The effects of saliency and task difficulty on visual search performance in ageing and Alzheimer’s disease

Andrea Tales a,1, Janice Muir a, Roy Jones b, Anthony Bayer c, Robert J. Snowden a,∗

a School of Psychology, Cardiff University, Cardiff CF11 3YG, Wales, UK
b The Research Institute for The Care of the Elderly, St. Martin’s Hospital, Bath BA2 5RP, UK
c Department of Geriatric Medicine, Llandough Hospital, Penlan Road, Penarth CF64 2XX, Wales, UK

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Abstract

We asked whether the poor performance on visual search tasks typical of patients with Alzheimer’s disease (AD) is the result of a selective deficit in the ability to shift attention from item to item, or the consequence of an inefficient processing of each item within the search set. We attempted to manipulate the ease of attention shifting and item processing in a visual search task by manipulating target salience and task difficulty, respectively. Significant effects of both target saliency and task difficulty for both AD patients and age-matched controls were obtained, with the AD group displaying greater effects of both of these manipulations than the controls. This interaction remained even when the reaction time data were log-transformed to account for the overall slower reaction times of the AD group. We conclude that inefficiency in visual search tasks in AD probably represents the product of both attention shifting and target processing factors.

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1. Introduction

In addition to memory and cognitive disturbances, deficits in a variety of attention-related tasks have been demonstrated in individuals with Alzheimer’s disease (AD). Some attention-related processes, are however, reportedly spared and the exact nature of attention-related dysfunction in AD remains controversial (e.g. Parasuraman & Hadby, 1993; Parasuraman, Greenwood, & Alexander, 1995; Parasuraman, Greenwood, & Sunderland, 2002; Perry & Hodges, 1999; Tales, Butler, Fossey, Gilchrist, Jones, & Troscianko, 2002; Tales, Muir, Bayer, & Snowden, 2002). Particularly as demonstrating poorer performance on an ‘attention-related’ task is not the same as demonstrating a selective deficit in this particular function.

For instance, if one were to show that performance on a particular task, let us say visual search (the focus of the present study), is worse for AD than for appropriate controls then does this necessarily mean that their ability to ‘search’ (i.e. to shift attention from item to item) is impaired? Such a result could, feasibly, be also explained by an inefficiency in processing each element within the search set, rather than any deficiency in moving attention from item to item. This important theoretical issue, the extent to which any deficit is specific to the function under scrutiny or whether it is a part of a more generalised cognitive slowing, has been addressed several times in the domain of natural ageing (Salthouse, 1985) but has rarely been addressed in the domain of attentional function in AD.

1.1. Visual search

Visual search is a common task used to determine attention-related performance in AD. In such a task, the participant is asked to detect or identify a target element (e.g. a red vertical line) which can be embedded in a field of non-target elements (e.g. green vertical lines). A substantial literature exists (for a review see Wolfe, 1998) that shows some searches (such as the one described above where the colour of the target element is very different from all the
non-target elements) can be completed quickly with no interference from the non-target elements. Other searches, particularly those where the target and non-target elements share similar features, appear difficult and take longer as the number of non-target elements increase.

1.2. Alzheimer’s disease and the visual search paradigm

Few studies (Foster, Behrmann, & Strauss, 1999; Greenwood, Parasuraman, & Alexander, 1997; Parasuraman et al., 1995; Parasuraman, Greenwood, & Alexander, 2000; Tales, Muir, et al., 2002) have so far examined visual search performance in AD patients. One of the most comprehensive studies, and illustrative of the points we wish to raise, is that of Foster et al. (1999). Participants searched for a particular target, a filled circle, in the presence of unfilled circles (they termed this a simple feature search) or in the presence of both unfilled circles and filled squares (they termed this a conjoined feature search). Their results were typical of the literature in several ways. First, performance was unchanged by the number of non-target elements for the simple feature search, but reaction times (RTs) rose with increasing number of non-target elements for the conjoined feature search. Second, this pattern of results was true for both controls and AD patients. Third, RTs were much longer for the AD group on both tasks. Finally, the slope relating RT to number of non-target elements was greater for the AD patients than for the controls (though see Parasuraman et al., 1995).

Crucially, Foster et al. (1999) made attempts to compare the pattern of results obtained to what might be expected from a more generalised slowing of cognitive performance. They constructed ‘Brinley plots’ (Brisley, 1965) where the performance of young control participants was plotted against the group under consideration. If performance of the group under consideration were to decrease at the same rate as the young controls such a plot would have slope of 1, whereas if they deteriorate more rapidly the slope is greater than 1. For the data from their conjoined feature task they obtained slopes of 3.64–5.2 and argued that these are beyond those seen in normal ageing, or those obtained from a battery of cognitive tasks on AD patients (Nebes & Brady, 1992). Thus, they conclude that the impairment seen in this task is beyond that which could be accounted for by a generalised slowing. Unfortunately, such an analysis cannot be performed on the feature search data. Despite the fact that the AD patients were profoundly slower on the simple feature search, Foster et al. (1999) suggest that such patients are only cognitively impaired ‘when the target item shares common features with other stimuli in the background.’

The underlying physiological basis for these results has generally been explained in terms of AD-related pathological change in the parietal cortex, an area involved in the shifting of visual spatial attention, and disturbances in the status of the neurotransmitter acetylcholine, also heavily implicated in the shifting of visuospatial attention (Alexander et al., 2002; Braak & Braak, 1991; Corbetta, Miezin, Shulu-Man, & Petersen, 1993; Corbetta, Shulman, & Petersen, 1995; Corbetta, 1998; Foster et al., 1999; Jagust et al., 1997; Levy et al., 2000; Rösler et al., 2000).

1.3. Visual search performance in AD: attention shifting versus item processing contributions

It is often assumed that visual search tasks that result in greater RTs with increasing number of items, require that attention be serially shifted from item (or group of items) to item. Any deficit in shifting attention should produce greater RT versus number of item slopes, and hence this task should be severely affected in AD patients. On the other hand simple feature searches are associated with the automatic attraction of attention to the target (based on salience mechanisms) without the need for the sequential shift of attention. Thus, the pattern of results obtained to what might be expected from a more generalised slowing is that AD patients simply take longer to process each item (or lack of slope to be precise) of this function as a result of AD, it does not explain why RTs should be greater for the patients in this task.

An alternative explanation to deficits in shifting attention is that AD patients simply take longer to process each item (or group of items). Let us hypothesise that the AD patient takes four times as long (compared to a young control) to process any individual item within the search array. This would then produce slopes that are far greater for the AD patients in the conjunction search, and indeed it would produce Brinley plots with slopes of around 4.0. The major advantage of this idea is that it can also explain the data from the simple search paradigm. Due to the salience of the target only one item is ever fully processed, no matter how many are presented. However, as the AD patients take longer to process this item so the RT versus items function lies far above that for the young control, but remains flat.

In the following experiments we attempt to provide evidence that might distinguish between the two possible reasons for the performance of the AD patients, namely a deficit in shifting attention versus a deficit in processing items. In the first experiment we attempted to repeat the basic findings of other studies on visual search. However, we have made some changes in methodology that we believe are necessary for appropriate comparisons to be made. In the second experiment we attempt to manipulate item processing, i.e. the time taken to process each item in the display, by manipulating the difficulty of the task, and at-
tempt to influence the efficiency of shifting attention from item to item by manipulating the salience of the target.

2. Experiment 1. The performance of AD patients on the visual search task

2.1. Methods

There have been criticisms in terms of possible confounding effects of many designs typically seen in visual search tasks, any of which could potentially differentially affect the performance of control and AD groups. For example, performance on visual search tasks is not only related to the number of items, but also to crowding effects, the eccentricity in the visual field of the elements, display size, and stimulus dimensions, and any number of possible interactions between these factors (Carrasco, Evert, Chang, & Katz, 1995; Duncan & Humphreys, 1989; Wolfe, 1998).

Furthermore, some visual search tasks require the detection of the target element, others some decision about the nature of the target element, and yet others the location of the target element. Indeed, in considering the study of Foster et al. (1999) although they appear to have kept the judgement the same (press a button if the target element, a filled circle, is present), it is clear that such a judgement could be made in a very different manner in the two tasks. In the simple feature search, the presence of any filled item is enough to trigger the ‘present’ response without any inspection of the item. However, for the conjunction task, presumably each item has to be inspected. In other words this study confounds what attracts attention to the item, with the decision to be made about that item (for a detailed discussion of this problem and its solution see Bravo & Nakayama, 1992). In the present study we therefore circumvented this problem by making the decision to be made about the target item (did it point left or right) orthogonal to the dimension that defines its salience (in this case colour versus shape) differences, and we used a configuration that made sure all items (both targets and non-targets) were equidistant from the fixation marker.

2.2. Stimuli

Fig. 1 illustrates the displays used in these experiments. All trials contained a target element that was either a (or a), (i.e. a left or right-pointing arrow) and the participants’ task was to indicate which of these occurred. The non-target, i.e. distractor elements, had the same form as the target but with the apex of the arrow pointing up or down. In one block of trials the target element was white whilst all the non-target elements were black. We prefer to term this the ‘colour salient’ (or ‘salient’ for short) condition rather than simple-feature search in order to avoid links to a specific theoretical viewpoint. In a further block of trials, the target element was black and so were all the non-target elements (Fig. 1). We term this the ‘colour not-salient’ (or ‘not-salient’) condition. We expected the target to be salient and therefore to ‘pop-out’ in the salient condition, irrespective of the number of items, whilst we expected RT to rise with an increase in the number of items in the non-salient condition. Note that the judgement made about the target (is it a (or a)) is the same for each task, and is independent of what defines the element as the target.

All stimuli were presented on a MAC Powerbook 180 computer that was viewed from a distance of 57 cm. The screens background luminance level was 37.5 cd m$^{-2}$. The black arrows had a luminance level of 2.0 cd m$^{-2}$. The white arrows had a luminance level of 73 cd m$^{-2}$, thus the contrast (l/I) of the targets and distractors were equal.

2.3. Arrangement of elements on screen

For both conditions, we used a ‘clock-face’ configuration with only two levels of items (1 [target alone] and 8 [target and 7 distractors]) in the display at any time. We positioned the target in a specific counterbalanced place within the clock-face to eliminate any differences in processing between right and left, and upper and lower, visual fields. The arrangement of the stimuli also meant that variation in visual acuity with retinal eccentricity was minimised, i.e. they were arranged in a circle centred at the fixation point so that

all the stimuli were equidistant from the centre of gaze. This configuration was also designed to reduce crowding problems as the items were always a set distance from one another. We used relatively small displays to ensure the useful field of view was not exceeded. Also by having few stimuli we reduced the effects of the common confound between set size and stimulus spacing (density) (Palmer, 1994).

The vertical and horizontal lines of the fixation cross-measured 18 mm, respectively. Each target or distractor element appeared radially and equidistant from the intersection of the lines forming the fixation cross at a distance of 21 mm and, when all 8 appeared, were equally spaced (see Fig. 1). Each line of the ‘<’ shape measured 5 mm in length and 1 mm in width. The fixation cross appeared simultaneously with the target and distractor items. The stimuli remained on-screen until a response was made. No feedback was given as to the accuracy of each response. For both the ‘salient’ and ‘non-salient’ conditions 32 trials with the target presented alone and 32 trials with the target surrounded by distractors were presented. Participants had to respond correctly to a minimum of 75% of targets for their data to be included in the statistical analysis.

2.4. Procedure

The participants were instructed to fixate on the centre cross at the beginning of each block and to respond as quickly but as accurately as possible to the orientation (right or left) of the target’s apex by pressing one of the two large buttons held in their hands on each trial. If the target was pointing to the right the right hand button was pressed and vice versa. All participants were asked to explain the task to the experimenter in order to demonstrate their understanding of the task requirements and all were required to perform a practice block of approximately 10 trials.

2.5. Design

The experiment had one between-subjects factor (group; AD and age-matched control) and one within-subjects factor (item number; 1 or 8).

2.6. Participants

Two groups of individuals participated in the study: one in which individuals had a diagnosis of mild to moderate probable Alzheimer’s disease and an age-matched healthy control group. The Alzheimer’s (AD) group was recruited from the memory clinics at Llandough Hospital, Cardiff and St. Martin’s Hospital, Bath and consisted of 12 individuals (nine male, three female), mean age 75.6 years (S.D., 4.3). The diagnosis of probable Alzheimer’s disease was based on neurological, physical and biochemical examination, neuropsychological testing, including the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975) family interview and detailed history, neuroimaging and psychiatric interview according to DSM-III-R and NINCDS-ADRDA criteria (McKhann et al., 1984). Individuals with additional psychiatric problems were excluded. The mean MMSE score for the AD group was 22.4 (S.D., 1.0). The mean education was 10.7 years (S.D., 1.9). One participant in the AD group was receiving Exelon and one was receiving Aricept. The rest were free of medication deemed likely to affect cognitive function. All the AD patients recruited were able to perform this task.

The age-matched older control group consisted of 16 healthy individuals (6 male, 10 female) mean age 77.4 years (S.D., 6.21). The mean MMSE score for the control group was 28.2 (S.D., 1.13). The mean years of education for the older controls was 10.5 (S.D., 1.5) years. The older adults were recruited from the community participant panels of the School of Psychology at Cardiff University and St. Martin’s hospital Bath. The older controls reported that they were free of medication deemed likely to affect cognitive function and all had taken part in previous studies that had involved neuropsychological testing. None of the participants had a history or clinical evidence (where available) of a major medical or neurological abnormality. Individuals in both groups had normal or corrected to normal vision and, if appropriate had visited an optician within the preceding 18 months. To further ensure visual capability appropriate for the task all participants were asked to read out loud the task instructions displayed on the computer screen, and given practice trials in which they were required to report what they could see on screen, i.e. to describe the fixation cross and the black and white arrows and which way they were pointing, i.e. to describe the orientation of the arrows. All participants gave informed consent and the research protocol was approved by the appropriate local research ethics committees.

2.7. Data analysis

RTs for ‘correct’ trials were grouped for each participant according to condition and median RT was calculated (as RTs are not normally distributed). The percentage of errors made was also calculated. In line with previous studies examining attention-related performance in ageing and AD, we analysed the median RT scores using an analysis of variance (ANOVA). In addition, we also transformed the scores by taking, for each participant, the logarithm of the median RT and performing ANOVA on these transformed scores. This was done for two reasons. First, the overall responses of the AD patients are slower than the older controls resulting in differences in the variance of RTs for these groups. This discrepancy violates one of the assumptions of ANOVA, namely homogeneity of variance, rendering the interpretation of the results problematic. When log-transformed, the variances are similar (see Section 1.2 of the introduction). Second, the overall slowing of function could potentially lead to larger search effects without specific dysfunction of
3. Results

3.1. Experiment 1a. Salient targets

Mean reaction times of the individuals’ median RTs are plotted as a function of the number of items in the display for the two groups in Fig. 2. ANOVA showed the expected difference between the old and AD groups \(F(1, 26) = 7.04, P < 0.05\). Despite the relatively flat function of Fig. 2, the effect of item number was significant \(F(1, 26) = 22.93, P < 0.0001\), however the interaction between these two variables did not approach significance \(F(1, 26) = 0.94, \text{ ns}\). The log-transformed data showed the same pattern of significant main effects of group \(F(1, 26) = 10.47, P < 0.01\), item number \(F(1, 26) = 25.77, P < 0.0001\), but no interaction \(F(1, 26) = 0.10, \text{ ns}\).

The percentage of errors produced in each condition is given by the figures adjacent to each data point in Fig. 2. ANOVA of the percentage errors also revealed a main effect of group \(F(1, 26) = 6.17, P < 0.05\) with the AD patients having a greater error rate than age-matched controls. There was no main effect of set size \(F(1, 26) = 1.49, \text{ ns}\), nor any interaction between the groups and set size \(F(1, 26) = 1.53, \text{ ns}\).

3.2. Experiment 1b. Non-salient targets

Mean reaction times of the individuals’ median RTs are plotted as a function of the number of items in the display for the two groups in Fig. 3. ANOVA showed the expected difference between the old and AD groups \(F(1, 26) = 11.70, P < 0.01\) and of number of items \(F(1, 26) = 53.59, P < 0.0001\). For this task the main effects were moderated by a significant interaction \(F(1, 26) = 15.24, P < 0.001\). The log-transformed data showed the same pattern of significant main effects of group \(F(1, 26) = 18.99, P < 0.001\), item number \(F(1, 26) = 765.15, P < 0.0001\), and interaction \(F(1, 26) = 18.43, P < 0.001\).

The percentage of errors produced in each condition are plotted as a function of the number of items for the salient target condition. The mean percentage errors made in each condition are displayed alongside the RT data. Error bars represent ±1 S.E. of the mean and where not visible the error bar is smaller than the symbol size.

4. Interim discussion

For our salient condition we expected that RTs would be independent of the number of elements, however we found that RTs rose as items increased from 1 to 8 (i.e. at 8.3 ms per item for AD and 5.4 ms per item for old-controls). It should be noted that this is modest and falls within the ‘flat’ slope as defined by other authors. Under similar stimulus conditions, but where the target simply requires detection, the slopes...
are nearer to zero (Foster, Behrmann, & Stuss, 1995). For our non-salient condition, we expected that RTs would be dependent upon the number of elements. This was indeed the case with 50.8 ms per item for AD, and 154.9 ms per item for old-controls. Our results, using an improved stimulus and methodology, are in complete agreement with those of the Foster et al. (1999) study. We find that RTs are much greater in the AD patients for the salient task but that the slope of the function is the same as that for the age-matched controls. For the non-salient condition, the RTs are again much greater in the AD group but the slope of the function relating RTs to number of items is much greater for the AD patients compared to the age-matched controls.? Crucially the slope of the RT versus number of items remained significantly different even when the RT data were log transformed so as to take account of any generalised slowing.

It was not clear, however, whether these results are a product of deficits in the ability to shift attention from item to item, deficits in the processing, i.e. the time required to process each element within the search set, or indeed a combination of these two factors. We therefore attempted to look at two experimental manipulations that might further reveal the nature of the AD-related deficit on this visual search task, using the classic method of additive logic, where for two variables to interact they must exert influence at the common site. If they exert that influence at different sites (or stages) of information processing, then the effect will be additive (Sternberg, 1969).

5. Experiment 2. Manipulating task difficulty and target saliency

5.1. Methods

5.1.1. Design

In Experiment 2 we varied the time required to process an item, in this case the target, by manipulating the difficulty of the target-related decision task; the more difficult the discrimination, the longer the time taken to respond. If element processing is slowed in AD we would expect greater decrements in AD for a hard compared to an easy task than for healthy older controls. We also varied the ease of shifting attention to an item, in this case the target, by manipulating its saliency (the higher the target saliency the greater its attention 'grabbing' qualities). If ability to shift attention to the target is compromised in AD then we should see a greater decrement in AD when target saliency is low. We assume that changes in saliency will mainly affect our ability to shift to the target location, whereas the changes in task difficulty will affect our ability to decide upon what target is present (Bravo & Nakayama, 1992; Snowden et al., 2001).

As such they should tap different stages of processes and be non-additive in their effects.
5.2. Experiment 2

5.2.1. Stimuli

The stimuli, and our underlying logic, are illustrated in Fig. 4. The stimulus always consisted of 4 elements. Each element had an outer ring and an inner dot (a ‘bullseye’ to complement the ‘arrows’ of Experiment 1). The task on each trial was to locate the target element, which was defined as the one with the darkest ring, and then to make a decision as to the position of the dot within the ring (was it to the left or right of the ring’s centre). We could manipulate the saliency of the target (by changing the darkness of the ring) independently of the difficulty of the task (by changing how far away from the centre of the ring the dot was). If the deficit in visual search task performance in AD patients is in the time taken to process the target then we should expect an interaction with our manipulation of task difficulty, whereas if the deficit is in shifting attention to the target we should expect an interaction with the saliency of the target.

5.2.2. Participants

Fourteen individuals with AD were recruited. However, 2 of these participants were unable to perform the tasks and are therefore not reported further. The AD group therefore consisted of 12 individuals with probable AD (five of these people had previously formed part of the group recruited for the first study reported in this paper). In the AD group there were six males, six females. Mean age 75.9 years (S.D., 4.7). The mean MMSE score was 22.5 (S.D., 1.3). The mean years of education was 10.2 (S.D., 1.6) years.

The age-matched older control group consisted of 18 individuals (16 of whom formed the older adult control group for Experiment 1). All those recruited were able to perform the task. The mean age of the older group was 77.9 years (S.D., 5.8). The mean MMSE score was 28.2 (S.D., 1.3). The mean years of education was 10.6 years (S.D., 1.6).

Recruitment for both groups followed the same criteria as that for experiment one.

5.2.3. Arrangement of elements on screen

On screen, viewed at a distance of 57 cm, four rings were presented within a square outline of side 95 mm. The inner diameter of each ring was 20 mm; the outer diameter was 25 mm. Each ring was spaced equidistantly from each other and their centres measured 24 mm radially outwards from the intersection of the two lines that formed the fixation cross. The fixation cross at the centre of the display was made up of two lines 6 mm in length. The dot placed inside each ring had a diameter of 3 mm and could appear 5 or 2 mm to the left or right of the centre of the ring the dot was. If the deficit in visual search task performance in AD patients is in the time taken to process the target then we should expect an interaction with our manipulation of task difficulty, whereas if the deficit is in shifting attention to the target we should expect an interaction with the saliency of the target. These stimuli were presented in 4 blocks, where each block contained 8 trials for each condition presented in a randomised manner making a total of 32 trials for each condition. Over all conditions, the position of the target ring was counterbalanced in order that it appeared equally at each of the four possible locations and the position of the dot within the target ring was counterbalanced in order that it appeared equally to the left or right of centre.

In each trial the dots inside the non-target rings were counterbalanced to be on the right or left of the ring centre at the same distance as the dot in the target ring. This was to ensure that it was only the difference in salience that attracted the observer to the target ring.

5.2.4. Procedure

The participants were instructed to locate the target (the darkest ring) and then to make a decision about the position of the dot within that ring, i.e. was it to the left or right of the centre. If the dot was to the left of centre, the left hand-held button was pressed and vice versa. The participants were instructed to perform the task as quickly but as accurately as possible.

![Fig. 4: Schematic of stimulus display for the high salience—easy task and the low salience—hard task conditions.](image)
6. Results

6.1. Non-transformed data

A three-way ANOVA was performed on the reaction times data with salience (low, high) and task difficulty (easy, hard) as repeated measures, and group (AD, old-controls) as a between-subjects factor. There was a significant main effect of group \( F(1, 28) = 27.19, P < 0.0001 \) as expected with the AD patients taking longer to complete the task than the old-controls. Both the manipulations of salience \( F(1, 28) = 52.66, P < 0.0001 \), and task difficulty \( F(1, 28) = 10.01, P < 0.005 \) had the desired effect of increasing reaction times for low salience targets and for high difficulty tasks.

Of crucial importance to our hypotheses were the possible interactions between group and salience, and between group and task difficulty. Fig. 5a and b illustrates the plots of these two interactions. Both the interaction between group and salience \( F(1, 28) = 13.52, P < 0.001 \), and that between group and task difficulty \( F(1, 28) = 6.54, P < 0.05 \) were significant. Inspection of Fig. 5a shows that the first interaction was due to target salience having a greater effect on the AD patients (836 ms) than the old-controls (274 ms), (i.e. the lower the salience the greater the RT). Likewise Fig. 5b shows that the second interaction was due to task difficulty having a greater effect on the AD patients (595 ms) than the old-controls (63 ms).

Fig. 5c illustrates the interaction between target salience and task difficulty. In line with our notion that these may access different processing stages these variables did not interact significantly \( F(1, 28) = 0.12, \text{ns} \). The three-way interaction was not significant \( F(1, 28) = 1.21, \text{ns} \).

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![Fig. 5](image-url)  
**Fig. 5.** Mean reaction time (of the participants’ median RTs) in milliseconds for the normal data, illustrating (a) the interaction between group and target salience, (b) the interaction between group and task difficulty and (c) the interaction between target salience and task difficulty. Error bars represent ±1 S.E. of the mean and where not visible the error bar is smaller than the symbol size.
6.2 Log transformed data

As outlined in the methods section we also analysed the RT data after being log transformed. The pattern of results altered only slightly. The main effects of group \(F(1, 28) = 39.89, P < 0.0001\), salience \(F(1, 28) = 59.94, P < 0.0001\) and task \(F(1, 28) = 27.97, P < 0.0001\) remained significant. More crucially, the interaction between group and task difficulty was still significant \(F(1, 28) = 6.64, P = 0.05\), however the interaction between group and target salience just failed to reach significance \(F(1, 28) = 3.56, P = 0.070\). Fig. 5b shows that the interaction between group and task difficulty was due to task difficulty having a greater effect on the AD patients \((103\log \text{units})\) than the older-controls \((0.036\log \text{units})\).

Finally the variables of target saliency and task difficulty did show an interaction in this log-transformed analysis \(F(1, 28) = 6.33, P < 0.05\). However this was due to a smaller effect of task difficulty for the harder task. This ‘interaction’ is to be expected if these stages are indeed independent processing stages. From Fig. 5c we can see that manipulation of task difficulty altered RTs by about 260 ms (at both salience levels), whilst manipulation of target contrast altered RTs by about 500 ms (at both task difficulties). Hence the difference of 260 ms occurring at both low and high target saliency is distorted by the log-transform as the baseline RT is around 500 ms different, and hence an interaction occurs. The three-way interaction was not significant \(F(1, 28) = 0.72, \text{ns}\).

6.3 Error data

The percentage of errors made in each condition is illustrated by the numbers near each data point in Fig. 5a-c. ANOVA showed that there was a main effect of group \(F(1, 28) = 9.15, P < 0.01\), but no main effects of target salience \(F(1, 28) = 0.14, \text{ns}\) or task difficulty \(F(1, 28) = 0.99, \text{ns}\). There were no significant interactions between group and target salience \(F(1, 28) = 0.08, \text{ns}\), group and task difficulty \(F(1, 28) = 1.12, \text{ms}\), salience and task difficulty \(F(1, 28) = 0.15, \text{ns}\), or three-way interaction \(F(1, 28) = 0.65, \text{ns}\).

The error data do not support the notion of a speed/accuracy trade-off (the AD patients are slower and make more errors). We therefore conclude that the pattern of results described for the RT data is due to genuine changes in ability to do the task rather than speed/accuracy trade-offs.

7. General Discussion

It is often assumed that visual search tasks that result in greater RTs with increasing number of items, require that attention be shifted from item to item and consequently that poor performance on such tasks is illustrative of a functional deficit within the attention shifting system. In a previous study, Foster et al. (1999) found that the slope relating RT to the number of non-target elements for such a task was significantly greater for AD patients than for the controls, suggesting an AD-related deficit in the shifting of attention. However, what is also clear from Foster et al. study is that even in a search task in which RT is relatively independent of item number, patients with AD are profoundly slower at responding to the target. It could be argued therefore that the poor performance of AD patients on a search task in which RT is dependent on item number, could be the result of an inefficiency in processing each element within the search set, or a combination of the two factors.

After confirming the results of Foster et al. (1999) using visual search tasks free from the potential confounding factors highlighted in Section 2.1, we attempted to provide evidence that might distinguish between the two possible reasons for the performance of the AD patients, namely a deficit in attention shifting or in information processing.

We designed a task in which attention shifting and processing efficiency was varied by manipulating target saliency and task difficulty, respectively. Both manipulations resulted in a disproportionate detriment in performance for the AD patients, even when the data were transformed so as to take account of the overall slowing of the AD group.

The lack of a significant interaction between salience and task difficulty suggests that these two factors probably are independent and may result from dysfunction within different brain regions affected by the disease. The diffuse nature of the effects of AD throughout the brain means that deficits in many different areas of processing will probably contribute to the results of testing (Arriaga, Growdon, Helley-Whyte, & Hyman, 1992; Forstl & Kurz, 1999; Gómez-Isla et al., 1997; Moser, Kompf, & Olschinka, 1995; Perry & Hodges, 1999; Rösler et al., 2000; Scheff & Price, 1993; Schofield & Mayeux, 1998). Consequently, any task of attention, that requires some form of information processing such as the discrimination of a target, or the need for a decision about some aspect of the target, is likely to reflect AD-related detriments in these processes as well (Pate, Margolin, Friedrich, & Bently, 1994).

The results indicate that AD patients perform poorly on the visual search tasks for two very basic, but separate reasons: inefficiency in shifting attention to a target and inefficiency in processing the information held within the target, i.e. two areas of hypofunctionality that culminate in poor overall visual search performance. Further research is necessary in order to determine whether it is the mechanism that physically shifts the focus of attention throughout the scene that is affected in AD, or whether it is the ability of salient items to initiate the shift (Li, 2002), particularly as regions of the brain such as the pulvinar nucleus, that encode saliency and thus affect the ability of a stimulus to attract attention, can contain AD-related pathology (Bott & Koch, 2000; Kujis, 1994). The relationship between generalised slowing and attention also requires further investigation.
The results from several previous studies have indicated that factors such as a reduction in the spotlight of attention or useful field of view, abnormalities in eye movements, basic visual functions and in object processing may be associated with AD and can all influence the efficiency of visual search performance (Armstrong, Nocklin, Sumi, & Alvedo, 1990; Corbetta, Stank, Rajaram, & Saffran, 1995; Fletcher & Sharpe, 1986; Leuba & Kraftsf, 1994; Rizzio, Anderson, Dawson, & Navrot, 2000; Tales, Butler, et al., 2002; Tales, Muis, et al., 2002; Wong-Riley et al., 1997). The results from the present study therefore add to the growing evidence that poor performance on visual search tasks in AD probably represents the combination of several factors rather than a single, specific attention-related deficit (Foster et al., 1999; Foster, 2001; Greenwood et al., 1997; Levy et al., 2000; Rössler et al., 2000; Parasuraman et al., 1995, 2000).

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References


