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Aging and performance on an everyday-based visual search task

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Research on aging and visual search often requires older people to search computer screens for target letters or numbers. The aim of this experiment was to investigate age-related differences using an everyday-based visual search task in a large participant sample ($n=261$) aged 20–88 years. Our results show that: (1) old–old adults have more difficulty with triple conjunction searches with one highly distinctive feature compared to young–old and younger adults; (2) age-related declines in conjunction searches emerge in middle age then progress throughout older age; (3) age-related declines are evident in feature searches on target absent trials, as older people seem to exhaustively and serially search the whole display to determine a target's absence. Together, these findings suggest that declines emerge in middle age then progress throughout older age in feature integration, guided search, perceptual grouping and/or spreading suppression processes. Discussed are implications for enhancing everyday functioning throughout adulthood.

1. Introduction

Older adults often report difficulties when searching for items within cluttered visual scenes (e.g., Kline et al., 1992; Kosnik, Winslow, Kline, Rasinski, & Sekuler, 1988). Research has been conducted on visual search and aging in everyday domains such as driving (e.g., Bédard et al., 2006), reading medication labels (e.g., Markowitz, Kent, Schuchard, & Fletcher, 2008), navigating web pages (e.g., Grahame, Laberge, & Scialfa, 2004), and face recognition (e.g., Hahn, Carlson, Singer, & Gronlund, 2006). Much of the research on visual search and aging though is laboratory-based and involves visual search displays on computer screens, using stimuli such as target letters within an array of other letters (Burton-Danner, Owsley, & Jackson, 2001; Foster, Behrmann, & Stuss, 1995). As older people often perform more poorly in laboratory compared to more real world contexts (Park & Gutchess, 2000), the first objective of this study was to investigate visual search abilities with older age in an everyday-based task involving a more naturalistic array of items than symbols on a computer screen, namely, searching shelves of pasta-filled jars for particular target items.

Previous research also tends to compare younger and older adults' performance while neglecting the middle-aged, making it difficult to ascertain how performance changes across the adult lifespan. However, age-related differences emerging before older age may be precursors to future declines and hence may provide important information not just for theories of cognitive aging, but also for the design and implementation of early interventions. A second objective of this study was therefore to contribute to filling this gap in the literature. For this purpose we investigated the performance of a large sample of participants across adulthood (20s to 80s).

This research was run as a single experiment, but its presentation and results are divided into two sections for the sake of clarity. The first analysis extends the laboratory-based literature to examine target search times on everyday feature, double conjunction, and triple conjunction searches across the adult lifespan. The second analysis also investigates performance across a range of ages, but extends previous work by examining age differences in search time on target absent trials in a feature search as well as conjunction search. The aim was to investigate the extent to which adults of different ages used the self-terminating strategy of stopping searching when they realised that the target was absent. The rationale and hypotheses for each analysis are detailed below.

1.1. Visual search in feature and conjunction searches throughout adulthood

In laboratory-based visual search tasks, participants scan lists of letters, pictures, or words in search of a particular target item. In a typical feature search the target differs from distractor items in terms of a single feature, and search times tend not to differ much between younger and older adults, or change as increasing numbers of distractors are added

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to the display (Burton-Danner et al., 2001; Foster et al., 1995; Oken, Kishiyama, & Kaye, 1994). When age differences have been found, they tend to be small and partially accounted for by age-related slowing and other processes such as distractibility and spatial resolution (e.g., Davis, Fujawa, & Shikano, 2002). However, the more distinct targets are from distractors in feature search, the less likely age differences are to be found (e.g., Whiting, Madden, Pierce, & Allen, 2005). This shows that younger and older adults can often detect a target similarly fast, and suggests that they do not have to search items in the display one by one. According to feature integration theory (Treisman, 1993; Treisman & Gelade, 1980), this is because elementary perceptual features such as colour and shape are extracted rapidly and in parallel over broad spatial areas (Burton-Danner et al., 2001; Plude & Doussard-Roosevelt, 1989; Scialfa, Esau, & Joffe, 1998), resulting in 'perceptual pop-out' (Treisman & Gelade, 1980) of the target. Thus, successful detection of targets in feature searches seems to occur through bottom-up processes (Donner et al., 2002; Grossberg, Mingolla, & Ross, 1994).

In a typical conjunction search though, the target differs from distractors in terms of a conjunction of two or more features, such as searching for a red *X* within an array of green *X*s and red *O*s. Older compared to younger adults often demonstrate significantly slower search times as additional distractors are added to the display (Burton-Danner et al., 2001; Donner et al., 2002; Wolfe & Cave, 1999). Feature integration theory (Treisman, 1993; Treisman & Gelade, 1980) proposes that this is because the features registered during the extraction stage are not sufficient for perceptual pop-out. Instead, features have to be matched between target and distractors in a predominantly serial manner, that is through feature integration processes.

According to Wolfe's guided search model (Wolfe, Cave & Frenzel, 1989; Wolfe, 1994), these serial processes may only need to function across a limited region of the visual field at any one time (depending on the features being searched for), as information from parallel processors can be used to guide the deployment of spatially limited resources. For example, in the conjunction search, only half of the items (the red items) are potential targets, because a parallel colour processor can guide search to the red items to look for the red *X*, thus eliminating the green items. Both theories agree that the detection of targets requires more effortful or top-down processing in conjunction compared to feature searches, which is more difficult for older than younger adults.

Some visual searches, however, require levels of processing not previously acknowledged by feature integration theory. For example on triple conjunction searches requiring the comparison of three features between target and distractors, search times are sometimes no different to or faster than double conjunction searches requiring the comparison of two features (Humphrey & Kramer, 1997; Quinlan & Humphreys, 1987; Wolfe et al., 1989). The guided search model explains these findings by considering the activation of certain features. That is, one parallel processor may activate all locations for one feature, while second and third parallel processors activate all locations for the second and third features of the target item within the triple conjunction search. The more distinctive one or more of the features are, the faster these processes will operate. This process reduces the set of potential target items to a subset, and a spatially limited process then searches for the target item. This could lead to search times for triple conjunction searches approximating those of double conjunction searches, as serial search would not take much more time for three compared to two features (particularly if one or more of the features in the triple search were particularly distinct).

In the current study we explored visual search performance in a large sample and across different ages (20s to 80s) instead of focusing on just the performance of one younger group versus one older group. This approach builds on the few previous studies which have investigated visual search across the lifespan. For example, Hommel, Li, and Li (2004) examined trends in visual search from 6 to 89 years old to investigate whether the processes which improve during child development are those which decline with older age. They used a computer task in which participants searched for a target (a filled white circle) among an array of distractors (unfilled white circles in a feature search, and filled white squares as well as unfilled white circles in a conjunction search). They found that age decrements were more pronounced in early and later life, more so for conjunction than feature searches, yet the developmental trend was asymmetrical; while children's performance was particularly affected by the mere presence of distractors, performance was particularly impaired in older age on target absent trials and with increasing numbers of distractors. Hommel et al. argued that while children have difficulty with distractibility, older people's performance is influenced more by a more cautious search style (i.e., exhaustive search under target absent conditions) which may be the result of compensating for neurocognitive decline. The present study extends Hommel et al.'s approach by focusing on performance throughout adulthood and older age, using a more everyday context, and comparing performance between different forms of conjunction search.

Specifically, the current study aimed to investigate search times not just between feature and conjunction searches, but also between double and triple conjunction searches in which the triple conjunction search contained one feature more distinctive than the others. To do this, we created one feature search, one double conjunction search and one triple conjunction search. The feature search was designed to have a high level of distinctiveness between target and distractors to ensure that feature extraction processes would be sufficient to detect the target. We designed the double conjunction search so that the target item would differ in one gross feature from half of the distractor items and would share another gross feature with the rest. This was to ensure that two features would have to be compared between target and distractors and that serial search (feature integration or aspects of guided search) would be required to detect the target. Lastly, we designed a triple conjunction search so that the target would differ from distractor items in terms of three gross features. One of these features, though, was made more distinctive than the others to test whether this made the triple conjunction search the same difficulty level as the double conjunction search.

It was predicted that age would have an increasing effect on visual search speed as task demand increased. Search times would not significantly differ between age groups for the feature search, but might become significantly slower on the double and triple conjunction search before older age, and would significantly slow throughout older age itself.

For all ages it was predicted that search times would be significantly faster on the feature search compared to the double and triple conjunction searches, and would show no significant difference between the double and triple conjunction searches.

1.2. Exhaustive search versus stopping at target in feature and conjunction searches

Previous laboratory-based search tasks show that in double conjunction searches, younger and older adults use the self-terminating strategy of stopping searching the rest of the display once the target is detected. This is evidenced by an approximate 2:1 ratio of search times on target absent to target present trials, which indicates a serial search of the whole display on absent trials (Madden, Pierce, & Allen, 1996; Plude & Doussard-Roosevelt, 1989; Van Zandt & Townsend, 1993). Serial searches are not always required however on target absent trials. For example, in feature searches younger adults detect a target almost as quickly as detecting its absence and produce absent-to-present ratios of approximately 1:1 (Burton-Danner et al., 2001; Wolfe et al., 1989). This suggests that younger adults stop searching the display as soon as the target is rapidly extracted (through parallel processing) on present trials, and as soon as target absence is rapidly detected on absent trials. It is not clear, however, whether older adults can quickly detect the absence of a target like younger people during feature searches. In Hommel et al.'s (2004) lifespan study, older people in their 60s to 80s (but not in younger age groups) showed significantly longer search times on absent trials in laboratory-based feature