $SE = 2.79$). However the interaction Time x Group was non-significant $F(1,22) = .987$, $p = .331$, indicating that both groups reported fewer cognitive failures at Time 2 relative to Time 1, thus the CPAT group did not seem to benefit more than the control group here (see Figure 5.22).

Cognitive failures questionnaire: comparison of performance at Time 3 relative to Time 2

A mixed design ANOVA was conducted with Time (2 and 3) as the within subjects factor and Group as the between subjects factor. The results revealed no significant difference between Groups $F(1,22) = <1$, $p = .971$. Although the main effect of Time was non-significant $F(1,22) = <1$, the interaction was significant $F(1,22) = 5.320$, $p =.031$. However Paired t-tests indicated that for both groups the difference between Time 2 and 3 was actually non-significant CPAT: $t(11) = -1.892$, $p = .085$; Control: $t(11) = 1.515$, $p = .158$. As can be seen in Figure 5.22 at Time 3 the number of reported cognitive failures for the CPAT group increased relative to Time 2, whereas for the Control group the number of reported cognitive failures continued to decrease at Time 3 in comparison to Time 2. Thus the CPAT training did not impact on subjective reported cognitive failures at any Time.

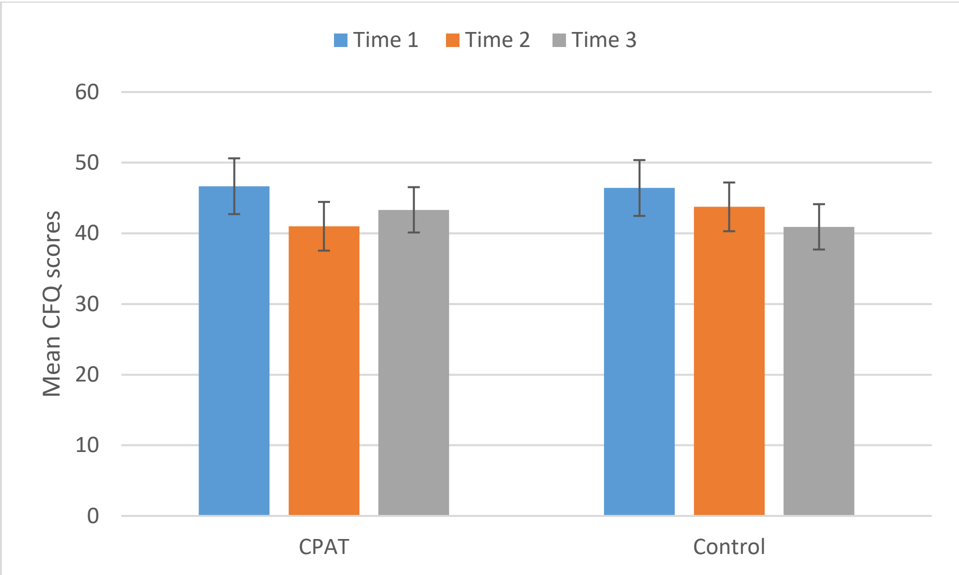


Figure 5.22. Cognitive Failures Scores for both groups at Time 1-3 (with standard error bars).

5.1.3 Discussion

Effects of training at Time 2

In this study a computer-training intervention was used for older participants, which targeted specific aspects of attention - notably sustained attention, selective attention, and executive attention. Performance in the experimental (CPAT) group was compared with that of an active control group, and generalisation of performance was assessed on a range of cognitive tasks tapping executive and attentional functions as well as on some tasks reflecting everyday cognitive failures (Cognitive Failures Questionnaire (Broadbent et al., 1982)). We found no evidence for improved attention measures of sustained attention and visual search following the intervention. However, overall RTs improved significantly across the peripheral cueing task, the stroop-like task, visual search task, and the motor task (ILs and total movement time).

In respect sustained attention (measured by the continuous performance task) there were no significant results in respect of RTs and standard deviations. Thus demonstrating that neither the CPAT training nor the computer games used by the Control group had any impact on improving sustained attention. As mentioned above whilst the Anguera et al. (2013) study reported finding improvements in their experimental group this was based on RTs only rather than standard deviation of RTs. As such it is possible that it is difficult to achieve significant improvement on a sustained attention task. In addition it is worth noting here that as can be seen in Figures 5.13 and 5.14 the data indicate that the CPAT group did improve RTs and standard deviation of RTs from baseline to Time 2 and thus it is likely that the non-significant results can be attributed to a lack of power here. Furthermore the baseline standard deviation of RTs for the CPAT group was 70.18ms here which is small in comparison to the baseline for the patients in the Sampanis (2014) study (106.8ms), thus suggesting that performance in the CPAT group was already efficient which would make significant improvement difficult.

In the motor task participants had to select a singleton target, whose location switched across trials, and point to the selected target. Data on ILs revealed that the CPAT group in particular improved at Time 2 and had significantly reduced IL RTs on streaks 1 and 4 which had at Time 1 (streaks 1 and 4) had the slowest IL RTs. The

Control group in contrast made no significant improvements in any streak from Time 1 to Time 2. Thus the CPAT group (after training) seem to have improved deployment of focal attention and information processing, as they were less affected (as their responses were more efficient when the location of the target changed) by 'streaks' in the location of the target after training compared with the Control group. These data suggest that the time to select the target was facilitated by attentional training (note that initiation times reflect the very first stage of the motor response) as was the ability to switch to the new target location after a switch in the streak (at streak 1).

Alongside the effects of training on initiation times there were also effects on the total movement RT (time from button release to time when point is fixed). As at Time 1 both groups had relatively similar RTs for the total movement, whereas at Time 2 the CPAT group was significantly faster than those in the Control group who at Time 2 actually had slower RTs than at Time 1. Thus the benefit to the CPAT group was a significant improvement in their speed of movement. The improvements seen here in respect of overall time could be indicative of improvements in information processing and speed of movement. Again if a greater amount of valid data had been available here it is possible stronger evidence of this would have emerged. The deviation of the movement indicates the level of interference caused by the change in the target location, as the initial movement is erroneously directed to the incorrect location the movement must then be corrected slowing RT. There were no effects of training on the deviation of the movement demonstrating therefore that training did not significantly reduce the level of interference caused by the change in target location.

Results of the Cognitive Failures Questionnaire (Broadbent et al., 1982) indicate that both groups reported fewer cognitive failures at Time 2 relative to Time 1, it appears that the CPAT group benefitted numerically more, but this was not significant. Thus suggesting that the CPAT training was not associated with greater benefits in reducing the subjective occurrence of forgetfulness, confusion and inattention than playing the readily available, cost free computer games that the Control group used. It seems both activities were beneficial to subjective cognitive performance. An intervention carried out by Peretz et al. (2011) which aimed to improve cognitive functioning in older adults reported a similar outcome. Peretz et al. (2011) had an experimental group which was given coaching on improving cognitive performance on 21 different computerized activities, and an active control group which played 12 computer games (mainly problem solving and memory based). Peretz et al. (2011) reported that the outcome measures indicated both groups demonstrated improved performances on focused and saturated attention, memory recognition and mental flexibility measures. The authors suggest that the benefit to the control group could be attributed to the fact that many processes and abilities are engaged when playing computer games. Thus the finding of the current study corroborates those of Peretz et al. (2011) by demonstrating that playing ordinary computer games can be beneficial to cognitive functioning.

A limitation of the current study is that it is likely that the small number of participants in each group resulted in a lack of statistical power which may have meant that non-significant results were revealed. It is possible that if there were more participants and thus more statistical power additional significant results may have been found. However this was not possible here due to time and cost restrictions. This study nonetheless is useful in evaluating the effectiveness of the CPAT program in healthy older adults.

Conclusion for comparison of Time 1 to Time 2

The findings reported here indicate to some extent that the CPAT training improves RTs. The evidence which seems to suggest this is that the CPAT group's performance was faster at Time 2 relative to Time 1 on the Pointing task, the Peripheral cueing task, the Stroop-like task, and the visual search task. In addition the data indicate the training received by the CPAT group is associated with improvements in the ability to switch attention as evidenced by the reduced effect of streak 1 in the pointing task. However it is important to note that no additional benefits were evident in the CPAT group at Time 2 relative to the Control group on the Continuous Performance task, and the Singleton Search task. Furthermore the results of the Cognitive Failures Questionnaire provide evidence that the benefits of both the CPAT training and the computer games used by the Control group transfer into improved performance in everyday life activities. However it is worth highlighting that it is possible that rather than the benefits of both activities being equally (subjectively) beneficial to both groups that the questionnaire is not sensitive enough for test re-test analysis.

The findings of this study indicate that this cognitive intervention develops an improvement in RTs even on tasks on which no training was given, thus demonstrating clear transferrable benefits which some previous studies have not succeeded in doing (Owen et al. 2010, and Reijnders et al., 2013). Where studies have demonstrated improvements in performance on tasks where no training is given (Auguera et al. 2013) it could be evidence that rather than cognitive training leading to improvements in specific cognitive functions such interventions instead drive general improvements in speed of processing. Nonetheless as these transferable benefits here are evident on tasks which differ to those on which training is provided this suggests an advantage of the CPAT program, as previous studies have failed to succeed in doing this (Papp et al., 2009). Thus this intervention has also succeeded in addressing the needs identified by Toril et al. (2014) for new interventions using video game training to enhance healthy older adults' cognition. The relative success of this intervention is attributed to the training tasks used here being better targeted to specific aspects of attention and working memory which are implicated as being integral to higher cognitive functions such as executive functioning (Willcutt et al., 2005), and fluid intelligence (Engle, Tuholski, Laughlin & Conway, 1999). This is an important step as it is imperative that declines in these cognitive functions are ameliorated (Glisky, 2007) in order for older adults to live independent lives (Wilson et al., 2002) and remain safe (Seidler et al., 2010).

Discussion for comparison between Time 3 and Time 2

The aim of these follow up measures (Time 3) was to address the question of whether CPAT training benefits are maintained from T2. Addressing this question is central to evaluating the effectiveness of the intervention in a meaningful manner. The findings indicate that where improvements were evident at Time 2, at Time 3 these improvements largely remained stable over the follow-up period (4 months) without any further training having been given. In particular, at Time 2 improvements were evident in terms of RTs on the peripheral cueing task, the stroop-like task, visual search task, and the motor task (ILs and total movement time), and at Time 3 the CPAT groups' performance had remained stable on the peripheral cueing task, the stroop-like task, and the visual search task. In addition to improved performances in the CPAT group remaining stable over the follow-up period, further improvements at Time 3 relative to Time 2 were evident on the motor task in terms of IL RTs, and total movement time.

In respect of ILs on the motor task a significant main effect of group was revealed indicating that RTs for the CPAT group were faster than the Control groups'. As such the CPAT saw a greater improvement in RTs at Time 3 than the Control group, which suggests that the CPAT training is more proficient than practice alone at improving deployment of focal attention and resolving internal conflict.

Also the motor task results revealed as would be expected that overall Total movement RTs improved with Time, whereby Time 2 was faster than Time 1, and Time 3 was faster than Time 2. Furthermore, results show that the CPAT group improved their Total movement RTs to a greater extent than the Control group, as such providing further evidence that the training received by the CPAT group is more beneficial than the practice effects which could be said to be causing the improvements in the Control group's performance.

Overall it seems that the evidence of the IL aspect of this motor task indicates that CPAT training is associated with improved focal attention, and the improvement in movement RTs demonstrates an ability to solve internal conflicts that are associated with switching faster and thus improved speed of information processing, at Time 3. Note that these findings are present on tasks on which no training has been given and thus there is evidence of transferrable skills being gained. Moreover these benefits are evident 4-months after the completion of training.

In respect of sustained attention, no significant results were found both in relation to RTs and standard deviations for either group at Time 3, as was the case at Time 2. This demonstrates that neither the CPAT training nor the Control group's computer games had a beneficial impact on sustained attention.

The findings in relation to the cognitive failures questionnaire (Broadbent et al., 1982) indicate that at Time 3 the scores had increased in comparison to Time 2 for the CPAT group but had continued to decline (although not significantly so) for the Control group. Thus it seems that whilst the Control group's activities were beneficial in reducing the number of perceived cognitive failures experienced over a 4-month period, this was not the case for the CPAT group. It is interesting that the lowest score recorded for both groups here was 41. In Broadbent et al.'s (1982) study it is reported that scores collected from seven different groups ranged from a high of 79.3 (Oxford subjects) to a low of 35.02 (car factory workers). Thus the scores recorded in the current study seem quite low, particularly as participants here were older adults. As such it is possible that for this age group the scores here had reached the lowest likely point and thus when the CPAT group had reached this low level at Time 2 it was improbable that scores for this age group were going to improve further, whereas for the Control group at Time 2 there was still room for improvement.

5.1.4 General discussion

Together the results of this chapter demonstrates that speed of information processing is improved by CPAT training, and that this improvement remains largely stable over a 4-month follow-up period. This is evident in the improvement at Time 2 on the Stroop-like task whereby the CPAT group improved RTs relative to Time 1. Critically, the improvement on the stroop-like task has been achieved without training this specific task. That is, the improvement here is evidence for transfer effects following the CPAT training on other attention and executive function tasks.

In addition this chapter relating to the intervention demonstrates improvements to and maintenance over time, of improvement in selective attention in terms of RTs. There was no evidence here that search behaviour changed. Performance on the Pointing task (note no training had been provided on this task), and the Visual search task provides supporting evidence of this, in that at Time 2 the CPAT group showed greater improvement than the Control group on the motor task – in terms of initiation latency and total movement time, and this was still true of ILs for Time 3; on the Visual Search task at Time 2 the CPAT group had greater RT gains than the Control group, and this remained stable over time.

Furthermore improved performance in the CPAT group was evident in Orientating of attention task at Time 2 relative to Time 1. However, improvement here was not specific for orienting and reflected an overall reduced RTs. Nevertheless, not only that this task in itself was not trained within CPAT, the actual trained tasks in CPAT do not involve an orienting attention training. Indeed, the improvement we document here is indicative of a general improvement rather than a specific change in orienting of attention.

In addition both groups seemed to have benefited on the Singleton search task at Time 2, from a reduced singleton distractor effect relative to Time 1, and although this was not evident at Time 3, both groups had faster RTs at Time 3 relative to Time

2. As such it appears that both the CPAT training and the computer games used by the Control group can improve speed of information processing. And whilst the benefit is greater in the short term (i.e. immediately after training at Time 2), some benefit does last for the longer-term (i.e. 4-months after training finished).

Results for this intervention in relation to the subjective measure of the CFQ (Broadbent et al., 1982) show that both groups benefitted from a reduction in perceived cognitive failures at Time 2 relative to Time 1. On this measure the Control group continued to (subjectively) improve whereas the CPAT group did not. As such it seems possible that any cognitive stimulation could have a positive impact on this measure of forgetfulness, confusion, and inattention.

Therefore the CPAT program appears to be effective at improving performance relating to the aspects of attention on which training is given as well as on additional aspects of attention for which no training is given. These improvements are for the most part maintained over a 4-month period after training and as performance is generally better in the CPAT group than the control group this program can be said to be more effective than generic cognitive stimulation gained from playing computer games (which do not target specific aspects of attention), and practice effects. As improvements are seen in tasks which differ to those on which training is given and even on tasks where no training is given it is clear that transferrable skills are gained from this program, and that it can help to improve RTs which tend to slow with age, thus this program could positively impact daily functioning.

A possible explanation for the Control group often performing least well at Time 2 is that at Time 1 they were trying very hard because they had only just met the researcher and were influenced by demand characteristics and social desirability (and possibly even the determination to demonstrate that they had no cognitive decline), and at Time 2 they were more relaxed and thus where less influenced by these factors. Then at Time 3 they were benefiting from not only the practice effect but also many of them had intimated that they had continued to play the games used for their 'training sessions' at home on their own computer, and it is possible that this additional cognitive stimulation produced the benefits often seen at Time 3 for this group. In contrast the CPAT group saw their best performance on most tasks at Time 2, and this was often a significant improvement from Time 1 to Time 2, as such it would seem appropriate to attribute this improvement in performance to the benefits gained from the CPAT program. Furthermore as significant declines were not evident at Time 3 (relative to Time 2), it seems the CPAT training is substantially better at slowing cognitive decline in comparison to mere practice effects or other forms of cognitive stimulation (from computer games).

Whilst many measures were taken to ensure this intervention was of high quality there are still ways in which it could be improved, one of which is that volunteers could be screened in relation to cognitive impairments and health status prior to participation. Whilst this study had requested healthy volunteers, this is obviously open to interpretation, in that relatively speaking someone with chronic diabetes may not view themselves as being seriously ill, but nonetheless has sleeping difficulties etc. which can hinder performance on an intervention such as this.

Furthermore it is obvious that this intervention would benefit from more participants in each group, as well as less noisy data on the motor task. In addition it was not considered that participants in the Control group would enjoy the games they played to such an extent that some of them would seek out these games and thus take them up as a pass time (see Appendix B), and that this would consequently become a confounding variable impacting on the evaluation of this intervention. As such in future it is recommended that games which are played by the Control group are not simply those which are readily available and cost-free, instead it might be better to create games or purchase some to limit the likelihood of this occurrence. In addition, a passive control group that do not play any computer games during the intervention could also be added to the design.

In addition future work on this program could compare trained older adults' performance to that of untrained younger adults, as well as look at fMRI to compare brain region activity in untrained older adults in comparison to trained older adults to examine whether the CPAT program impacts positively on the changes in the brain that are associated with ageing. Moreover it is possible that this program could be of value to dementia patients in that if it could slow the onset or advancement of dementia then it could make a dramatic difference to those individuals' lives.

CHAPTER 6

DISCUSSION

6.0 General Discussion

This thesis has attempted to elucidate two issues with respect to attention in ageing. First, the contribution of top-down and bottom-up processes in visual search was examined as well as how they may be affected by age. To that end I have focused on a visual search task in which a singleton distractor can appear (argued to automatically capture attention in a bottom-up manner; Theeuwes, 1991). I also examined the effect of stored knowledge (colour association of real life objects) on search performance to further examine whether older adults can utilise such information to better cope with the conflict between bottom-up and top-down selection cues. Finally an attention training intervention was carried out with a group of older adults to test the efficacy of such cognitive training not only at improving attention but also providing stable long term benefits which could transfer to non-trained task and translate to daily living in general for this population.

6.1 Singleton search chapters

Chapter 2 investigated the notion that visual search is primarily driven by bottom-up cues and that this is more pronounced as we age (Lustig et al., 2001; Pratt & Bellomo, 1999). In two experiments a singleton search task was utilised so that the colour singleton could either only be a distractor (Experiment 2.1) or both a distractor or a target (Experiment 2.2). Thus, Experiment 2.2 may encourage a 'singleton' mode of visual search (Bacon & Egeth, 1994). Young and older adults' performance in these two experiments was compared.

The results of Experiment 2.1 challenge the notion of bottom-up dominance in visual search as the occurrence of a colour singleton distractor had no effect when a target was present. If bottom-up cues dominate selection regardless of task conditions, then the presence of a singleton colour distractor (which is the most dominant bottom-up cue) should have affected performance. In Experiment 2.2 I found the typical singleton effects under conditions encouraging 'singleton' mode.

Interestingly, I found no difference in the role played by the colour singleton for young and older participants in either of the two experiments. This finding suggests that older participants were able to utilise top-down processes to a similar extent as younger participants in order to overcome bottom-up cues (e.g., when the target was present in Experiment 2.1). Thus, my findings here support the conjecture that top-down processes are preserved in old age (Madden et al., 2004) and can be utilised in the context of a visual search task in which strong bottom-up cues need to be overcome.

Participants' age did have some impact on performance (though not with respect to the singleton distractor). First, older participants were generally slow compared to young participants, which is a typical effect in ageing (e.g., Salthouse et al., 2000). Second, older adults demonstrated no display size effect (difference in performance for 4 vs. 6 display items) when the singleton distractor was absent, unlike the younger adults who were always faster when there were 4 items in the display (relative to 6). The lack of display-size effect in the old participants could point to a number of speculations, particularly regarding the link between the speed of attention shifts and the distance the attention focus needs to travel. For instance, it could be argued that the distance the attention spotlight needs to travel in one 'jump' from one item to the next in the smaller set size is larger than the equivalent distance in the larger set size (as inter-item distance was not constant across conditions). Therefore, we may suspect that these differences affect attention shifts in old age more than in young age (Greenwood & Parasuraman, 2004). Nonetheless, using a Brinley plot analysis it was indicated that the difference in performance between the groups may in fact be associated with the general slowing in the older adults and is therefore not specific to the display-size manipulation. As such, it still remains an open question as to whether differences in the speed of shifting attention in the visual field play a role in visual search differences across the ages.

In Chapter 3 Experiments 2.1 and 2.2 were used to collect eye-tracking data from young adults, and the results of Chapter 3 corroborate the RT findings reported in Chapter 2. That is, in Experiment 3.1 I once again found the occurrence of a colour singleton distractor had no effect when a target was present. Thus, corroborating the conjecture that bottom-up guidance does not dominate visual search. In Experiment 3.2, (as was the case in Experiment 2.2) I found the typical singleton effects under conditions encouraging 'singleton' mode. Interestingly the target was more likely to capture attention when in the presence of a singleton distractor (relative to singleton distractor absent). Thus, my findings here support the notion that the presence of a salient singleton distractor can actually facilitate search for a target by enabling speeded rejection of that object, relative to a non-salient distractor (Geng and DiQuattro, 2010) which may require rely on a reactive suppression mechanism (Braver, 2012) that is triggered late in the search task (Geng, 2014). Therefore the findings of this experiment also indicate that it is possible to ignore a salient singleton during parallel search if the feature search mode is adopted (Bacon and Egeth (1994).

In chapter 4, the search task employed real life objects which have strong colour associations and therefore tap stored knowledge (Tanaka & Presnell 1999). The question I was asking is whether the ability to rely on stored knowledge will be beneficial to older adults when performing a visual search task, as stored knowledge is not associated with decline in old age (Horn & Cattell, 1967). It was hypothesised here that when a target or singleton distractor colour corresponds with stored knowledge they will exert a more efficient hold over attention selection particularly for older participants. Again two experiments were used. In Experiment 4.1 the target was always incorrectly coloured whilst the singleton distractor was sometimes presented as correctly and sometimes incorrectly coloured and in Experiment 4.2 both target and singleton distractor could be correctly or incorrectly coloured. In Experiment 4.1, when the target was always incorrectly coloured, the colour of the singleton distractor (correctly or incorrectly coloured) had no effect on performance across the two age groups. In other words, when the target was always incorrectly coloured there was no impact of stored knowledge representations in relation to the singleton distractor for both younger and older adults. I interpret this finding as further evidence of strong top-down control utilisation across the two groups (perhaps through the adoption of a feature mode of search; Bacon & Egeth, 1994; Folk et al., 1992; Leber & Egeth, 2006), so that a correctly coloured item did not capture attention more than an incorrectly coloured one as long as the target of the search did not correspond with stored representation.

Whilst participants' age once again did not impact on the effect of a singleton distractor, it did nonetheless impact on performance. First, older adults were once again slower than younger adults to respond which as previously mentioned is a typical effect in ageing (e.g. Salthouse et al., 2000). Second, there was a greater difference in RTs for older adults between target present and target absent in comparison to the younger adults. Similar findings have previously been reported (Plude & Doussard-Roosevelt, 1989; Hommel et al., 2004; Scialfa et al., 1998) and have been attributed to the general slowing which is associated with ageing. Here a Brinley plot analysis suggested that to some extent the performance of younger adults did predict that of the older adults which fits well with the notion that there is no difference in ability between older and younger adults to utilize top-down processing (Madden et al., 2004).

In contrast, in Experiment 4.2, whether or not the singleton was correctly coloured did have an effect on performance. First, search was more efficient when the singleton was correctly coloured. Thus an incorrectly coloured singleton was generally more distracting. Second, when searching for a target that corresponded to stored knowledge whether or not other items also corresponded to stored knowledge had an effect on performance across both groups. Moreover, overall performance was in fact better when the target was incorrectly coloured (and therefore did not correspond with stored knowledge). Thus, not only was the effect of the distractor being correctly or incorrectly coloured diminished in this situation but also generally the occurrence of a singleton distractor per se. was less interfering. This again supports the notion that under conditions promoting a feature mode (i.e. incorrectly coloured target item), when perhaps identification of a target item is more demanding search is more efficient in avoiding bottom-up cues.

Interestingly, participants age did impact on performance in relation to the singleton distractor in this experiment. There was evidence that for the smaller display size younger participants were more sensitive to the correctness of a coloured singleton (when the target is present and correctly coloured) than the older participants. However these differences were relatively small, and as before the Brinley plot analysis indicated that the younger adults' performance once again did to some extent predict the older adults'. Thus it seems that these differences may be attributable to the normal ageing process.

These results demonstrate several things – firstly they provide yet further evidence that parallel search is unlikely to be solely a bottom up process, because it is not always the case that a salient irrelevant item captures attention. Second, they strongly suggest that when search is more difficult (i.e. the target is incorrectly coloured and thus does not correspond with stored knowledge) feature search mode is utilized and top-down guidance prevails (Chen & Zelinsky, 2006). Thus, it would seem in real-life situations (i.e. when the target does correspond with stored knowledge) the likelihood of bottom-up interference is increased. These results also highlight that older adults are equally as able as younger adults to utilize top-down processing in search (Madden et al., 2004). Moreover these results also demonstrate that younger and older adults are equally influenced by their stored knowledge. Thus, these findings extend previous research findings which have reported that older adults' performance on memory tasks can benefit from stored knowledge (Badham & Maylor, 2015; McGillivray & Castel, 2010).

6.2 Intervention chapter

In the final experimental chapter of the thesis (Chapter 5) I have tested the potential efficacy of a computerised attention training program with healthy older adults. In particular, I was aiming to assess whether such a domain general intervention program (training various aspects of attention including sustained attention, selective attention and executive attention) can transfer to non-trained objectively measured cognitive tasks as well as to more general subjective measures of quality of life. I was also particularly interested in whether any effects following the intervention program remain stable. Performance was therefore assessed in the two groups of older adults before, immediately after, and 4-months following the intervention program. While the experimental group underwent attention training using CPAT (Shalev et al., 2007) the active control group used freely available computer games. Generally, post-intervention measures revealed improved performance relative to baseline on a variety of measures which was particularly pronounced for the CPAT group.

Improvements in performance of the CPAT group at Time 2 were evident on a Stroop-like task (measuring conflict resolution), a motor task (IL and total movement time; measuring spatial attention as well as motor control) and a visual search task (measuring selective attention), as well as on a peripheral cueing task (measuring attention orienting). Improvements in both groups' performance at Time 2 relative to Time 1 was evident on Broadbent et al. (1982) Cognitive Failures Questionnaire (subjective measure of forgetfulness, confusion, and inattention), and the singleton search task.

On most tasks the intervention group out-performed the control group at Time 2. The evidence demonstrates that the CPAT group benefited at tasks on which training was provided i.e. selective attention (visual search), as well as on tasks on which no training was provided (motor task – focal attention and motor control, stroop-like task – conflict resolution, and peripheral cueing – orientating of attention). The improvements brought about by the CPAT training indicate that the intervention improves aspects of executive functioning which as defined by Miyake et al. (2000) involves task maintenance and updating, switching and response inhibition. Thus CPAT training develops transferable skills which can then benefit daily living in older adults (Wilson et al., 2002 and Seidler et al., 2010) by ameliorating or moderating cognitive declines (Glisky, 2007).

This chapter also addressed the question of whether the enhanced performance on the various outcome measures remained stable four months after the conclusion of the training with no further training being given. The results revealed that at Time 3 there was evidence that the benefit seen in the CPAT group at Time 2 had remained stable on the tasks measuring orienting attention, resolution conflict, and selective attention. Improvements at Time 3 relative to Time 2 were evident for the CPAT group in spatial attention and motor control, importantly no training was given on this. There was also an improvement in performance at Time 3 relative to Time 2 in RTs on a singleton search task, however here both groups were faster at Time 3 than they were at Time 2. Indicating that the CPAT training offered no additional benefit on this task. Thus, the findings demonstrate that the CPAT intervention is an extremely efficacious program which has potential to positively impact on many older adults' experience of daily living on a long-term basis (at least 4-months). The relative success of CPAT as evidenced here is attributed to the training tasks specifically targeting certain aspects of attention and working memory which are implicated as being integral to higher cognitive functions such as executive functioning (Willcutt et al., 2005), and fluid intelligence (Engle et al., 1999).

6.3 Addressing the questions and integration with previous research

The findings of this thesis indicate that when stimuli consist of shapes and colours (and do not have stored knowledge associations), top-down guidance can be utilized where strong bottom-up cues need to be avoided. This evidence fits with the notion that attention is captured according to attentional control programming which is brought about by a top-down control setting, and therefore it is possible to ignore objects which do not fit this control setting (Folk et al., 1992). Which contrasts with Theeuwes' (1991) claim that salience captures attention in a bottom-up manner even when it is irrelevant. Furthermore in this thesis we see that search for a target can in some in some situations be facilitated by the presence of a singleton distractor. This fits with the postulation that top-down processing ensures that the singleton distractor is rapidly rejected because prior knowledge that this is not the target guides selection of top-down search in a rapid and flexible manner (Geng & DiQuattro, 2010). In turn this suggests that top-down processing is possible in parallel search (Bacon & Egeth, 1994). Moreover this thesis demonstrates that older participants are equal to younger participants in their ability to utilize top-down process as has previously been demonstrated by Madden et al. (2004). Apparent age related differences were found to be attributable to the general slowing which is associated with the ageing process.

In relation to stored knowledge this thesis has demonstrated that when the target is more difficult to identify (because it does not correspond with stored knowledge) a feature mode of attention is utilized resulting in greater top-down control (Bacon & Egeth, 1994; Leber & Egeth, 2006). Furthermore, we see here that younger and older participants are equally influenced by this reversed effect of stored knowledge association i.e. it is more difficult to ignore an irrelevant singleton distractor when the target corresponds with stored knowledge. Thus suggesting that in real-life situations there is a greater likelihood of interference when objects correspond to stored knowledge associations. To some extent this finding fits with the notion that stored knowledge representations bias attention (Olivers et al., 2011). Evidence suggests that scene context may influence search in natural environments (Mack & Eckstein, 2011), as successful and independent living is ever important in an ageing population (Seidler et al., 2010; Wilson et al., 2002) future research should examine the effects of scene context in natural environments in relation to ageing. In addition it would be interesting to extend this current study further by investigating whether there is any impact of stored knowledge when the stimuli have more than one diagnostic colour association – such as grapes, olives etc., this would enable examination of whether older adults are equal to younger adults in their ability to utilize stored knowledge in less predictable situations.

The intervention carried out here demonstrates that a computerized program of attention training can improve RTs and thus speed of information processing on tasks which measure various aspects of attention and motor skill, and importantly not only on tasks where training has been given, but also on tasks where no training has been given. Moreover the evidence also suggests that the benefits of the training remain stable over a period of four months during which time no training occurred. The findings of the CPAT intervention therefore support the notion cognitive interventions with older adults can improve performance in relation to information processing and attention (Reijnders's et al., 2013; Toril et al., 2014). Improved performance of information processing is of particular importance as declines here limit cognitive performance during ageing (Salthouse, 1985). Furthermore as the CPAT program targeted specific aspects of attention the findings here can help to clarify that speed of information processing is most likely to be the cause of the improvements in performance which are often reported in relation to cognitive training in older adults (Papp et al., 2009; Reijnders et al., 2013; Toril et al., 2014). This would also support the deliberation that in the Anguera et al. (2013) intervention the reported improvements represent a general improvement in speed of processing rather than in specific attention mechanisms or executive control as is documented. This then leads us to question to what extent cognitive training interventions with older adults are able to improve performance on anything other than information processing speed.

With regards to the performance of the control group which continued to improve during the period from taking outcome measures and the four month follow up it seems most likely this was due to the confounding variable of many of the participants in this group enjoying playing the games so much during training that they continued to do so after training had finished (see Appendix B). As such it seems possible to conclude from this that whilst the CPAT training was more effective immediately following training the continued playing of more general games does appear to be beneficial in ameliorating some of the cognitive declines associated with ageing. As such this fits with the postulation that maintaining frequent cognitive stimulation into older adulthood can improve some aspects of cognitive functioning (Wilson et al., 2003). Overall the data indicate that CPAT training is a very successful and efficacious intervention which does seem able to ameliorate some of the declines associated with ageing, and whilst some benefits appear to be long-term it seems benefits could be more extensive if training were longer or even continuous. It would be valuable for future research to compare the performance of the older adults who were training using the CPAT program to that of younger adults without training, to see whether the benefits gained are making older adults' performance comparative to younger adults. This would inform us of the extent of the benefits gained by this training. In addition future research could collect fMRI data to allow examination of whether the difference in performance between the CPAT group and the control group is due to changes in the functioning of the brain or simply behaviour based – to get at the neural mechanisms of training. It would be interesting too to examine the efficacy of using this intervention with dementia patients.

6.4 Limitations

Several limitations in the current thesis should be noted. First, while eye tracking data was collected for young participants I was not able to collect it for older adults. This meant that it was not possible to examine whether there were any differences between the groups in what first captures attention, duration of attention or indeed whether the singleton distractor was facilitating search for the older participants, as well as the younger participants. This information would also have been beneficial in Chapter 4 where colour association was manipulated, and would have improved our ability to interpret performance between the groups. However as the older adults generally took longer than the younger adults to complete the experiments, and some of the younger participants had complained that the equipment was uncomfortable it was not deemed suitable or appropriate to ask older participants to carry out this experiment. Nonetheless it would be beneficial for future research to overcome this issue in order to examine the impact of stored knowledge associations on search as an eye-tracking experiment to enable a more precise comparison between the groups, and the stimuli being correctly coloured relative to incorrectly coloured.

Finally, it is clear that the intervention study would have benefited from larger groups. Indeed some of the effects hovered around significance levels and it is therefore possible that with more participants in the two groups clear effects would have been revealed. One limitation associated with chapter 5 are that it would have been beneficial to have had more participants, however once again there were time constraints, as well as money constraints – as participants were paid (£6 per hour) for the intervention which was deemed necessary given the level of commitment required here. A further limitation of this chapter is that the subjective measures of cognitive performance were self-report measures which were completed in front of the researcher, thus increasing the likelihood of bias reporting. As such it would be beneficial for future research to ask family members or carers to provide this information. Whilst a single-blind design was utilized here, it would be beneficial in future to employ a double-blind condition.

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Appendix A

Table 1. *The overall correlation between RT and number of errors according to Target Presence, Singleton Presence and display size in younger and older adults for Experiment 2.1.*

Group	Condition								
	TpSp4	TpSp6	TpSab4	TpSab6	TabSp4	TabSp6	TabSab4	TabSab6	
Young	-.465	-.391	-.040	-.390	-.130	.186	.645	-.119	
	p>.05	p>.05	p>.05	p>.05	p>.05	p>.05	p<.05	p>.05	
Older	.597	.054	-.381	.330	-.235	.528	.153	.031	.597
	p<.05	p>.05	p>.05	p>.05	p>.05	p<.05	p>.05	p<.05	p<.05

Tp = Target present; Tab = Target absent; Sp = Singleton present; Sab = Singleton absent; 4 = 4 items in the display; 6 = 6 items in the display.

Table 2. *The overall correlation between RT and number of errors according to Target Presence, Singleton Presence and display size in younger and older adults for Experiment 2.2.*

Group	Condition									
	TSSab4	TSSab6	TpSp4	TpSp6	TpSab4	TpSab6	TabSp4	TabSp6	TabSab4	TabSab6
Young	-.629	-.262	-.600	-.555	-.309	-.415	-.365	-.126	.102	-.49
	p<.05	p>.05	p<.05	p<.05	p>.05	p>.05	p>.05	p>.05	p>.05	p>.05
	-.240	.285	-.250	-.272	-.050	-.051	-.235	.527	-.176	.082
Older	p>.05	p>.05	p>.05	p>.05	p>.05	p>.05	p>.05	p<.05	p>.05	p>.05

TS = Target Singleton; Tp = Target present; Tab = Target absent; Sp = Singleton present; Sab = Singleton absent; 4 = 4 items in the display; 6 = 6 items in the display.

Table 3. *Non-significant results for the singleton distractor absent ANOVA for Experiment 2.2*

Effect	F value	df	p value
TC x Gp	1.909	1,35	0.176
DS x Gp	0.182	1,35	0.673
TC x DS	1.969	1,35	0.169
TC x DS x Gp	1.104	1,35	0.3

TC = Target Colour. DS = Display Size. Gp = Group.

Table 4. *Results for the singleton distractor present ANOVA for experiment 2.2*.

Effect	F value	df	p value
DS	2.937	1,35	0.095
TP x Gp	0.909	1,35	0.347
SD x Gp	2.588	1,35	0.117
DS x Gp	0.422	1,35	0.52
TP x SD x Gp	0.005	1,35	0.946
TP x DS x Gp	0.539	1,35	0.468
SD x DS x Gp	0.237	1,35	0.629
TP x SD x DS	0.594	1,35	0.446
TP x SD x DS x Gp	0.109	1,35	0.743

DS = Display Size. TP = Target Presence. SD = Singleton Distractor. Gp = Group.

Appendix B

Qualitative study

Introduction

A systematic review carried out by Reijnders et al. (2013) which evaluated cognitive interventions for healthy older adults and those with MCI, reported that although there was evidence that the interventions resulted in some cognitive improvement, the quality of the interventions was typically low. One of the suggested ways to improve the quality of such interventions was for future interventions to include subjective outcome measures.

Qualitative methodology is used to describe attributes within data which has been collected from small (samples) groups via conversations in real-life settings (Braun and Clarke, 2013). Within qualitative research the participants' experience and opinions are valued and rather than being reduced to numbers the data the conversation is examined for patterns or themes that are brought about by the participant. As qualitative methodology is posited to be particularly beneficial when it is desirable to capture the individual's point of view (Braun and Clarke, 2013), it seems this would be an appropriate way to subjectively examine the impact of a cognitive intervention.

According to Bandura (1989) the stronger an individual's belief that they have the ability to carry out a task the stronger their persistence and efforts will be to achieve their goal. Furthermore according to Bandura (1989) cognitive training which raises efficacy and develops cognitive skills is likely to have long lasting effects and be generalizable to other tasks. As it has been reported that older adults are vulnerable to negative emotions (Galvin et al., 2006) it seems that not only is it important to increase older adult's self-efficacy in relation to cognitive functioning – as this could have lasting and transferable benefits, but also this could benefit older adults by reducing negative emotions and thus improve feelings of well-being in older adults. Friedrich (2003) reported that better psychological ageing is associated with greater psychological well-being, as well as better quality of life. Furthermore Friedrich (2003) also reported that successful ageing manifests higher functioning. Thus it seems that if the current (CPAT) intervention can improve older adults' self-efficacy in relation to cognitive functioning it is possible that this could have a positive impact on well-being and quality of life.

Method

Participants

The participants were those who undertook the cognitive intervention for older adults – there were 24 older adults in total, with 12 in each group. Ages ranged from 61 years and 82 years across both groups.

Materials

There were thirteen questions in total for the Time one interview; the questions addressed demographic information, activities and hobbies, current cognitive performance (separated in to memory, concentration, attention etc. (see Appendix B.1)) and performance now relative to younger years. For the Time 2 interview there were six questions which addressed whether the participant felt the intervention had had any impact, and what aspects they did and did not enjoy about the intervention (see Appendix B.2).

Procedure

Questions for the Time 1 interview the schedule had been designed specifically for this intervention and asked thirteen questions in total, and depending on length and depth of replies took between 15 minutes and 50 minutes to complete. The researcher by this time had spent approximately just over two hours with each individual participant which allowed for enough of a relationship to be built to allow the participant to feel comfortable (and not defensive) to talk openly about themselves and their experiences. The aim of the Time1/baseline interview was to establish the typical type of activities these older adults engage in, and explore whether they were aware of any decline in their cognitive functioning which was impacting on daily life.

The questions on the schedule for Time 2 interviews had also been specifically designed for this intervention. These interviews lasted between 8 and 25 minutes to complete. The aim of this interview was to investigate whether participants reported any subjective improvement in their daily performance after having taken part in this intervention. As well as to assess whether the intervention was felt to be arduous or enjoyable, and inform us of any possible changes which could be made in order to improve the participants' experience.

Interviews were recorded using a mobile phone; this was then transferred on to a (pass word protected) computer as a voicenotes file from which transcripts were typed in word. The review – comment function was used to identify themes in the data.

Interviews were then transcribed. Thematic analysis was deemed the most appropriate method of analysis here because it is flexible enough to be applied to a variety of theoretical and epistemological approaches whilst still providing a thorough account of the data (Braun & Clarke, 2006). These data were analysed in an inductive manner i.e. allowing the themes to emerge from the data, rather than in a deductive manner in which themes are or theories are tested. The epistemological approach here was experiential realist as the matter of interest was how the participants make sense of and understand their experiences of cognitive functioning on a daily basis.

Results

Time 1

Once transcribed the individual interviews were examined for codes and comments scribed accordingly. The next step was to bring all the individual interviews together according to groups (CPAT and Controls) and gather some general themes. The two sets of themes were then compared and at this point it became apparent that the two sets of themes were very similar and the decision was made to combine them to make just one group of themes for all of the participants. This is desirable in the sense that it means there are no discernible differences between the two groups with regards to their subjective cognitive performance, and therefore unlikely to impact on performance or outcome of the intervention. As a result of these similarities it seemed that there was no longer any need to analyse the two groups separately for themes which underlie the participants' perception of their own cognitive performance.

The overarching theme that seemed to come out of this analysis is that on the whole participants tend to take part in a mixture of physical and cognitively stimulating hobbies and pastimes for Fulfilment. There was only one participant (from a total of twenty-four) who stated only cognitively stimulating hobbies, joking that 'once I did something physical' (LD) when asked about physical hobbies/pastimes. Whilst these two types of activities are volunteered in equal measures as pass times they do seem to be reflected on differently. This could be due to the fact that the focus of this interview was largely cognitive functioning but also it is possible that it is symptomatic of an underlying tendency on the whole to be less concerned with cognition generally or perhaps it is a tendency to 'play down' the importance of cognition, which of course could be a self -defence/protective mechanism because the prospect of having cognitive functioning issues is too distressing to process.

When asked 'Is there anything you don't currently do that you would like to do?' replies tended to fall in to two categories: there was nothing that they would like to do that they don't currently do and the other and most common reply related to a physical activity, ranging from 'swimming' (PR) to 'riding a motor bike' (ljD). There were no responses relating to cognitive functioning, seemingly indicating that physical activities are either seen as more important or fulfilling or at least are prioritised differently to cognitive activities. Further support for this notion comes from responses given when asked if there was anything preventing participation in an activity and the most common responses were time, motivation and most pertinently physical inability. The physical inability then fell in to two further categories whereby participants reported having a physical injury e.g. 'a bad ankle' (DH) etc. or no longer being able i.e. being too old to be able to play rugby anymore 'you adjust your expectations as you get older'. (BN)

Highlighting this point further is that when asked 'how important are these activities to you?' responses tended to indicate that the activities were important - ranging from quite important to (RW) 'it's my life' and this was sometimes related to a particular activity e.g. 'Oh the cooking and the allotment I find uh very satisfying, in that I um get great pleasure out of both of them' (AG). Also responses often noted that there is a great deal of enjoyment associated with physical activities and this is often related to the social aspect of the activity, which is often cited as something that is (JP) 'missed since finishing work'. And where responses indicated that physical inability was preventing participation there was a great sense of frustration associated with this. This seems to suggest not only are physical activities of higher importance but they are more enjoyable – possibly because they fulfil a need for socialising which has decreased since retiring.

With regards to cognitive activities there were direct and indirect types of cognitive hobbies, with direct being cross words and other types of puzzles, and indirect being holding position of secretary for the fishing club etc. When asked 'Is there anything you don't currently do that you would like to do?' no responses were in any way related to cognitive activities thus seemingly suggesting that cognitive activities are not perceived as activities or hobbies that are particularly desirable or perhaps are not seen as specific hobbies or activities at all. The nature of cognitive activities participants engaged in varied greatly from doing puzzles to being secretary of chess club and a member of Mensa. Most participants used a computer to some extent, the majority used one frequently and many of the participants used computers to play games ranging from matching shapes etc. to chess.

When asked about current cognitive performance (specifically concentration, attention, memory and executive functioning) and whether any lapses had been experienced in these areas, the most common reply was that lapses in concentration had been experienced, in addition many participants report having memory lapses. When participants mention these lapses it is on the whole without any concern saying 'well it could be that I put that down to I'm a pensioner' (KE) and 'yes, I do lose the thread sometimes there and I do can occasionally lose concentration or forget shopping and stuff but nothing'. (RC). It seems these lapses are perceived as a normal part of ageing and thus are no cause for concern. There is further evidence of this perception of normal ageing in responses given to participants being asked 'would you say you experience these kinds of events more than you would like?', and 'Have the number of times and severity of these events changed in recent years, in comparison to when you were younger?' Whilst some participants claim to notice no difference in cognitive performance 'I wouldn't say so too much' (BS) as a result of ageing and some others mention that their memory isn't as good as it was, however, by far the most common answer is to say there is some difference but to justify this, e.g. (DC) 'It's part of life really and everybody day dreams' and (JP) 'it's part of ageing isn't it'. As such it seems that whilst on the whole these older adults had experienced some changes in cognitive functioning as they age but this change is simply accepted or perceived as normal.

When participants were asked whether they had adopted any strategies to help with memory or attention the most common response was that they write things down and rely on this e.g. (AG) 'Yes, um, yes, we do keep a good calendar, which helps, but that's uh fine. As long as we all remember to write on what we're doing', and (JP) 'Yes, I do take notes', and (LD) 'now it all goes down in the diary'. There were also some more elaborate strategies such as (LjD) 'go out cycling mentally', and (JP) 'I um, put something in a specific place. I have to do something to make myself remember to do it'. Perhaps the most insightful answer to this question came from (GB) who admitted openly 'I also avoid doing somethings because I don't want to get too stressed about memory', demonstrating that it is better to avoid attempting to do a task rather than to try to do it and thus highlight an issue which would give cause for concern.

Participants were asked 'Is there anything in particular you are hoping to get out of it?' Only three of the twenty four participants did not reply with a direct yes to this question, suggesting that almost all of the participants had volunteered to take part in this intervention in the hope that they would improve some aspect of their cognitive functioning (they were not aware that there were two groups and that one was a control group, as such they all believed they were coming to take part in an intervention that may help to improve cognitive functioning). Whilst some replies were simply yes, with nothing in particular specified, the most typical response was that it would be good to see an improvement in memory and or attention e.g. (RW) 'memory training, or something', and (BN) 'To remember whether I've locked the door or not'. And (BS) 'I want to be able to focus better'.

The overarching theme to come out from Time 1 was Activities past and present, with sub-themes stemming from this overarching theme being Physical and Cognitive activities, which in turn stem in to themes such as Motivation and Enjoyment which then go down to lower levels themes such as Injury and Too old (for full Thematic map see Appendix B.3).

It would seem that overall the responses given in interviews at Time 1 highlight a slight contradiction, in that whilst for these participants cognitive functioning does not appear to top their lists of enjoyable pastimes and that where they do acknowledge some level of change in these functions over time they portray these as nothing to be concerned about, they are nonetheless willing to volunteer to take part in an intervention which requires a great deal of commitment in the hope that it *may* improve some aspect of cognitive functioning. This seems to suggest they possibly have an underlying concern that perhaps they do not wish to voice or that they have not explicitly thought about their own cognitive functioning on a daily basis. As such it will be interesting to see in the interviews at Time 2 whether taking part in the intervention has increased participants' awareness of their cognitive functioning.

Time 2

As the aim of the intervention was to improve attention and memory in the experimental group in comparison to the control group it is necessary to analyse the Time 2 interviews in terms of two separate groups. All Time 2 interviews took place at the end of the session for taking outcome measures, this always took place in the same room and where possible at the same time of day as the baseline measures.

CPAT Group

The themes that emerged from the CPAT group Time two interviews, whilst different in some respects to the Control group, did overlap to some degree – which is not surprising given that the participants were in a single blind situation participating in different games but in all other respects it was the aim of the intervention to ensure all participants had a similar experience. The overarching theme for the CPAT group was Cognition; participants in the CPAT group seem to be much more focused on cognition. Whether they benefited from improved cognitive functioning or simply had been made more aware of their cognitive functions they all commented on their experience as being positive and thus report enjoying participation, gaining something from taking part and indicating that they would repeat the experience as they feel they benefitted from it.

Following interviews at Time 1 it became apparent that participants did not seem to have a great awareness of their cognitive functioning as such it is interesting that participants in the CPAT group seem to have increased awareness of cognitive functioning, as it corroborates the findings that at Time 2 participants in this group showed improved performances on the various experiments used to take outcome measures.

The sub themes stemming from the overarching theme of Cognition were increased awareness of cognitive functioning and perceived improvement in cognition. Only two participants in this group did not specifically state that they either perceived an improvement in their cognitive functioning, or had developed an increased awareness of their cognitive functioning. One participant (BN) during the Time 2 interview stated 'it's shown me I need to concentrate more' indicating an increased awareness of cognitive functioning and then later wrote a letter (see Appendix B.4) saying 'I haven't had to go back to find out if the door was locked for quite some time.' The same participant goes on to say 'also haven't come back from shopping short of an article, even once'; thus highlighting an actual perceived improvement in cognitive functioning, as an addition to the reported increased awareness. This participant also writes that it might have been beneficial to have been given time to ponder the questions prior to the interview, which is potentially something which may have been an interesting step to take. Another participant (PR) states 'I feel my brain is going a lot quicker', which is interesting once again in light of the experimental outcome measures which seemingly demonstrate the result of the intervention at Time 2 in the CPAT group is an improvement in information processing.

All participants report that overall the experience of taking part was a positive experience regardless of whether they reported having perceived an actual improvement or developing an increased awareness of cognitive functioning suggesting that evaluation of the intervention was not based solely on outcome. An example of evidence that participation was a positive experience is when LD says 'yes it's been helpful and really enjoyable' in response to being asked 'do you feel the intervention has made any difference to you in any way at all?' Another clear example that the participant found the experience to be positive is seen when LjD states 'All of it' in response to being asked 'Is there anything in particular that you have enjoyed about the intervention?' Whilst on the surface the themes here may appear to be similar to those of the control group (below) where the theme of positive experience (with many participants enthusing about the experience) leading in to sub themes of worthiness and highlights. However with the CPAT group the results are different in that the theme of overall experience (whereby participants explain that they have enjoyed the experience but there were aspects of it that were less enjoyable) with the lower level themes stemming from this being enjoyment and gain.

Whilst all participants in this group indicated that the overall experience had been positive many participants indicated that there were aspects of the intervention which were less enjoyable. This is a tendency which was less evident in the control group and is represented here by the sub theme labelled enjoyment. The majority of the participants in this group mentioned at least one task that they didn't enjoy, as is evident when asked 'is there was anything that you didn't enjoy?' LjD replies 'Uh, the mindless tasks', it is later established that these are the baseline and outcome measures. In response to the same question RC says 'Some of the tasks can be a bit tedious but I, no. No, some bits I enjoyed some less than other bits' and MC specifies a training task (CPT) that was felt to be a less enjoyable part of the intervention 'Um, probably that car [laughing], it was a pain in the neck.' However whilst it could seem that this group were less positive about the intervention than the control group, this is not the case as is shown above participants did report having enjoyed their participation, nonetheless they were more likely to openly report aspects that they had not thoroughly enjoyed, it is possible that this is linked to their training tasks which could conceivably have been more demanding resulting in participants feeling more fatigued in turn prompting a stronger response.

The lower level theme of gain emerged as most participants indicate that they feel they benefited in some way from taking part in this intervention, reported benefits range from helping the cause of science as was reported by RC 'certainly helpful to the cause of science.', to feeling useful as was the case for MC who stated 'if it's useful to someone else, that's what matters' and JP who said 'Um, I think it gives you a bit of added purpose in life, because you're doing something useful.' However the most pertinent gain mentioned here was that of improved self-efficacy which was specifically stated by five participants. This is demonstrated clearly by DH who stated 'and feeling that I can do that because at 80 sometimes you think um I don't know whether I can do it, I guess it's confidence in a way.' Another clear example of improved self-efficacy is demonstrated by LjD who said 'Yes, the brain still works, you can actually do something with it. Yes, I've actually thought of uh going back to OU (Open University) again'. A further example of this is given by BC who when talking about how he has improved on the tasks said ‘Yes, it was very reassuring. Yes, there was a nice feeling about that’.

In conclusion the overarching theme to come out from the CPAT group at Time 2 was Cognition, with sub-themes stemming from the overarching theme of Cognition being increased awareness of cognitive functioning and perceived improvement in cognition with the lower level theme being positive experience from which came the lower level themes of enjoyment and gain (see Appendix B.5).

Control Group

The over-arching theme for the control group at Time two appeared to be perceived gain; it seemed that all these participants felt they had gained something from taking part in this intervention, reported gains ranged from learning to use a computer mouse to perceived improvement in attention and memory. As this was an active control group is it possible that the games they were playing resulted in some improvements in cognitive functioning however results of experimental tests indicate that performance of those in the control group at Time two overall was generally maintained rather than improved thus suggesting that those in this group who reported benefiting from the intervention were experiencing a placebo effect or perhaps the reported benefits in cognitive functioning were the result of demand characteristics. Nonetheless these perceived benefits in cognitive performance are likely to result in improved self-efficacy which in turn could benefit everyday life.

Reported gains fell in to two categories (sub-themes), there were gains in terms of enjoyment and gains in terms of skills, participants often reported experiencing both. The first question participants were asked was Following the intervention have you noticed any changes in your ability to recall information, switch tasks or focus attention in everyday life or during your hobbies/socialising or work? and whilst ten of the twelve participants reported experiencing some improvement in cognitive functioning at a later stage of the interview, the majority of participants (seven) answered no in response to this question. This suggests that they had not experienced such an obvious improvement in cognitive performance that it was noticeable and at the fore front of their mind, only after thinking about this did it seem to the participants that there perhaps had been improvements.

Interestingly two participants specifically state that the intervention increased their awareness of cognitive functioning (AG and BS), both seem to view this in a positive manner and report that they got a great deal of pleasure from taking part and would happily do so again. It would be interesting to repeat the Time 1 interview with these participants to determine whether this awareness impacts on their answers relating to daily cognitive functioning.

When asked 'Do you feel the intervention has made any difference to you in any way?' the most common reply related to improved concentration levels as highlighted by DP It's helped me concentrate more, on things that I'm doing rather than rather than um, just looking at something and RVW Made me concentrate better. Other answers indicated pleasure at learning new skills an example of this is JD's reply it's taught me to eh use a mouse and DC's reply And I've learned something that I didn't before, so. It is worth noting that in response to this question all participants report having experienced some benefit even though this was the control group demonstrating that the intervention had a positive effects in addition to those which were intended. As such it would seem that positive experience is a sub-theme stemming from the gaining of skills and enjoyment because in addition to the positive effects of gain all participants reported enjoying their participation. An example of which is when asked whether there was any particular aspect that had been specifically enjoyable, DiP replied Oh yes, I feel better, I feel better for it I really do, I mean that and I just liked the whole, I enjoyed the whole thing, I mean that, DC's response also clearly highlights this Oh I've really enjoyed it. And he goes on to say all of it.

A further theme which emerged was highlight; on the whole participants in this group indicated that they had most enjoyed the games they had played and had least enjoyed the taking of baseline and outcome measures. Evidence of this is seen in the response of KE I loved playing the games and RW stated particularly the Mah-jong the most GB's responses shows clearly that whilst the games/training was enjoyable I enjoyed playing the games, but the baseline/outcome measures were less so - going on to say I found some of the longer tasks boring, like the pointing one we did earlier (the longer tests and the pointing task are the baseline/outcome measures). Also RvW indicated less enjoyment of the baseline/outcome measures, saying 'those were quite taxing I thought'. It is also worth noting here that many of the participants in this group intimated that they had continued playing the games (Minesweeper, Solitaire, and Mah-jong) used for their training sessions at home on their own computer, thus providing further evidence of the enjoyment gained here.

Another sub-theme was worthiness – of the intervention; this theme seemed to be tied to the positive experience theme. This theme seemed to emerge as participants indicated that they would repeat the experience because they found it interesting and an enjoyable challenge indicating that they felt the intervention was worthy of their time and effort, as KE's response shows 'Well because I enjoyed it'. I thoroughly enjoyed it and learned from it DiP's statement is another clear example of this, when asked why she would be willing to repeat the experience she replied 'Actually, the challenge, that's what it is', and went on to say 'So just to say that I thoroughly enjoyed it, the whole experience and definitely would do it again'.

In conclusion the overarching theme to come out from the control group was gain, with sub-themes being enjoyment and skills, the lower level theme being positive experience from which came the sub themes highlight and worthiness. Participants overall demonstrated that they had gained from taking part in the intervention whether just in terms of enjoyment or a subjective belief that they had improved their cognitive functioning. In addition it was evident that participants had particular highlights and lowlights, and had felt participation was worthwhile (see Appendix B.6).

Conclusion

These findings based on Thematic analysis of semi-structured interviews provides evidence that as a result of participating in this experiment all participants not only had a positive experience but also perceived having gained to some extent from the intervention. Moreover these findings provide further support that at Time 2 the CPAT group experienced an improvement in cognitive functioning which in turn resulted in improved self-efficacy. It is possible that this could be a result of the feedback and points system used by the CPAT program was not only motivating participants to work hard and improve performance but was in fact regarded as a test and thus was more challenging than the games played by the control group and therefore possibly explains why the CPAT group were more inclined than the Control group to report aspects of the intervention that they did not enjoy. Furthermore the

Control group did have the option of continuing to enjoy playing the games on which they played for their training sessions, after the completion of training, which the CPAT group did not and this potentially could influence perceived levels of enjoyment.

Appendix B.1

Cognitive functioning and well-being in older adults.

Interview Schedule

Introduction

You are here as you have volunteered to take part in an intervention which aims to improve attention. Attention is a blanket term which and in this case refers to the ability to concentrate for sustained periods of time, the ability to switch tasks efficiently whilst maintaining concentration and to avoid being distracted by irrelevant information. Each of these cognitive abilities are known to effect our executive control processes. Executive processes are those which underlie our ability to problem solve and plan.

The purpose of this interview is to discuss with you how you feel you currently perform on these types of tasks and whether this has any impact on your daily life.

Are you happy to continue and is it OK to record this, please? The recording will only be used for my work and will not be used publicly

1. Can you tell me about your occupation or profession (prior to retirement)? What did it involve and how long were you/ have you been doing it? And did you enjoy it and find it satisfying?
   If you did not work externally to the home previously (say homemaker, carer then focus on this or voluntary work)?
2. Is there anything you don't currently do that you would like to do? Can you tell me what prevents you doing this? Hobbies/socialising.

*Things used to do
*Things would have liked to but not possible

3. How many activities/hobbies do you take part in at the moment, can you describe them to me?

*Physical or mental
*How long been doing it
*How much time a week

4. How important are these activities to you? Can you explain to me what benefit or enjoyment you get from these activities?

5. Do you find you have ever or sometimes lose concentration during these activities/hobbies? Can you describe such a time?

*Distracted by something
*Forgotten what doing or done
*Difficulty in staying ‘tuned’ in for as long as is required.

6. Can you tell me about a time when you have experienced any lapses in concentration, attention or memory, during every day activities e.g. shopping, reading, paying bills or even watching TV programmes etc? Can you give me an example?

7. Do you sometimes feel or have you ever felt that you struggle to find the relevant information or a particular item you want or need when it is set amongst a lot of irrelevant information or items? Can you tell me what happened?

8. How do you feel when you are required to suddenly change from doing one activity to another? Are you confident that you can do so accurately and efficiently with no detrimental effects on yourself or the task?

9. Do you experience any difficulties in planning events such as outings or holidays? And how would you describe your ability to solve any issues or overcome obstacles e.g. public transport times not corresponding well with a planned meeting?

10. Do you experience these kinds of events more than you would like? Do you have a strategy for dealing with them?

11. Have the number of times and severity of these events changed in recent years (relative to when you were younger)?

12. Can you tell me whether you are hoping to gain anything in particular from taking part in this intervention?

13. Is there anything else you would like to add?

*Items of interest or related to the question

Prompt Questions: Can you tell me more about that?
Can you give me an example?
In what ways?
Now let's talk about
Going back to what you said
Can I just clarify

Appendix B.2

Outcome interview schedule

1. Following the intervention have you noticed any changes in your ability to recall information, switch tasks or focus attention in everyday life or during your hobbies, socialising or work?

2. Do you feel the intervention has made any difference to you in any way?

    *****Confidence?

3. Is there anything in particular you have enjoyed about the intervention?

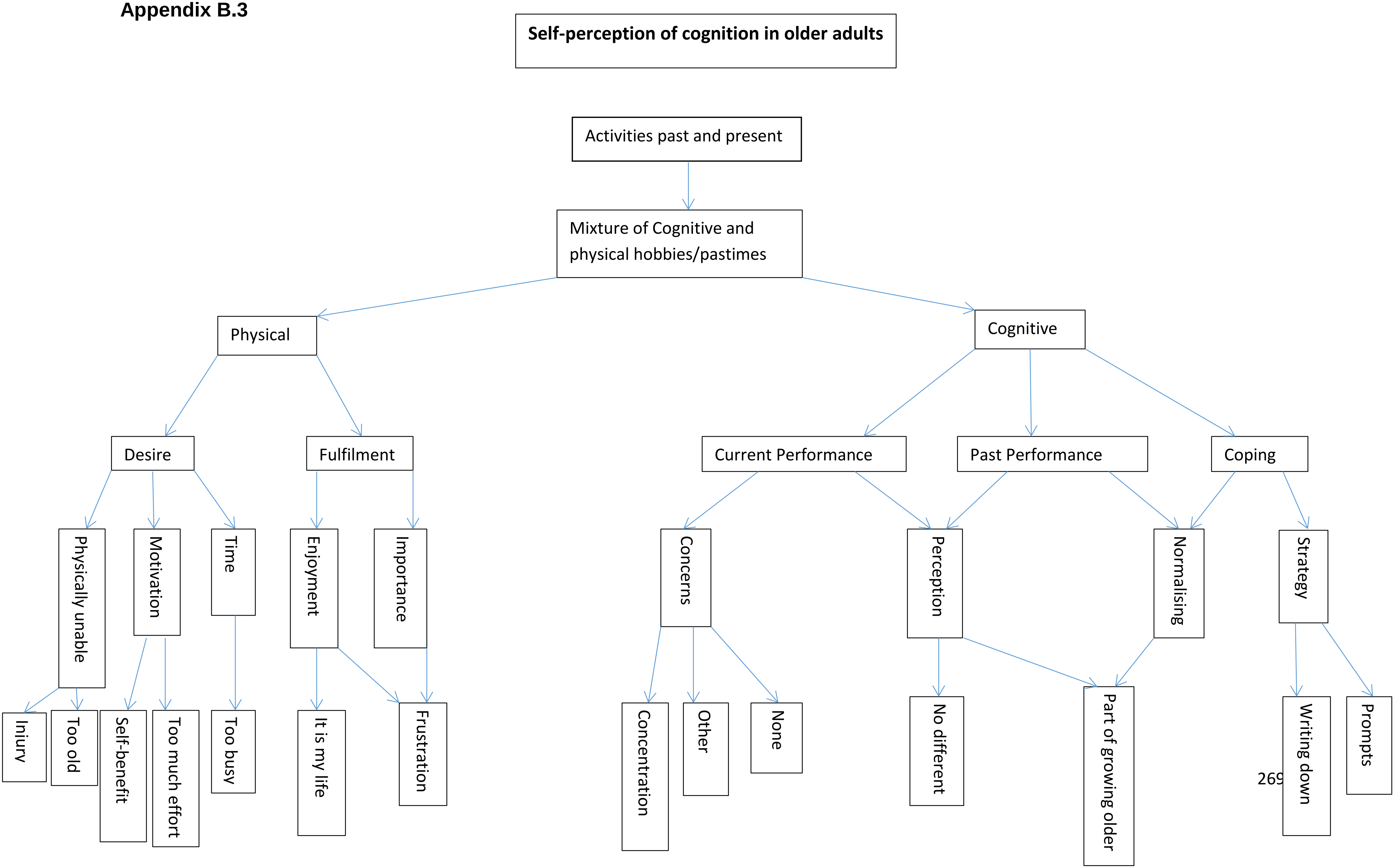
4. Is there any part of the intervention you did not enjoy?

5. Would you do the intervention again, or recommend friends do it?

    a. Why?

6. Is there anything else you would like to add?

Appendix B.3


Self-perception of cognition in older adults
Activities past and present
Mixture of Cognitive and physical hobbies/pastimes
Physical
Cognitive
Desire
Fulfilment
Current Performance
Past Performance
Coping
Physically unable
Motivation
Time
Enjoyment
Importance
Concerns
Perception
Normalising
Strategy
Injury
Too old
Self-benefit
Too much effort
Too busy
It is my life
Frustration
Concentration
Other
None
No different
Part of growing older
Writing down
Prompts

Appendix B.4

Hi Mo,

I can’t find your email address so note as follows.

I was considering your questions after the last session, and it occurred to me that I haven’t had to go back to find out if the door was locked for quite some time. Probably 6 weeks. I also haven’t come back from shopping short of an article, even once.

I also completed Minesweeper, expert level, 3 times over the weekend: I must be concentrating better.

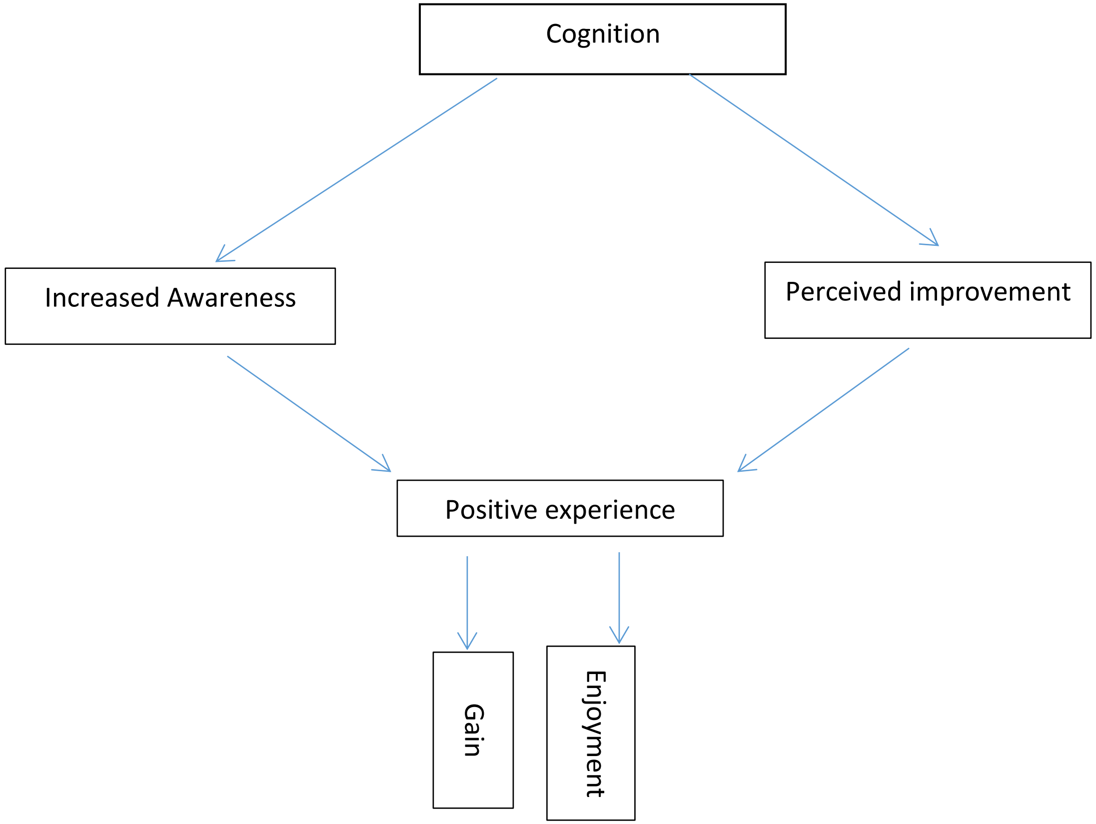
I hope this is useful to you, and suggest that if I had been forewarned of the questions after the penultimate session, I would have had time to consider my replies.

Trying to help, not criticise.

Best wishes

Appendix B.5

Perception of invention effects for the CPAT group



Appendix B.6

Perception of invention effects for the Control group