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Visual search for real world targets under conditions of high target–background similarity: Exploring training and transfer in younger and older adults

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Real world visual search tasks often require observers to locate a target that blends in with its surrounding environment. However, studies of the effect of target–background similarity on search processes have been relatively rare and have ignored potential age-related differences. We trained younger and older adults to search displays comprised of real world objects on either homogenous backgrounds or backgrounds that camouflaged the target. Training was followed by a transfer session in which participants searched for novel camouflaged objects. Although older adults were slower to locate the target compared to younger adults, all participants improved substantially with training. Surprisingly, camouflage-trained younger and older adults showed no performance decrements when transferred to novel camouflage displays, suggesting that observers learned age-invariant, generalizable skills relevant for searching under conditions of high target–background similarity. Camouflage training benefits at transfer for older adults appeared to be related to improvements in attentional guidance and target recognition rather than a more efficient search strategy.

1. Introduction

Whether our goal is to locate keys on a cluttered desktop, our car in a parking lot, or hazards while driving, efficient and successful search is a critical component of many daily activities. Given its central role in broad functioning, visual search has been the subject of a great deal of basic research. The traditional search paradigm is straightforward; an observer might be asked to locate a target letter amongst some set of distracter letters (see Wolfe, 1998, for a review). Target presence and set size, defined as the number of objects in the display, are common manipulations. Objects are traditionally viewed on a homogenous background and spaced evenly in some random pattern. From these studies a wealth of information has been amassed related to the low-level visual features extracted by the visual system (Julesz, 1981; Treisman & Gelade, 1980; Treisman & Gormican, 1988) and the processes that use these features to guide attention to a target (Motter & Belky, 1998; Wolfe, 1994; Wolfe, Cave, & Franzel, 1989; Zelinsky, 1996).

Although the majority of the search literature has focused on behavior in young adults, a considerable amount of work has also been devoted to understanding the specific challenges older adults face as they engage in search. These studies have yielded a number of interesting findings. Older adults perform similarly to younger adults when searching for a target defined by a single unique feature (Humphrey & Kramer, 1997; Whiting, Madden, Pierce, & Allen, 2005), or singleton, but are less efficient when looking for a target defined by a combination of two features, typically referred to as a conjunction search (e.g., Folk & Lincourt, 1996; Kramer, Martin-Emerson, Larish, & Andersen, 1996; Madden, Pierce, & Allen, 1996). The non-differential performance of older adults in singleton search has been cited as evidence that the pre-attentive processes necessary for feature extraction are preserved with age. Conjunction search differences have been attributed to a decline in the ability of older adults to integrate previously extracted featural information into perceptual units (Plude & Doussard-Roosevelt, 1989), a process traditionally associated with serial attention (e.g., Treisman & Gelade, 1980; Wolfe et al., 1989). Considering the decline in performance displayed by older adults during conjunction search, it is somewhat surprising that other studies have found that in triple-conjunction search tasks, search for a target defined by three features, younger and older adults again exhibit similar improvements in performance (Humphrey & Kramer,

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1997). Some have attributed this improvement to the availability of additional top-down information, in this case provided by an additional visual feature that might be used by older adults to compensate for some of the age-related declines thought to occur in some low-level visual processes, such as perceptual grouping (Madden et al., 1996; Plude & Hoyer, 1986). Despite the fact that older adults show impaired performance in conjunction search tasks, the additional target feature afforded by triple-conjunction search might allow for increased top-down activation of the target object. This increased activation would in turn increase the signal of the target and result in a higher overall signal to noise ratio between the target and distractor objects, making search easier (Humphrey & Kramer, 1997; also see Wolfe, 1998, for discussion of triple-conjunction search in younger adults). Such an interpretation is consistent with the proposal by Craik and Jennings (1992) that older adults' cognition can often benefit from increased environmental support.

While the existing literature has painted a thorough picture of how search behavior and performance changes with age, it remains unclear whether those findings can be generalized to complex search tasks that better reflect the environments typically found in the real world. Tasks in which observers search for simple geometric shapes or rotated letters can teach us a great deal about basic search processes, but they lack the complexity and semantic content inherent to more realistic environments. One key way in which laboratory search tasks often differ from more realistic search tasks is in terms of target–background similarity. In contrast to traditional laboratory search tasks where an object array might be presented on a black background, search environments in the real world frequently contain targets presented on a complex, and often visually similar background. For example, when driving a car one might need to locate a street sign that blends in with surrounding trees (e.g., McPhee, Scialfa, Dennis, Ho, & Caird, 2004), or monitor the environment for pedestrians that might blend in with background areas (especially under low visibility conditions). Given the importance of such tasks it is critical that we have an understanding of how age-related cognitive decline might influence performance, and investigate means of augmenting performance decrements.

Research relating target–background similarity to search performance has been limited. Wolfe and colleagues (Wolfe, Oliva, Horowitz, Butcher, & Bompas, 2002) explored search behavior in tasks in which the search objects were presented on a complex background. They observed that increases in target–background similarity resulted in a corresponding increase in response times, generally in the form of an additive cost to the *y*-intercept of the response time by set size function rather than an increase in the function's slope. More recently, Neider and Zelinsky (2006) developed the camouflage search paradigm, which uses real world objects (e.g., children's toys). For each target a corresponding background is created by repeating a portion of the target item over a canvas. The background is then used as an underlay for the corresponding target object and additional distractor items, resulting in a search task where the target melts into the background while the distractors remain salient. Since the target and background in this paradigm share similar features, a good strategy for locating the target is to ignore salient distracter objects and restrict search to the background regions of the display. Observations of response times were similar to those reported by Wolfe et al. (2002), however, supplemental eye movement analyses revealed surprising results. In the course of searching, observers preferred to make eye movements to salient target-dissimilar distracter items while target-similar background regions were relatively neglected (also see Boot, Neider, & Kramer, 2009, for an investigation of training and transfer in camouflage search). These findings lent support to arguments for the importance of low-level visual information in guiding attentional mechanisms (e.g., Itti & Koch, 2000), as well as accounts of object-based attentional representations (e.g., Baylis & Driver, 1993; Duncan, 1984; Kramer & Jacobson, 1991; Prinzmetal, 1981; Vecera & Farah, 1994).

Unfortunately, the previous studies examining background effects on search behavior were limited to the study of young adults. Hence, questions regarding how target–background similarity might influence search performance in older adults remain unanswered. How does performance in difficult search tasks in which the target is poorly segmented differ between younger and older adults? On the one hand, we might expect older adults to perform poorly in such tasks if the age-related decrements thought to occur in other low-level visual processes, such as perceptual grouping (Madden et al., 1996; Plude & Hoyer, 1986, but see Humphrey & Kramer, 1999), extend to processes that might be important when searching for camouflaged targets, such as those responsible for segmentation. On the other hand, even if such low-level processes did become less effective with age, it is possible that older adults might be able to utilize high-level strategies, such as increased attention to background regions of the display, to compensate for declines in low-level processing. An evaluation of performance differences across age groups is sure to evoke an additional question: if performance in a camouflage search task does vary with age, is it possible, with practice or training, for older adults to perform more like younger adults, and does this improvement transfer to other camouflage-type search tasks? Transfer of training has previously been shown to be quite limited (e.g., Ahissar & Hochstein, 1996; Ball & Sekuler, 1982; Ball et al., 2002; Fahle, Edelman, & Poggio, 1995; Fahle & Morgan, 1996; Fiorentini & Berardi, 1981; Furmanski & Engel, 2000; Shiu & Pashler, 1992), however, previous research by Boot and colleagues (Boot et al., 2009) has shown that training in camouflage search for one set of search objects transfers to similar search tasks using novel objects in younger adults. It is unknown whether older adults show similar transfer of training effects. Questions of training are of interest not only for their implication in understanding basic cognitive mechanisms, but also for their relevance to real world applications (Hertzog, Kramer, Wilson, & Lindenberger, 2009; Kramer & Willis, 2002).

The goal of the current study was to shed light on both these broad questions. Specifically, we examined how younger and older adults compare in performance on a camouflage search task and whether any observed differences could be attenuated with training. To do so we trained both younger and older adults in a number of training sessions using the camouflage search paradigm developed by Neider and Zelinsky (2006), and then evaluated performance in a transfer session where observers searched for novel camouflaged objects in novel backgrounds.

2. Method

2.1. Participants

Sixteen undergraduate students (age 18–25, M = 20, SD = 1.75) from the University of Illinois at Urbana-Champaign and sixteen high-functioning and independent-living older adults (age 55–78, M = 65, SD = 6.9) who were recruited from the community were paid $32 for their participation in 4 40–60 min sessions that took place over the course of several days. All participants had normal or corrected-to-normal vision, as assessed with a Snellen chart for visual acuity and Ishihara plates for color vision.

2.2. Apparatus, stimuli, and design

All stimuli were identical to those used by Neider and Zelinsky (2006). Forty targets and distractors images of real world objects were selected from the Hemera Photo Objects Database, with each object scaled to fit within an 80×80 pixel ($3.3° \times 3.3°$) bounding box. All objects fell within the category of children's toys, and included items such as stuffed animals, toy vehicles, and games. For each object a 35×35 pixel tile was copied from the center and repeated over a blank 800×600 pixel canvas to create a corresponding target-similar camouflaged background (see Fig. 1a for a sample search display). In non-camouflaged displays all search objects were presented on a gray background (RGB: 128, 128, 128; see Fig. 1b for a sample search display). Eight younger adults were trained on camouflaged targets and eight were trained on non-camouflaged targets. Eight older adults were trained on camouflaged targets and eight were trained on non-camouflaged targets.

All observers participated in three training sessions during which a total of 900 trials were completed (300 per session), and one transfer session (300 trials). Both target presence (50% present and 50% absent) and set size (9 and 19) were manipulated, with all factors randomly interleaved across all trials.

Two sub-sets of objects (Set A and B) were created from the full set of 40 toy images by randomly assigning objects to one sub-set or the other. The sub-set of objects participants were trained on was counterbalanced between participants, and at the transfer session, participants searched for objects from the opposite sub-set (i.e., novel objects). In each trial, the search objects were randomly assigned to locations on an imaginary 10×7 grid spanning

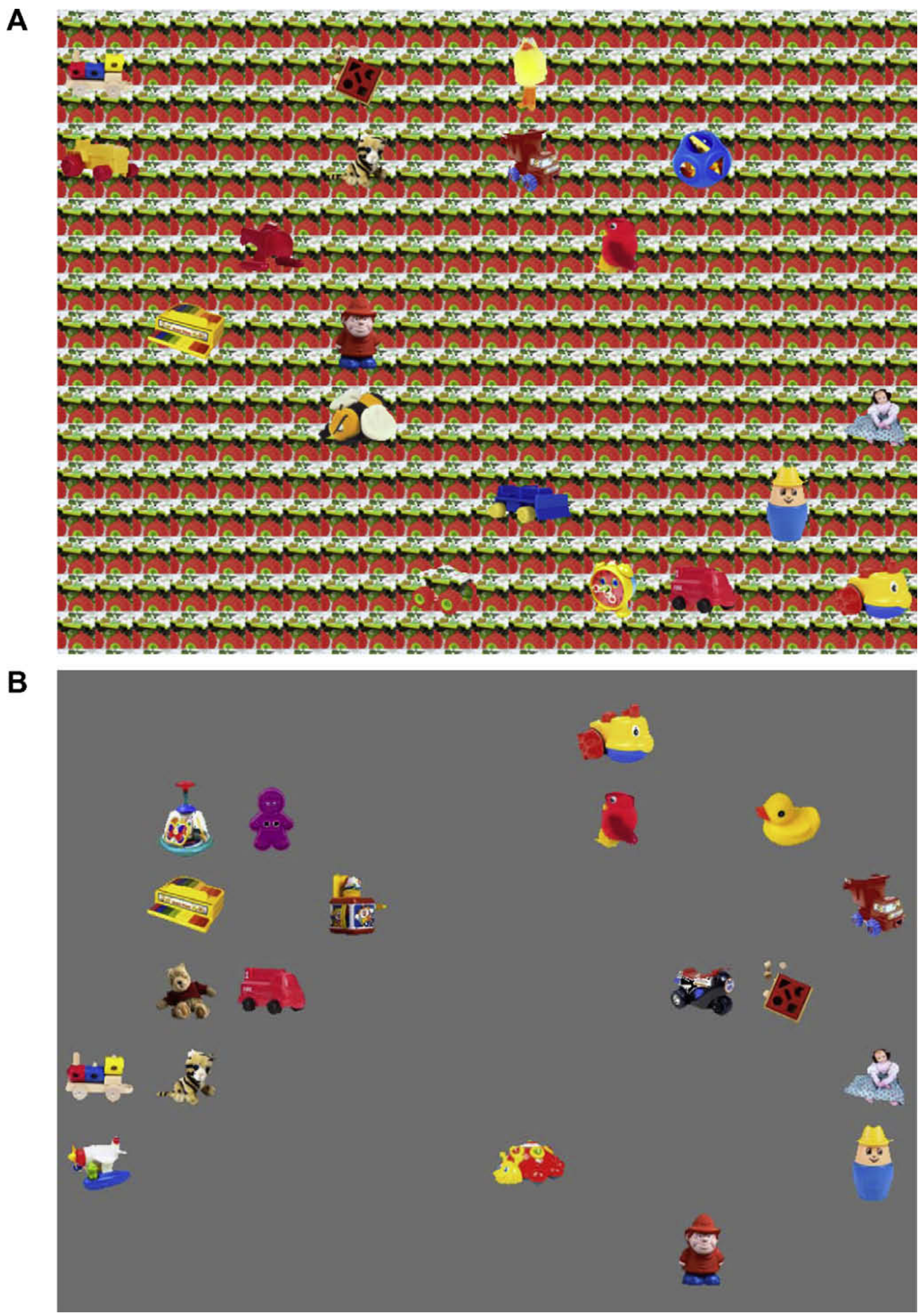

Fig. 1. Representative search displays in the (A) camouflage and (B) no camouflage conditions. In both samples the set size is 19. In the camouflage sample the target is a toy truck located center-bottom. The target in the no camouflage sample is a toy fireman located right-bottom.

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Table 1
Data for camouflage (Camo) and no-camouflage (No Camo) trained participants in all sessions. Response times (RT) are reported in ms, accuracies (ACC) in % correct, background fixations as proportion of fixations to the background (BackFix) and slope in ms/item. S = small set size, L = large set size.

		Session 1				Session 3				Transfer			
		Present		Absent		Present		Absent		Present		Absent	
		S	*L*	*S*	*L*	*S*	*L*	*S*	*L*	*S*	*L*	*S*	*L*
Camo-older	RT	3210	4552	7382	8946	2523	3189	6764	7873	2328	3140	6549	7889
	Acc	0.8	0.68	0.91	0.88	0.87	0.8	0.98	0.95	0.87	0.8	0.98	0.96
	BackFix	0.57	0.46	0.63	0.49	0.65	0.50	0.70	0.56	0.60	0.50	0.69	0.53
	Slope	134		156		66		110		81		134	
No Camo-older	RT	1035	1363	1789	2691	913	1206	1551	2555	3853	4608	9607	11332
	Acc	0.96	0.92	0.99	0.99	0.96	0.93	0.99	0.99	0.83	0.72	0.97	0.95
	BackFix	0.54	0.47	0.55	0.49	0.56	0.51	0.57	0.49	0.62	0.51	0.66	0.54
	Slope	32		90		29		100		75		172	
Camo-younger	RT	1811	2208	4565	5684	1453	1786	3487	4190	1339	1714	3844	4867
	Acc	0.88	0.81	0.99	0.98	0.89	0.86	0.99	0.99	0.93	0.87	0.99	0.99
	BackFix	0.65	0.56	0.69	0.60	0.72	0.63	0.75	0.65	0.69	0.59	0.74	0.63
	Slope	39		111		33		70		37		102	
No Camo-younger	RT	739	928	947	1483	558	705	684	1075	1555	1848	3370	3822
	Acc	0.95	0.89	0.98	0.98	0.89	0.88	0.98	0.96	0.86	0.74	0.98	0.98
	BackFix	0.56	0.53	0.55	0.50	0.61	0.52	0.61	0.55	0.68	0.55	0.72	0.57
		18		53		14		39		29		45	

the entire display. The central 6 locations on the grid were kept empty in order to minimize the likelihood that the target would be fixated directly following the onset of the search display.

All search displays were presented in full color on a 21" (34° × 25°) CRT monitor at a resolution of 800 × 600 pixels. Eye movements were recorded using an SR Research EyeLink II eye tracker sampling at 500 Hz. All eye measures (e.g., fixations, saccades, etc.) were quantified using the default EyeLink algorithms. Response times and accuracy were recorded with a Microsoft gamepad, with the left trigger indicating a target present response, and the right trigger indicating a target absent response.

2.3. Procedure

Observers began each trial by fixating a centrally located dot (RGB: 0, 0, 0) on a gray background (RGB: 128, 128, 128) and pressing a button. The dot was then replaced by the target object. After 1.5 s the target was replaced by the search display. Observers were instructed to locate the target as quickly as possible while maintaining high accuracy. Each trial ended after the observer made a target present or target absent button-press response. After each trial, feedback was given indicating whether or not the observer's response was correct. Average speed and average accuracy were presented every twenty trials. Participants were instructed to improve speed while not sacrificing accuracy.

3. Results

The first twenty trials of each session were considered practice and were not analyzed.[1] Analyses focus first on camouflage effects, then training, and finally transfer effects. One participant in the older adult no-camouflage training group was administered the incorrect version of the task during the transfer session, and hence was excluded from all analyses.

3.1. Effects of camouflage: response times (session 1)

First, we examine the effect of target–background similarity (camouflage) and whether target–background similarity differentially impaired the performance of older adults. Response times for both the camouflage and no-camouflage training groups are presented in Table 1. Response times for session 1 were entered into an ANOVA with set size (9 vs. 19) and target presence (present vs. absent) as within-subject factors and target–background similarity (camouflage vs. no-camouflage) and age (younger vs. older) as between-subject factors. This analysis revealed main effects of set size ($F(1, 27) = 103.70$, $p < .001$), target presence ($F(1, 27) = 87.64$, $p < .001$), target–background similarity ($F(1, 27) = 78.78$, $p < .001$), and age ($F(1, 27) = 16.68$, $p < .01$). Typical of visual search, response times were longer when the target was absent and when the set size was large, and additionally, response times were longer when the target was similar to the background. In general, older adults responded more slowly than younger adults. A number of interactions were also significant: target presence interacted with target–background similarity ($F(1, 27) = 40.23$, $p < .001$), set size interacted with target–background similarity ($F(1, 27) = 15.51$, $p < .01$), and target presence interacted with set size ($F(1, 27) = 20.22$, $p < .001$). Of primary interest, age interacted with target–background similarity suggesting a greater impact of camouflage for older adults compared to younger adults ($F(1, 27) = 5.21$, $p < .05$). A significant interaction between age and set size indicates that younger adults searched more efficiently ($F(1, 27) = 9.15$, $p < .01$; all slopes are shown in Table 1). However, there was no differential effect of target–background similarity on the search efficiency of older adults as indicated by the lack of a significant set size × age × target–background similarity interaction ($F(1, 27) = 2.0$, $p = .17$). Overall, observers were slower when searching camouflage displays compared to non-camouflage displays. This difference was reflected both in an additive cost to the *y*-intercept of the response time by set size function and an increase in the function's slope. It should be noted that although both *y*-intercepts and slopes increased with target–background similarity, the change in the *y*-intercept was strikingly large, typically on the order of several seconds, suggesting that pre-attentive visual processes were impaired when the target and background shared similar visual characteristics.

3.2. Effects of Camouflage: Accuracy (Session 1)

Accuracies for both camouflage and no-camouflage training groups are also shown in Table 1, and were entered into an identical ANOVA. This analyses revealed main effects of set size ($F(1, 27) = 36.26$, $p < .001$), target presence ($F(1, 27) = 117.65$, $p < .001$), and target–background similarity ($F(1, 27) = 20.59$, $p < .001$). This

[1] The reader may wonder how eye blinks were accounted for, especially given the length of trials and prior work demonstrating differential blink rates of older and younger adults (Watson, Maylor, & Bruce, 2005). Data reported here include trials on which eye blinks occurred, but removal of these trials do not change the reported pattern of results.

ANOVA also revealed a marginal effect of age ($F(1, 27) = 3.62$, $p = .07$). A number of interactions were also significant: target presence interacted with target–background similarity ($F(1, 27) = 24.09$, $p < .001$) and set size interacted with target–background similarity ($F(1, 27) = 7.26$, $p < .05$). In general, observers were less accurate when the target was present and also when the set size was large, especially under conditions of camouflage. Of critical interest, target–background similarity interacted with age suggesting a greater cost for older adults compared to younger adults ($F(1, 27) = 6.82$, $p < .001$).

3.3. Training effects: response times (session 1 versus session 3)

To assess the ability of observers to improve their search performance with training, we analyzed response times across training sessions in both target present and target absent trials.

In target present trials (Fig. 2 for camouflage participants, Table 1 for no-camouflage participants) older adults were slower to find the target than younger adults, $F(1, 27) = 29.36$, $p < .001$. All observers took longer to find the target as the number of distractors increased, $F(1, 27) = 58.63$, $p < .001$, but the time cost of additional distractors was greater for older adults, $F(1, 27) = 10.49$, $p < .05$. These findings are consistent with previous work relating visual search to cognitive aging (e.g., Humphrey & Kramer, 1997). A central question in our study was whether or not training could improve search performance in camouflage search tasks, and whether the outcome of such training varied with age. The observed pattern of data suggests that performance can be improved in a camouflage search task based on a training regimen; both no-camouflage- and camouflage-trained observers found the target faster in session 3 compared to session 1, $F(1, 27) = 85.14$, $p < .001$, with camouflage-trained participants showing larger training benefits than no-camouflage-trained participants, $F(1, 27) = 7.43$, $p < .05$. Even more interesting, the effect of training was larger for older adults, $F(1, 14) = 10.34$, $p < .005$, with older adults in the camouflage training group showing a larger improvement relative to younger adults than no-camouflaged-trained older adults, $F(1, 27) = 11.10$, $p < .005$. It is possible that the differential improvement displayed by older adults was related to the fact that they started out worse than the younger adults and had more to gain. The differential improvement displayed by older adults compared to younger adults was reflected not only in faster overall search time, but also in an improvement in search efficiency as indicated by a significant set size × training session × age interaction, $F(1, 27) = 4.23$, $p < .05$. The slope of the response time × set size function of camouflage-trained participants improved with training by nearly 102% for older adults (session 1 slope = 134 ms/item; session 3 slope = 66 ms/item) compared to an improvement of only 19% for younger adults (session 1 slope = 39 ms/item; session 3 slope = 33 ms/item), whereas slopes in the no-camouflage training condition remained relatively stable across training. It should be noted that regardless of this large improvement by older adults, younger adults still found the target with greater efficiency both before and after training. It is also unclear from the response times measures whether the observed training improvements were driven by some high-level strategy shift (e.g., learning to search background regions of the display), an improvement in the efficiency of low-level visual processes, or improved guidance toward the target.

The data in target absent trials were somewhat similar (Fig. 2 for camouflage participants; Table 1 for no-camouflage participants). All observers were slower to make a response as more items were added to the display, $F(1, 27) = 138.77$, $p < .001$, but improved overall with training, $F(1, 27) = 34.18$, $p < .001$. No-camouflage-trained participants were quicker to complete their search, $F(1, 27) = 58.34$, $p < .001$, but camouflage-trained participants showed larger performance improvements with training, $F(1, 27) = 12.56$, $p < .005$. Older adults were again slower in general than younger adults both before and after training, $F(1, 27) = 13.61$, $p < .005$. However, in target absent trials older adults did not show greater improvement than younger adults, $F(1, 27) = 3.34$, $p = .08$, and although search efficiency also improved overall with training, $F(1, 27) = 7.14$, $p < .05$, this improvement did not vary with age, $F(1, 27) = .04$, $p = .84$. Finally, search efficiency for camouflage-trained participants improved more with training than it did for no-camouflage-trained participants, $F(1, 27) = 4.82$, $p < .05$.

One possible explanation for the attenuated training benefits displayed by older adults in target absent trials relative to target present trials is that in target absent trials older adults may have adopted more conservative termination criteria (Kramer & Madden, 2008). Alternatively, it is possible that this lack of differential improvement for older adults in target absent trials can be attributed to the mechanism of improvement in target present trials. If performance improvements from training were largely due to an improvement in low-level visual processes (e.g., the ability to segment the target from the background) or an improvement in target guidance then it is possible that this improvement might have been attenuated in target absent trials where no target existed to be segmented or provide visual guidance.

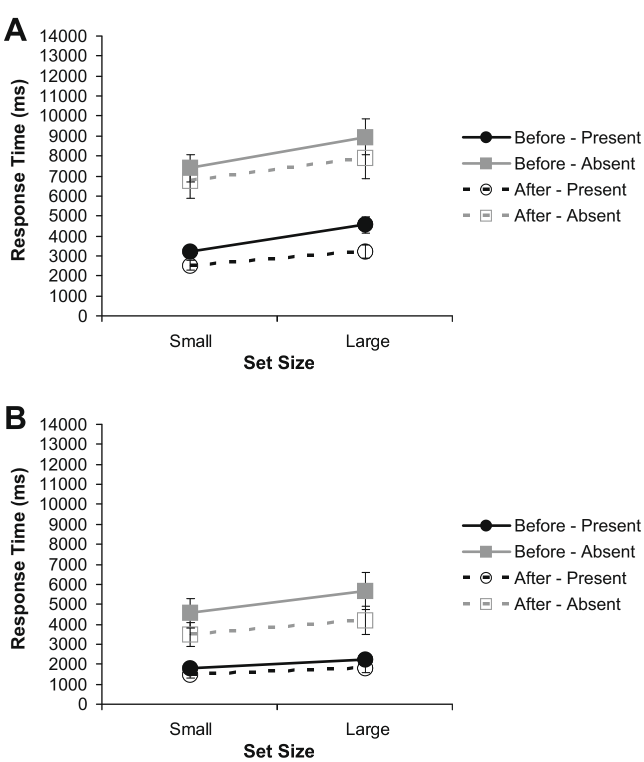

Fig. 2. Response times during training session 1 and training session 3 for (A) older and (B) younger adults in the camouflage training group.

3.4. Camouflage group training effects: accuracy (session 1 versus session 3)

It is clear from the response time data that both younger and older adults were able to locate camouflaged targets faster with training; however it is unclear whether this improvement resulted from better tuned search processes, or a shift in search termination criteria. If the former is the case then we would expect search accuracy to remain the same, or improve with training, whereas if the latter were true then we might expect accuracy to decrease with training. This pattern would reveal that the decreased response times we observed with training were actually the byproduct of a speed–accuracy tradeoff rather than some improvement in the ability to search camouflaged displays.

Our data support the view that search processes became better tuned to searching camouflage displays with training resulting in improved response times. As Fig. 3 shows, in target present trials older adults were no more likely to miss the target than were younger adults ($F(1, 14) = 1.72$, $p = .21$), and both older and younger adults missed fewer targets with training, $F(1, 14) = 30.68$, $p < .001$. Additionally, a significant training session × age interaction indicates that older adults enjoyed a larger benefit from training than did younger adults, $F(1, 14) = 6.81$, $p < .05$. A similar pattern was observed in target absent trials. Although older adults tended to make more false alarms than younger adults ($F(1, 14) = 5.26$, $p < .05$), both age groups made fewer false alarms overall with training, $F(1, 14) = 12.23$, $p < .005$. As in target present trials, older adults benefited more from training than did younger adults, $F(1, 14) = 12.26$, $p < .005$, although it is possible that this differential improvement in target absent trials was related to the fact that younger adult's accuracy was near ceiling in that condition both prior to and following training.

3.5. Transfer effects: response times

Observers in the camouflage training group benefited from practice; search for camouflaged targets was faster, more efficient, and more accurate in training session 3 compared to training session 1. However, does training on one set of camouflage displays transfer to camouflage search displays containing novel objects? Furthermore, if training does induce transfer, how does performance compare to that of observers trained on non-camouflage search displays, and does this effect differ with age? To answer these questions we compared performance in the final training session with that during the transfer session, where all observers, regardless of training group, searched for novel camouflaged objects. If training engendered transfer on novel camouflaged objects then we would expect to find performance at transfer to be equal or better than that in the final training session. Slower response times would indicate that training on one set of camouflage targets does not fully transfer to novel targets and distractors.

Response times for both the training groups (camouflage vs. no-camouflage) as a function of testing session (final training session vs. transfer session), target presence, set size, and age are shown in Figs. 4 and 5, respectively. To more easily examine whether training translated into consistent performance at transfer we analyzed each training group separately. As indicated by the lack of a significant main effect of testing session, there was no significant cost at transfer for observers in the camouflage training group in either target present, $F(1, 14) = .94$, $p = .35$, or target absent, $F(1, 14) = .06$, $p = .80$, trials; training on one set of camouflaged targets transferred to novel camouflaged targets. A significant main effect of age in both target present, $F(1, 14) = 18.40$, $p < .005$, and target absent, $F(1, 14) = 8.07$, $p < .05$, trials reflects the fact that older adults were generally slower than younger adults, but the absence of a significant test session × age interaction indicates that transfer was not differentially affected by age ($F(1, 14) = .03$, $p = .87$, in target present trials; $F(1, 14) = 1.22$, $p = .29$, in target absent trials). Additionally, in both target present, $F(1, 14) = 24.05$, $p < .001$, and target absent, $F(1, 14) = 43.64$, $p < .001$, trials observers took longer to find the target as set size increased, but this effect did not vary with testing session or age.

An examination of the data from the no-camouflage training group reveals a much different story. In stark contrast to the camouflage training group, Fig. 5 shows that observers in the no-camouflage training group suffered large performance decrements when transferred to displays containing novel camouflaged targets in both target present, $F(1, 13) = 74.58$, $p < .001$., and target absent, $F(1, 13) = 34.48$, $p < .001$, trials. Once again, older adults were

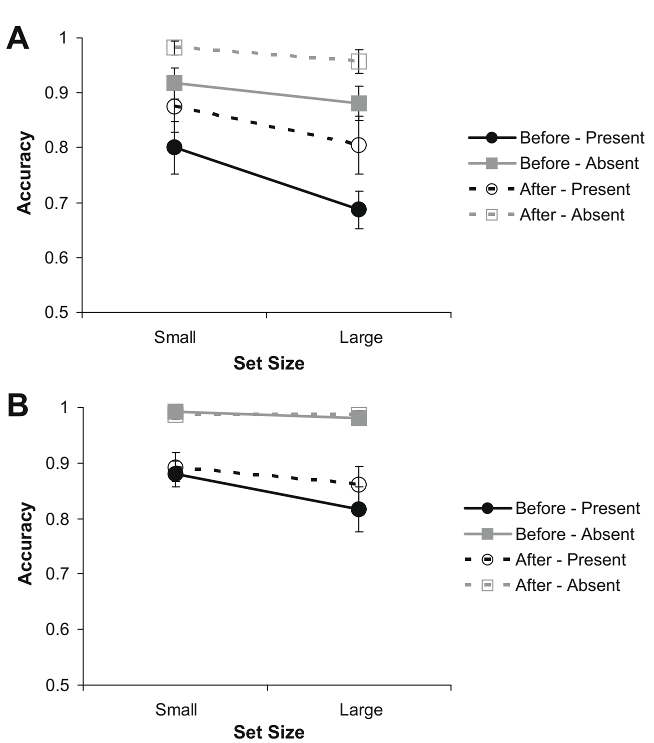

Fig. 3. Accuracy during before and after training for (A) older and (B) younger adults in the camouflage training group.

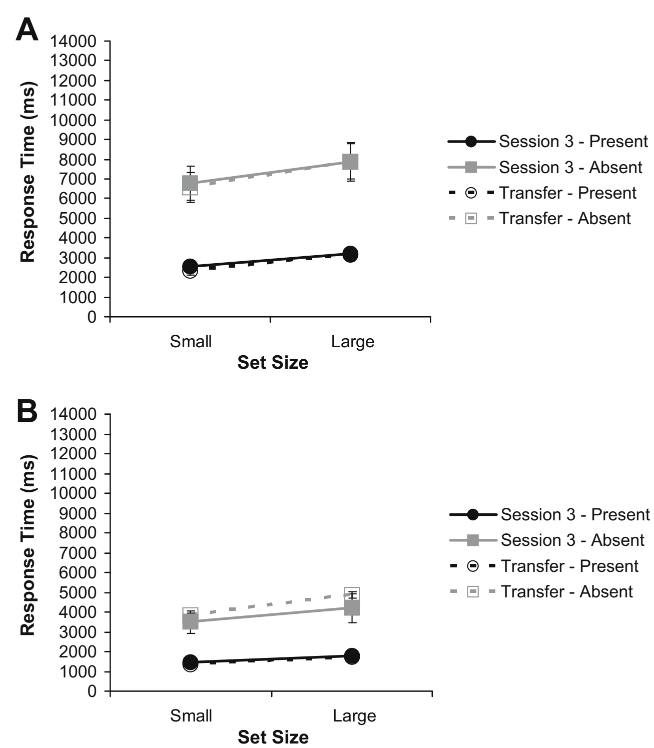

Fig. 4. Response times before and after training for (A) older and (B) younger adults in the camouflage training group.

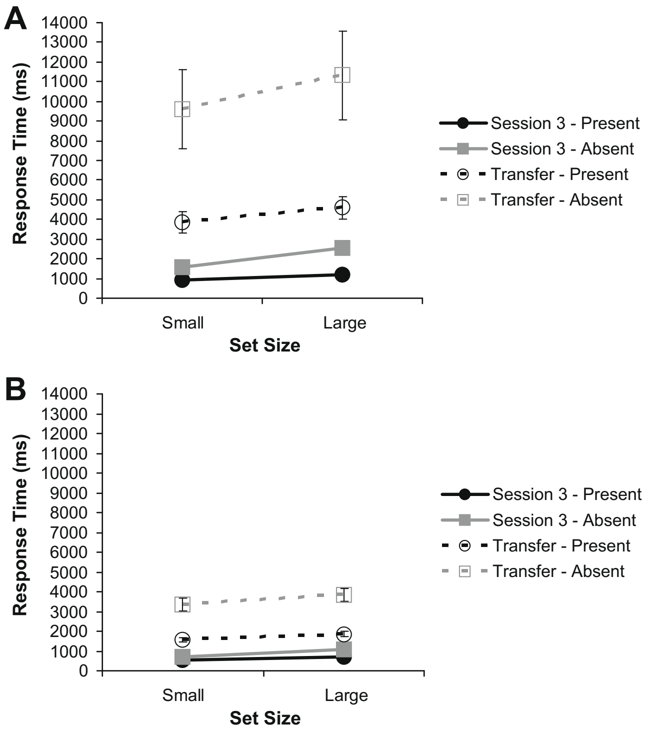

Fig. 5. Response times during training session 3 and at transfer for (A) older and (B) younger adults in the no-camouflage training group.

slower overall ($F(1, 13) = 28.87$, $p < .001$, in target present trials; $F(1, 13) = 9.04$, $p < .05$, in target absent trials), however the cost of switching to novel targets that were camouflaged after training on non-camouflage displays was much larger for the older adults than it was for the younger adults ($F(1, 13) = 18.30$, $p < .005$, in target present trials; $F(1, 13) = 14.06$, $p < .005$, in target absent trials). Furthermore, this difference was evident not only in the *y*-intercept of the response time x set size function, but also in the slope. Both older and younger adults were slower to find the target as items were added to the display, as indicated by the main effect of set size in both target present, $F(1, 13) = 46.46$, $p < .001$, and target absent, $F(1, 13) = 95.63$, $p < .001$, trials. Older adults, however, were generally less efficient searchers than younger adults, as indicated by a significant set size x age interaction ($F(1, 13) = 18.30$, $p < .005$, in target present trials; $F(1, 13) = 26.66$, $p < .001$, in target absent trials). Finally, the test session x set size interaction indicates that both age groups were less efficient at transfer ($F(1, 13) = 8.92$, $p < .05$, in target present trials; $F(1, 13) = 8.20$, $p < .05$, in target absent trials). In target absent trials, older adults suffered a larger efficiency decrease than younger adults, $F(1, 13) = 5.82$, $p < .05$, perhaps reflecting a more conservative decision-making criteria.

3.6. Transfer effects: accuracy

Accuracy at transfer, shown in Fig. 6, was generally high for the camouflage training group. All observers were less accurate as set size increased in both target present, $F(1, 14) = 27.79$, $p < .001$, and target absent, $F(1, 14) = 5.81$, $p < .05$, trials, with older adults less accurate in target absent trials than younger adults, $F(1, 14) = 6.81$, $p < .05$. Importantly, accuracy did not differ as a function of test session, nor were any other differences statistically significant. The lack of a difference in accuracy as a function of testing session or age confirms that whatever observers learned about searching for camouflaged targets during training transferred to search for novel camouflaged targets, and that this ability to transfer was not impacted by the observer's age.

Performance, in terms of accuracy, was much different in the no-camouflage training group. As shown in Fig. 7, all observers in the no-camouflage training group were less likely to successfully report the presence of the target as set size increased in both target present, $F(1, 13) = 5.82$, $p < .05$, and target absent, $F(1, 13) = 4.92$, $p < .05$, trials. Accuracy also dropped significantly at transfer in target present trials, $F(1, 13) = 24.08$, $p < .001$, with performance in large set size trials particularly impaired, $F(1, 13) = 23.51$, $p < .001$. Although older adults showed slightly lower accuracy than younger adults at transfer in target absent trials, $F(1, 13) = 9.98$, $p < .01$, overall, observers managed to maintain a high-level of accuracy, regardless of the fact that they had not been trained on camouflaged displays, $F(1, 13) = 2.95$, $p = .1$. No other effects were statistically significant.

The fact that observers in the no-camouflage training group showed decreased accuracy in target present trials, but generally maintained accuracy in target absent trials is interesting, and suggests that one of the factors underlying improvement in camouflage-trained observers might be an enhancement in the mechanisms responsible for segmenting targets from the background. If training on camouflage displays improves an observer's ability to differentiate a camouflaged target from the background then observers who were not trained on camouflage displays might be expected to miss more targets in target present trials, since targets would be poorly segmented. False alarms, however, might not be impacted, as no target is present to be segmented in target absent trials.

3.7. Proportion of fixations to objects versus backgrounds

It is clear from the manual response data that training on a set of camouflaged targets and search displays translates into better performance on novel camouflaged targets and displays compared

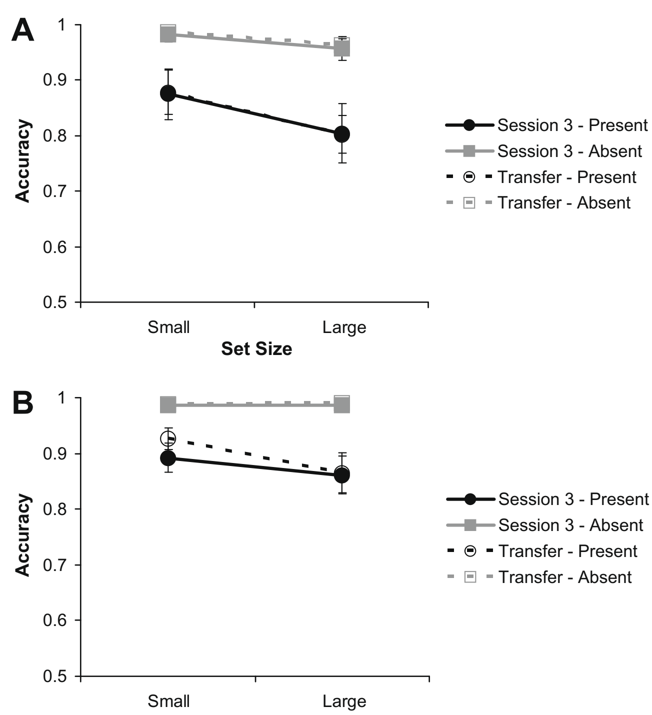

Fig. 6. Accuracy during training session 3 and at transfer for (A) older and (B) younger adults in the camouflage training group.

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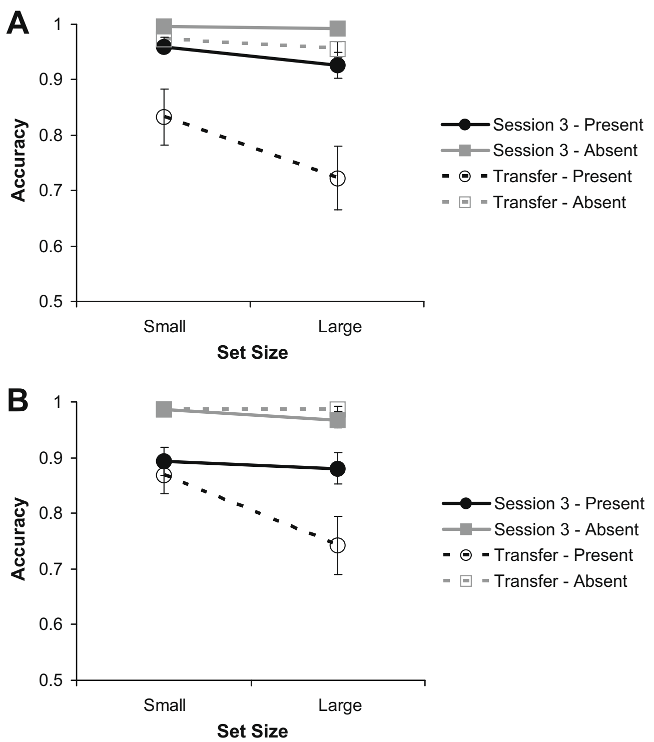

Fig. 7. Accuracy during training session 3 and at transfer for (A) older and (B) younger adults in the no-camouflage training group.

to observers not trained to search camouflaged displays. However, what is the mechanism of that training and transfer? To examine this question we analyzed the proportion of fixations during a trial that observers made to the background compared to the objects in the display (a fixation was counted as being on an object if it fell within 1.66° of an object's center).[2] If training resulted in a high-level strategy shift toward searching background regions of the display where camouflaged targets were likely to appear then we would expect the proportion of background fixations to increase with training. That is, if camouflage-trained participants learned that the target was never a salient object (i.e., the target was most similar to the background causing it to "melt" into the background region), then they could direct their search away from the distractor objects (all of which were highly salient) and toward the background display regions where the target was most likely to be located. We would also expect this pattern to differ across training groups since the no-camouflage training group was not trained on camouflage displays, nor did they show that their training on non-camouflage displays translated into similar performance on camouflaged displays at transfer.

The proportion of fixations on the background during training for both the camouflage and no-camouflage training groups are shown in Table 1. To examine training effects, an ANOVA was performed with target presence, set size, and training session (1 vs. 3) entered as within-participant variables, and training group and age entered as between-participant variables. Overall, older adults made fewer background fixations than younger adults, $F(1, 27) = 5.23$, $p < .05$, and observers in the no-camouflage training group made fewer background fixations than observers in the camouflage training group, $F(1, 27) = 8.66$, $p < .01$. Not surprisingly, all observers made more fixations to the background in target absent trials, $F(1, 27) = 9.23$, $p < .01$, and fewer background fixations as items were added to the display, $F(1, 27) = 172.01$ $p < .001$. The latter can likely be attributed to the fact that as the number of objects in the display increases, the amount of background area decreases. Both the effects of target presence, $F(1, 27) = 8.79$, $p < .01$, and set size, $F(1, 27) = 16.08$, $p < .001$, varied with training group; camouflage-trained participants made more background fixations in target absent trials and in the high set size condition than no-camouflage-trained observers. While the proportion of background fixations increased with training, $F(1, 27) = 17.12$, $p < .001$, this increase was not significantly larger for observers in the camouflage training group, $F(1, 27) = 2.21$, $p = .15$. However, an interaction between session, target presence, target–background similarity, and age does seem to suggest that older adults, with training, do tend to pay more attention to the background, particularly when the target is absent $F(1, 27) = 6.65$, $p < .05$).

To explore eye fixation patterns at transfer, the proportion of fixations on the background for the transfer session were entered into an ANOVA with set size and target presence as within-participant factors and training group as a between-participant factor. Of interest, there was no significant effect of training group ($F(1, 27) = .23$, $p = .64$), nor did training group interact with any other variable (all p values >.12). However, similar to the previous analysis, older adults fixated the background less frequently compared to younger adults ($F(1, 27) = 4.91$, $p < .05$).

What do our analyses of background fixations tell us about the mechanism(s) underlying training and transfer in our camouflage search task? If a high-level oculomotor strategy shift was the driving force behind the response time improvements shown by the camouflage training group during training and at transfer then we would have expected to see a higher proportion of fixations made to the background with training, with camouflage-trained participants continuing to use this strategy at transfer. This was not the case. In general, little differential change in the proportion of fixations on the background was observed between the two training groups, and no difference between groups was observed at transfer in terms of fixations. While it is clear that camouflage-trained participants were learning to search camouflage scenes, it does not appear that this learning was associated with a strategy shift in which overt attention was deployed preferentially to the background regions of the display. It is, of course, possible that learning may have been based on a shifting of covert attentional mechanisms toward background regions, but our data do not allow for a definitive examination of such an account.

3.8. Target Guidance and Recognition

Based on our analysis of background fixations it appears unlikely that the improvements in camouflage search and subsequent transfer of training to novel camouflage targets exhibited by camouflage-trained participants resulted from a high-level shift in oculomotor search strategy. If camouflage-trained participants did not alter their search strategies with training, then what did these observers learn that allowed them improve their ability to detect both previously seen and novel camouflaged targets? One possibility is that low-level visual mechanisms became better tuned to the camouflage search task with training. Considered in the context of two-stage models of visual search (e.g., Treisman & Gelade, 1980; Wolfe et al., 1989), such augmentation might allow pre-attentive processes to produce a more robust representation of the display for focused attentional mechanisms to operate on. If this was in fact the case, camouflaged-trained participants would likely bene-

[2] In these analyses, whether or not a fixation fell on an object was based on a distance of 1.6 degrees, similar to previous work using this paradigm (e.g., Boot et al., 2009; Neider & Zelinsky, 2006). However, the same analysis using a much more liberal criterion (3.2° which may better reflect the extent to which participants explore areas far from salient objects) also indicated no difference between training groups at transfer.

Table 2
Number of saccades made and response time (ms) after fixation by camouflage- and no-camouflage-trained observers in target present trials at transfer. S = small set size, L = large set size.

	Younger		Older	
	S	*L*	*S*	*L*
Camouflage trained	3.89 (.86)	4.99 (1.17)	5.79 (1.33)	8.20 (2.39)
	988 (220)	1280 (323)	1633 (420)	2267 (678)
No-camouflage trained	4.41 (1.13)	5.91 (1.52)	10.35 (3.16)	13.36 (4.47)
	1109 (303)	1448 (428)	2704 (1030)	3537 (1320)

Note: values in parentheses indicate one standard deviation of the mean. Response times are presented below the number of saccades for the corresponding condition.

fit from improved guidance toward and improved recognition of the target with training.

To provide a measure of search guidance we analyzed the number of saccades required to initially fixate the target by camouflage- and no-camouflage-trained participants at transfer in target present trials (Table 2). Transfer trials were selected in order to provide a post-training contrast of what might have been learned during training to augment camouflage search ability. Target absent trials were omitted from the analysis, since no target was present to fixate in those trials, as were trials in which the target was not fixated (~36% of total target present trials, which did not vary significantly as a function of either age or camouflage training group). If camouflage-trained participants benefited from improved visual guidance following training then we would expect a more direct oculomotor route to the target (i.e., fewer saccades would be needed to locate the target). Data were analyzed using ANOVA, with age and training group entered as between-participant variables, and set size entered as a within-participant variable. Overall, older adults required more eye movements to fixate the target than younger adults, $F(1, 27) = 34.97$, $p < .001$, and camouflage-trained participants needed fewer saccades to fixate the target than no-camouflage-trained participants, $F(1, 27) = 12.71$, $p < .01$. Interestingly, this effect was largely driven by older adults, as indicated by a significant age × training group interaction, $F(1, 27) = 6.99$, $p < .05$. Camouflage-trained older adults required approximately 40% fewer saccades to reach the target than no-camouflage-trained older adults, $F(1, 13) = 10.56$, $p < .01$). Younger adults exhibited a similar pattern, however, on a much smaller and non-significant scale, $F(1, 14) = 1.52$, $p = .24$. Not surprisingly, additional saccades were needed to locate the target as set size increased, $F(1, 27) = 99.16$, $p < .01$, with older adults needing more eye movements than younger adults as items were added to the display as indicated by a significant set size × age interaction, $F(1, 27) = 12.16$, $p < .05$.

To examine whether the ability of camouflage- and no-camouflage-trained participants to recognize targets improved with training we analyzed the time it took for participants to make a button-press judgment once the target object was fixated in target present trials at transfer (Table 2). Analysis parameters were similar to those described for the previous saccades to the target analysis. Similar to the measure of saccades to the target, older adults required more time to recognize the target following fixation, $F(1, 27) = 31.73$, $p < .001$, and camouflage-trained participants recognized the target more quickly than no-camouflage-trained participants, $F(1, 27) = 7.81$, $p < .01$. Again, a significant age × training group interaction, $F(1, 27) = 4.76$, $p < .05$, indicates that older adults benefitted more from camouflage training than younger adults. On average, camouflage-trained older adults recognized the target nearly 1200 ms faster than no-camouflage-trained older adults once the target was fixated, $F(1, 13) = 6.58$, $p < .05$. Again, younger adults showed a similar, but non-significant pattern of differences, $F(1, 14) = .81$, $p = .38$. All participants required more time to recognize the target as items were added to the display, $F(1, 27) = 104.81$ $p < .001$, with the cost of additional items being larger for older adults, $F(1, 27) = 17.75$ $p < .001$.

Whereas camouflage- and no-camouflage-trained participants showed similar patterns of background fixations at transfer, examination of our target guidance and recognition measures revealed a much different story. Specifically, camouflage-trained participants required fewer saccades to fixate the target, and, once the target was fixated, required less time to recognize it. This pattern was exaggerated in older adults and was consistent with the larger response time and accuracy benefits of camouflage training exhibited by camouflage-trained older adults compared to camouflage-trained younger adults. Overall, these guidance and recognition differences suggest that the benefits garnered from camouflage training might be tied to an improvement in the effectiveness of pre-attentive visual mechanisms to extract and represent information for serial attention to parse; more robust representations allow for better guidance and easier recognition of the target.

4. Discussion

Previous studies of visual search comparing performance between younger and older adults have revealed a wealth of information regarding the changes that occur in attentional mechanisms with age. In traditional laboratory search tasks, older adults perform well in singleton (Whiting et al., 2005) and triple-conjunction search (Humphrey & Kramer, 1997), but poorly on conjunction search (Plude & Doussard-Roosevelt, 1989), suggesting that the attentional mechanisms responsible for feature extraction are largely spared from age-related decline, while those responsible for the integration of featural information into perceptual objects are not. However, to some extent, top-down information may be useful in compensating for such decline. Our examination built on this previous work by extending the study of search in older adults to pseudo-realistic stimuli, in which real world objects were presented on target-correlated complex backgrounds. In addition, we examined the efficacy of training on this realistic search task, and whether or not any effect of training transferred to similar, but novel camouflage search tasks. Although older adults were generally slower and less accurate than younger adults overall, both age groups exhibited performance improvements with training. Furthermore, observers trained on camouflage displays, regardless of age, showed no performance cost when searching novel camouflage displays, whereas observers trained on non-camouflage displays suffered a large performance cost when transferred to camouflage displays.

Our findings have a number of implications for basic theoretical accounts of aging and attention, as well as for application in the real world. First, although younger adults suffer a performance cost when searching for targets that are highly similar to the background, older adults suffer an even larger cost. This cost is represented both by an additive time cost in the *y*-intercept of the response time by set size function, and an increase in search slope.

An increase in slope might implicate a decreased ability for attentional mechanisms to *select* items, while an additive response time cost indicates some decline in the ability of low-level visual processes to initially parse a scene. In terms of slope costs, younger adults and older adults both demonstrated decreased search efficiency with increasing target-background similarity, suggesting that serial selection processes were somewhat impaired by target-background similarity. This observation is contrary to previous findings indicating that target–background similarity is typically represented only in additive *y*-intercept costs (Neider & Zelinsky, 2006; Wolfe et al., 2002). However, these previous studies utilized within-subjects designs whereas in our study target–background similarity was treated as a between groups factor. Hence, these slope differences must be considered cautiously in the context of previous work. In contrast, our findings of an additive response time cost under camouflage conditions for older adults' replicates previous findings from younger adults (Boot et al., 2009; Neider & Zelinsky, 2006; Wolfe et al., 2002). In our study, this additive cost was quite large, ranging from approximately 1–3 s for younger adults and approximately 2–5 s for older adults. The fact that older adults suffer a larger additive reaction time cost than younger adults suggests that at least some low-level visual and attentional processes are susceptible to age-related declines, although further research will be needed to identify these specific processes.

A second implication from our findings is both theoretical and applied in nature. Although older adults initially performed poorly when searching for camouflaged targets, camouflage search was amenable to training. Camouflage-trained older adults displayed large response time and accuracy improvements over the course of three training sessions. Although younger adults also improved, older adults enjoyed *larger* training benefits. Specifically, older adults showed a 102% improvement in search efficiency (as measured by the slope of the response time by set size function) in the camouflage search task following training; younger adults exhibited a similar, but smaller improvement (19%). These improvements in item-by-item processing efficiency could indicate that with training, camouflage-trained observers were able to form more robust scene representations, allowing for easier recognition of items inspected by focused attention. Hence, it may be the case that even though some of the attentional mechanisms responsible for camouflage search suffer from age-related decline, these mechanisms might still be improved with practice on a given task allowing older adults to perform even very difficult search tasks better with training.

Our findings also suggest that training on camouflage search tasks not only improves performance but also produces transfer of training benefits when searching novel camouflage displays. Observers trained on camouflage displays were not impaired when searching novel camouflage displays. This transfer of training was observed for both older and younger adults. Although this transfer might be construed as narrow (i.e., given that subjects performed the same task in training and transfer), the fact that there was any transfer at all was surprising given previous work in the perceptual learning literature showing that transfer of training is often very limited (e.g., Ahissar & Hochstein, 1996; Ball & Sekuler, 1982; Ball et al., 2002; Fahle & Morgan, 1996; Fahle et al., 1995; Fiorentini & Berardi, 1981; Furmanski & Engel, 2000; Shiu & Pashler, 1992). Whether practice on a search paradigm such as the camouflage search task might transfer to the difficult searches older adults perform in their daily lives (e.g., searching for hazards while driving) is an interesting and open question.

All camouflage-trained subjects demonstrated clear training and transfer effects in our camouflage search task, but what mechanisms underlie this improved performance? One possibility is that with training observers developed oculomotor strategies (e.g., searching the background regions) that maximized search efficiency under the investigated camouflage conditions. Our analysis of eye movements, however, suggests that this was not the case. Although observers in the camouflage training group made more fixations to the background with training, this trend reversed at transfer with no corresponding drop in performance. Additionally, observers in the no-camouflage training group also showed an increased likelihood to fixate the background with training, even in the absence of camouflage. Hence, it would seem that additional background fixations were not indicative of a specific strategy shift, but rather were due to an increase in the number of center of gravity fixations (Findlay, 1982; Findlay, 1987; Zelinsky, Rao, Hayhoe, & Ballard, 1997). While these center of gravity fixations may not have been representative of a strategy shift, they may still be diagnostic of the mechanism underlying the improved performance in the camouflage training group. Specifically, these fixations may be further evidence that with training, participants were able to construct a more robust representation of the search display. Given the reduced noise that would be inherent to a more robust representation, center of gravity fixations could likely be planned more intelligently allowing for optimal allocation of attentional resources.

Additional evidence for an improvement in pre-attentive visual processes is provided by our analyses of target guidance and recognition. Two-stage models of search contend that features within a search display are initially extracted pre-attentively, and then bound in a serial manner via focused attention (e.g., Treisman & Gelade, 1980; Wolfe et al., 1989). Potential areas of interest within the pre-attentive representation can be biased if, for example, the features at a given location are similar to the visual features inherent to the target object (Wolfe, 1994; Wolfe et al., 1989). It stands to reason that more robust pre-attentive representations would therefore allow for more effective guidance of focused attention. Similarly, a less noisy representation would make it easier for serial attentional mechanisms to bind visual features, consequentially allowing for easier identification and recognition of objects. In our study, a measure of guidance was provided by analyzing the number of eye movements needed to initially fixate the target following display onset. Recognition was defined by quantifying the time needed by a participant to make a button-press response to the target once fixated. Overall, camouflage-trained participants needed fewer eye movements to fixate the target, and less time to recognize the target than their no-camouflage-trained counterparts. What's more, these differences were particularly robust in older adult participants.[3]

Given these findings, in addition to the large improvements in search efficiency displayed by camouflage participants with training, we speculate that camouflage training essentially provides the low-level visual processes responsible for generating pre-attentive representations with a chance to become better 'tuned' to our difficult search task. In older adults, some low-level visual processes are thought to be preserved (e.g., feature extraction), whereas others are thought to be susceptible to age-related decline (e.g., perceptual grouping; Madden et al., 1996; Plude & Hoyer, 1986, but see Humphrey & Kramer, 1999). Our findings suggest that although some declines may occur, sufficient plasticity still exists within the perceptual system to allow for improvement in these declining processes. This was particularly evident in our study, where the large response time and accuracy improvements displayed by camouflage-trained older adults at transfer in comparison with no-camouflaged-trained older adults were coupled with similarly large differences in our search guidance and target recognition

[3] Younger adults displayed a similar, but non-significant, pattern. However, similar and significant patterns of improvement have been shown in younger adults indicating that training benefits amongst younger and older adults are reflected in the same manner (Boot et al., 2009).

measures at transfer; as attentional representations become more robust (e.g., through training), search performance improves. The fact that younger adults also benefitted from camouflage training suggests that even age-intact perceptual processes (e.g., those involved in feature extraction) likely benefit from training.

Our findings not only answer a number of questions related to visual search and transfer of training in older adults, but also generate a number of interesting questions that should be addressed in future research. One of these questions pertains to the transfer aspect of our study. Although observers demonstrated a clear ability to transfer some general aspect of training on camouflage displays to novel camouflage displays, this transfer was somewhat narrow. A demonstration of whether or not training on our camouflage task would produce transfer in search for camouflaged items in real world displays would be useful in assessing the efficacy of our training protocol in real world contexts. Indeed, if improvement in pre-attentive visual processes underlies training and transfer in the camouflage search task then those benefits should extend to many of the less difficult search tasks often encountered in the real world, as more robust representations generally aid search processes. Additional studies examining retention of training would also be useful in establishing whether training on camouflage search tasks was retained over long periods of time, as would be required of any training program implemented to improve cognitive performance in older adults in every day tasks.

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