# The Relationship between Visual Search and Categorization of Own- and Other-Age Faces

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Abstract

Young adult participants are faster to detect young adult faces in crowds of infant and child faces than vice versa. These findings have been interpreted as evidence for more efficient attentional capture by own-age than other-age faces, but could alternatively reflect faster rejection of other-age than own-age distractors, consistent with the previously reported other-age categorization advantage: faster categorization of other-age than own-age faces. Participants searched for own-age faces in other-age backgrounds or vice versa. Extending the finding to different other-age groups, young adult participants were faster to detect young adult faces in both early adolescent (Experiment 1) and older adult backgrounds (Experiment 2). To investigate whether the own-age detection advantage could be explained by faster categorization and rejection of other-age background faces, participants in Experiments 3 and 4 also completed an age categorization task. Relatively faster categorization of other-age faces was related to relatively faster search through other-age backgrounds on target absent trials but not target present trials. These results confirm that other-age faces are more quickly categorized and searched through and that categorization and search processes are related; however, this correlational approach could not confirm or reject the contribution of background face processing to the own-age detection advantage.

*Keywords:* Face Perception, Age, Visual Attention, Age Categorization, Visual Search

# The Relationship between Visual Search and Categorization of Own- and Other-Age Faces

Faces are complex social stimuli carrying a range of social cues (e.g., sex, race, and age). These social attributes have an influence on the way that faces are attended to, processed, and remembered. For example, own-race, and own-age faces are more accurately remembered than other-race and other-age faces (Rhodes & Anastasi, 2012; Meissner & Brigham, 2001; Wiese, Komes, & Schweinberger, 2013). Evidence also suggests that these attributes influence how we allocate attention to faces in our environment. For example, in passive viewing tasks, eye-tracking revealed that young adult participants spent more time looking at key facial features (eyes, nose, and mouth) of young adult than infant faces (Proietti, Macchi Cassia, dell'Amore, Conte, & Bricolo, 2015) or more time looking at young adult than older adult faces (Firestone, Turk-Browne, & Ryan, 2007; He, Ebner, & Johnson; 2011). Children also spent more time looking at faces of other children in their school grade than children in other grades (Hills & Willis, 2016). These studies suggest that more attention is given to faces that are similar in age to us than to other-age faces; however, in all of these studies, each face was presented alone meaning that no other faces or objects competed for attention in the visual environment.

Studies aiming to assess whether facial age cues influence how attention is drawn towards faces in tasks where multiple faces compete for attention have produced more mixed results. For example, using the dot probe paradigm, when both infant and young adult faces were presented on the screen simultaneously for a brief time, young adult participants were faster to respond to a subsequent probe when it appeared in the same location as an infant face than when it appeared at the same location as an adult face (Brosch, Sander, & Scherer, 2007; Hodsoll, Quinn, & Hodsoll, 2010). Similarly, in a visual search task where participants searched for a target face that differed from the distractor faces in eye color, young adult participants were slower to detect targets when all of the faces in the search array were infants rather than young adult faces (Thompson-Booth et al., 2014). These studies suggest that young adult participants' attention is attracted to and/or held by infant faces more than by young adult faces.

A recent study also provided evidence to suggest that older adult faces may receive preferential attention in a task where multiple faces competed for attention (Neumann, End, Luttmann, Schweinberger, & Wiese, 2015). Young adult participants searched for young adult targets amongst older adult backgrounds or vice versa in search arrays presented for 200ms. Looking at response times, participants were no faster to detect older adult or young adult targets but participants were more accurate to respond when older adult faces were presented in young adult backgrounds than vice versa. This suggests that older adult targets may have been detected with greater ease than young adult targets. Together, these studies suggest that both older and younger other-age faces could preferentially attract or hold attention compared with own-age faces in tasks where multiple faces are presented concurrently.

However, a recent study, also using the visual search method produced results suggesting an attentional bias towards own-age rather than other-age faces (Macchi Cassia, Proietti, Gava, & Bricolo, 2015). Across two experiments, young adult participants searched for an infant (Experiment 1) or a child target (Experiment 2) amongst backgrounds of young adult faces or vice versa. Young adult participants were more efficient to detect young adult targets than vice versa. Ruling out a purely perceptual explanation for this finding, the own-age detection advantage was found in a sample of young adults with limited experience interacting with children, but not in a sample of preschool teachers who had more extensive experience interacting with children. These results were interpreted by the authors as an experience based own-age detection advantage. They argued that own-age faces captured participants' attention explaining faster detection times; however, inspection of the figures suggested that the search advantage emerged on both target present and target absent trials suggesting an alternative explanation for the results. It is possible that participants were faster to search through other-age backgrounds explaining faster responding on own-age target trials. This alternative explanation is consistent with previous studies which have found faster age categorization of other-age than own-age faces (Craig & Lipp, 2017; Johnston, Kanazawa, Kato, & Oda, 1997).

Considered together, the results of past studies lead to inconsistent conclusions about the influence of facial age cues on the allocation of attention to faces varying in age. Even considering the visual search results alone, one study suggested no detection advantage in response times, but more accurate detection of other-age faces (Neumann et al., 2015) and another suggested preferential allocation of attention to own-age faces (Macchi Cassia et al., 2015). These results may be due to the different methods adopted between the two studies. They may also be due to the use of younger other-age faces in one study, and older other-age faces in the other; however, previous findings and both socio-cognitive and experience based models of person perception (e.g., Brewer, 1988; Hugenberg, Young, Bernstein, & Sacco, 2010; Levin, 2001; Meissner & Brigham, 2001; Wiese, et al., 2013) predict that consistent age-processing biases should be observed for both younger and older other-age faces when using comparable methods.

As such, the first aim of the current investigation was to determine whether an own-age detection advantage would be observed using both younger and older other-age faces and in the same paradigm. Young adults searched for young adult faces in backgrounds of early adolescent faces (Experiment 1) and older adult faces (Experiment 2) or vice versa to determine the nature of the search advantage. Secondly, we aimed to investigate whether the own-age detection advantage could be accounted for by background processing rather than target capture alone. To investigate this question, participants in Experiments 3 and 4 completed both a visual search task and an age categorization task. We looked at whether there was a relationship between time taken to search through other-age relative to own-age backgrounds and time taken to categorize each face by its age. Finding this relationship would indicate that age categorization processes are likely to contribute to visual search performance.

## Experiments 1 and 2

Experiments 1 and 2 aimed to determine whether an own-age detection advantage would emerge using different ‘other-age groups’ (early adolescents and older adults). Given that the methods were more similar to those of Macchi Cassia et al. (2015) and that it is common to find consistent age processing biases for both younger and older other-age faces when comparable methods are used (Anastasi & Rhodes, 2006; Craig & Lipp, 2017; Crookes & McKone, 2009; He et al., 2011; Johnston et al., 1997: Proietti et al., 2015), it was predicted that participants would be faster to search through early adolescent and older adult backgrounds and to detect young adult targets than vice versa.

## Method

**Participants.** The target sample size was based on previous studies investigating visual search biases with face targets (e.g., Dickins & Lipp, 2014 [emotion]; Levin, 2000 [race]). Based on past studies, we recruited until at least 20 participants had signed up for each study and stopped testing once all recruited participants had taken part. A power analysis indicates that this target sample size would be sufficient to have an 80% chance of detecting a medium to large own-age detection advantage (cohen's $f$=.33) with an α of .05 and a .5 correlation between within participant measures. This effect size is smaller than the detection biases reported in the past literature. This resulted in 30 participants in Experiment 1 (12 Males, $M_{age}$=18.47, $SD_{age}$=1.14, *Range*=17–22) and 23 participants in Experiment 2 (7 Males, $M_{Age}$=18.69, $SD_{Age}$=2.01, *Range*=17–25). Participants received course credit in return for participation. One additional participant (aged 39) was not included in the sample of Experiment 1 as they were well outside the young adult age range defined by the ages of the face stimuli. This exclusion did not alter the significance or direction of the results.

**Stimuli.**

***Experiment 1.*** Stimuli were photographs of nine young adult (aged 19–31) and nine early adolescent (aged 10–13) Caucasian male faces displaying neutral expressions. Young adult faces were drawn from the FACES database (Ebner, Riediger, & Lindenberger, 2010) and the Productive Aging Database (Minear & Park, 2004). Early adolescent faces were the nine youngest male faces in the NIMH-ChEFS database (Egger et al., 2011). All faces selected appeared pre-pubescent. The images were cropped so that only the head was shown to minimize any potential effects of irrelevant stimulus properties which can affect visual search performance (Purcell, Stewart, & Skov, 1996; Savage, Becker, & Lipp, 2016). Faces were converted to grey scale, reduced to a similar size, edited to the same image quality, and placed on a grey background 175×175 pixels in size (see Figure 1 for example stimuli).

***Experiment 2.*** The nine male early adolescent faces used in Experiment 1 were replaced with nine male older adult faces aged 69–80 gathered from the FACES database (Ebner et al., 2010) and the Productive Aging Database (Minear & Park, 2004). Faces were edited in the manner described above.

**Procedure.** The experiments took place in a small group computer lab with no more than seven participants taking part at the same time. Each participant was seated in front of a 19in CRT monitor with a screen resolution of 1024×786 pixels and a refresh rate of 85 Hz. The experiment was executed in DMDX (Forster & Forster, 2003). Participants were asked to view groups of faces appearing on the screen and decide as quickly and accurately as possible whether all of the faces were the same age or whether one of the faces was different in age to the rest. Participants made their ‘same’ or ‘different’ response using the right and left shift keys on a standard keyboard. Response mapping was counterbalanced across participants.

Participants were presented with a randomized sequence of 144 trials comprising 72 target absent trials (36 trials with all own-age faces and 36 with all other-age faces) and 72 target present trials (36 trials with an own-age target amongst other-age backgrounds and 36 trials with an other-age target amongst own-age backgrounds). All trial types were presented intermixed. Pictures were presented in a 3×3 search array. Unlike Macchi Cassia and colleagues (2015), search array size was not varied. As the own-age detection advantage was most robust at the largest array size (8 faces; Macchi Cassia et al., 2015), employing one set size allowed us to investigate the search bias with a smaller number of trials than would be required to fully counterbalance targets, locations, and set sizes. The location of the pictures was jittered by 30 pixels left, right, up or down from nine fixed locations on the screen. Trials were arranged so that each face was a target four times and each of the nine array positions contained a target eight times. The location of the own-age and other-age targets was matched meaning that, both own-age and other-age targets appeared in each position equally often.

On each trial, a black fixation cross was presented for 500ms in the middle of a grey screen followed by the array of nine faces presented for 5000ms or until a response was made. Trials were presented in a pseudorandom order such that no more than three target present or target absent trials were presented consecutively. Experiment 2 proceeded in the same manner as Experiment 1 except the early adolescent faces were replaced with the older adult faces.

**Data preparation and analysis.** Incorrect responses and response times faster than 100ms or more than three standard deviations faster or slower than each participant's mean response time were excluded from analysis. Average response times were calculated and submitted to 2 (Background age: own-age, other-age) × 2 (Trial type: target present, target absent) repeated measures ANOVAs for each experiment. Data from one participant were not included in analysis of Experiment 2 as over 40% of their responses were incorrect or invalid. In all experiments, initial analyses indicated that participant gender did not significantly moderate any of the results so analyses are reported collapsed across this factor. Analysis of error rates across all studies also suggested a speed-accuracy tradeoff to be unlikely to account for response times. Error rate analyses are presented in a supplement.

## Results

**Experiment 1.** As shown in Figure 2, participants were faster to respond on target present than on target absent trials, $F(1,29)=120.01$, $p<.001$, $\eta_p^2=.81$, 90% CI[.68–.86], and faster to search through backgrounds of early adolescent faces and detect young adult targets than to search through backgrounds of young adult faces and detect early adolescent targets, $F(1,29)=7.06$, $p=.013$, $\eta_p^2=.20$, 90% CI[.02–.38]. There was no Background age × Trial type interaction, $F(1,29)=0.04$, $p=.837$, $\eta_p^2<.01$, 90% CI[.00–.05]. Participants were significantly faster to detect a young adult target in backgrounds of early adolescent faces on target present trials, $t(29)=2.21$, $p=.035$, $d_z=0.39$, 95% CI[0.02–0.76], $M_D$=80.90ms, and marginally faster to search through early adolescent than young adult backgrounds on target absent trials, $t(29)=1.98$, $p=.057$, $d_z=0.35$, 95% CI[-0.02–0.72], $M_D$=91.83ms.

**Experiment 2.** Consistent with Experiment 1, as shown in Figure 3, participants were faster to respond on target present than on target absent trials, $F(1,21)=106.87$, $p<.001$, $\eta_p^2=.84$, 90% CI[.69–.89] . They were also faster to search through older adult backgrounds and detect young adult targets than vice versa, $F(1,21)=6.58$, $p=.018$, $\eta_p^2=.24$, 90% CI[.02–.45]. These results were not moderated by a Trial type × Background age interaction, $F(1,21)=0.12$, $p=.729$, $\eta_p^2=.01$, 90% CI[.00–.13]. Looking at target present and target absent trials separately suggested that results were not driven by only one trial type. Participants were significantly faster to detect young adult targets in backgrounds of older adult faces than vice versa, $t(21)=3.32$, $p=.003$, $d_z=0.68$, 95% CI[0.22–1.15], $M_D$=112.21ms, and were also numerically faster to search through older adult than young adult backgrounds on target absent trials, $t(21)=1.56$, $p=.134$, $d_z=0.32$, 95% CI[-0.11–0.75], $M_D$=92.99ms.

**Discussion**

The aim of Experiments 1 and 2 was to determine whether the own-age detection advantage would be observed using different 'other-age groups' (early adolescents and older adults) under a constant method. As predicted, participants were faster to detect young adult targets than early adolescent and older adult targets. This finding suggests that the own-age detection advantage is observed when using faces of early adolescents rather than infants or children and using different methods and a larger number of different stimuli than used by Macchi Cassia et al. (2015). It also demonstrates that the own-age detection advantage generalizes to older other-age faces which are characterized by very different visual features. This finding suggests that the results were not specific to the image properties or features of one age group or one image database. This is consistent with the finding that the presence of an own-age detection advantage depended on participants' experience interacting with children (Macchi Cassia et al., 2015).

In both Experiments 1 and 2, the absence of a Background age × Trial type interaction suggested that the same mechanism may drive performance on target present and target absent trials. This finding is also consistent with Macchi Cassia et al. (2015) who reported an own-age detection advantage that was averaged across target present and target absent trials. Finding differences in the efficiency of search through own- vs. other-age backgrounds on both target present and target absent trials highlights an alternative explanation for the own-age detection advantage. Rather than faster capture by own-age targets, it is possible that participants were faster to categorize and reject other-age background faces. Faster rejection of other-age faces would be consistent with the previously reported other-age categorization advantage (Craig & Lipp, 2017; Johnston et al., 1997). This background processing explanation has also been proposed to explain detection advantages for targets defined by their emotional expression or their race (e.g., Horstmann, Scharlau, & Ansorge, 2006; Lipp et al., 2009; Shasteen, Sasson, & Pinkham, 2014).

## Experiment 3

Participants in Experiment 3 searched for young adult targets in older adult backgrounds and vice versa and completed an age categorization task. As in Experiment 2, it was predicted that participants would be faster to search through other-age backgrounds and detect own-age targets. It was also predicted that young adults would be faster to categorize older adult than young adult faces by age. Finally, it was predicted that the size of the other-age categorization advantage would be related to the size of the own-age detection advantage and the other-age background search advantage. This relationship would provide some indication that the speed of processing background faces contributes to the own-age detection advantage.

### Methods

**Participants.** As Experiments 3 and 4 aimed to investigate the relationship between two individual difference variables, we recruited a larger sample in order to have sufficient power (80%) to detect at least a moderately sized correlation ($r$=.30) with an alpha of .05 (two tailed; target $N$ at least 84). Eighty-eight participants (11 Males, $M_{age}$=23.06, $SD_{age}$=6.52, *Range*=17–49) provided complete datasets for both the visual search and the age categorization tasks. Some of these participants were over the age of 31 and thus outside the age range represented in the stimuli; however, as Experiment 3 was concerned with the relationship between visual search and categorization, these participants were retained. Their inclusion did not change the significance or direction of the reported results.

**Stimuli and procedures.** Experiment 3 proceeded in a similar manner to Experiment 2 apart from a few differences listed here. The experiment took place in a small computer laboratory with four testing terminals. Each participant was seated in front of a 24in LED monitor with a screen resolution of 1920×1080 pixels and a refresh rate of 120Hz. Experiment 3 used the same stimuli and experimental programming as Experiment 2; however, the programming had to be adapted for the different screen size, aspect ratio, and resolution. To retain image quality we did not enlarge the stimuli from Experiment 2 for the larger monitor size and resolution meaning that each image and the search array took up a smaller area on the screen in Experiment 3 than Experiment 2. The images always appeared in one of nine fixed locations centered on the middle of the screen.

In addition to the visual search task, participants completed an age categorization task. In this task, participants were presented with the faces used in the visual search task. They were asked to categorize each face as ‘old’ or ‘young’ as quickly and accurately as possible. On each trial, a black fixation cross was presented in the center of the screen on a grey background for 1000ms. This was replaced by one of the stimulus faces which remained on the screen until a response was made. If no response was made within 3000ms a new trial commenced. Participants categorized the age of each face by pressing the right and left shift keys with response mapping counterbalanced across participants. Each of the 18 faces was presented eight times in a randomized order resulting in 144 trials. Participants completed the visual search task and the categorization task in a counterbalanced order.

**Data preparation and analysis.** All data were processed as described above and analyses of visual search data were as above. Average response times for categorizing faces by age were analyzed with paired samples t-tests. Finally, to determine whether the own-age detection advantage could be accounted for by faster categorization and rejection of other-age background faces, difference scores were calculated. The other-age categorization advantage score was created by subtracting categorization times for older adult faces from young adult faces. The Other-age background search advantage score and the own-age detection advantage score were created by subtracting the mean search time through older adult backgrounds/detecting young adult targets from the mean time searching through young adult backgrounds/detecting older adult targets on target absent and target present trials respectively. The relationship between categorization and search performance was quantified with Pearson's correlations. Data from four participants were excluded as over 40% of their responses in the visual search task were incorrect or invalid.[1]

## Results

**Visual search task.** As can be seen in Figure 4, participants were faster to respond on target present than on target absent trials, $F(1,82)=283.71$, $p<.001$, $\eta_p^2=.78$, 90% CI[.70–.82]. Overall, they were no faster to search through older adult or young adult backgrounds, $F(1,82)=1.64$, $p=.204$, $\eta_p^2=.02$, 90% CI[.00–.09]; however, a significant Trial type × Background age interaction emerged, $F(1,82)=7.39$, $p=.008$, $\eta_p^2=.08$, 90% CI[.01–.19]. Participants were faster to search through older adult backgrounds than young adult backgrounds on target absent trials, $t(82)=2.10$, $p=.039$, $d_z=0.23$, 95% CI[0.01–0.45], $M_D=66.22$ms. On target present trials, however, participants were no faster to detect young adult or older adult targets, $t(82)=0.68$, $p=.495$, $d_z=0.07$, 95% CI[-0.14–0.29], $M_D=-12.09$ms.

[1] Initially, task order was included as a factor in analysis to determine whether it affected performance. Task order did not influence visual search performance, all $F$s<0.47, $p$s>.495, $\eta_p^2<.01$, 90% CI[.00-.06], but influenced performance on the age categorization task, $F(1,81)=11.31$, $p=.001$, $\eta_p^2=.12$, 90% CI[.03-.24]. The other-age categorization advantage was significant for participants who completed the categorization task first, $t(38)=6.42$, $p<.001$, $d_z=1.03$, 95% CI[0.64–1.42], $M_D=43.89$ms, but not for those who completed it second, $t(43)=1.91$, $p=.060$, $d_z=0.28$, 95% CI[-0.02–0.58], $M_D=12.30$ms. Task order did not influence the direction or magnitude of the correlations between search and categorization performance, zs<0.31, $p$s>.379.

**Categorization task.** Participants were significantly faster to categorize older adult (*M*=564.43, *SD*=101.38) than young adult faces (*M*=591.58, *SD*=104.52) by their age, $t(82)=5.46$, $p<.001$, $d_z=0.59$, 95% CI[0.36–0.83], $M_D=27.15$ms.

**Relationship between visual search and categorization performance.** There was a significant positive correlation between the magnitude of the other-age categorization advantage and the other-age background search advantage on target absent trials, $r(81)=.23$, $p=.035$, 95% CI[.02-.43]. The larger the other-age categorization advantage, the faster participants were to search through other-age backgrounds than own-age backgrounds on target absent trials. The correlation between the other-age categorization advantage and the own-age detection advantage on target present trials was not significant, $r(81)=.13$, $p=.238$, 95% CI[-.09-.34].

**Discussion**

The aim of Experiment 3 was to determine whether the own-age detection advantage observed in Experiments 1 and 2 and in previous research (Macchi Cassia et al., 2015) could be explained by faster categorization and rejection of other-age distractors rather than faster attentional capture by own-age targets. As in Experiments 1 and 2, there was some evidence for faster search through other-age than own-age backgrounds; however, there was no evidence for an own-age detection advantage on target present trials. Also consistent with past research (Craig & Lipp, 2017; Johnston et al., 1997), participants were faster to categorize other-age than own-age faces. The size of the other-age categorization advantage was positively correlated with the size of the other-age background search advantage on target absent trials, but not on target present trials. Finding a significant relationship between categorization and search performance on target absent but not target present trials may be because the own-age detection advantage observed on target present trials is not driven by faster rejection of other-age backgrounds. Alternatively, this correlation may not have emerged as, on average, participants were no faster to detect own-age targets in Experiment 3.

It is possible that the own-age detection advantage was absent in Experiment 3 because of methodological changes made between Experiments 2 and 3 to adapt the protocol to a new laboratory set up. Adapting the experiment from one laboratory to the next while maintaining the quality of the images meant that the search arrays in Experiment 3 occupied a smaller portion of the visual field than in Experiments 1 and 2. As the search arrays in Experiments 1 and 2 occupied a larger proportion of the visual field, participants may have had to move their head/eyes more to scan the search array and could only process one or a couple of images at a time around their point of fixation. In Experiment 3, participants may have been able to glean an impression of the majority of the search array with a single fixation so they may have engaged in different scanning strategies. These findings suggest that the own-age detection advantage observed in Experiments 1 and 2 may require that the search array occupies a larger proportion of the visual field. To try and reproduce an own-age detection advantage in the new laboratory, images were edited to be larger in order to more closely match the conditions of Experiments 1 and 2. A completely new set of faces was adopted as the same young adult faces were used in Experiments 1-3 raising the possibility that the visual properties of one or some of the young adult faces could be driving the own-age detection advantage observed.

## Experiment 4

It was predicted that participants would be faster to detect own-age targets and search through other-age backgrounds. It was also predicted that participants would be faster to categorize other-age than own-age faces. Finally, it was predicted that the relatively faster detection of own-age faces/search through other-age backgrounds would be related to relatively faster categorization of other-age than own-age faces.

### Method

**Participants.** Participants were 92 undergraduate student volunteers (17 Males, $M_{age}$=22.67, $SD_{age}$=7.79, *Range*=17-59) who received partial course credit in return for participating in the experiment.

**Stimuli.** A new set of young adult and older adult faces was used in this experiment. Nine young adult and nine older adult faces with neutral expressions that were not used in Experiments 1-3 were taken from the FACES database (Ebner et al., 2010). These faces were edited in the manner described above and resized to be placed on a grey background 238×238 pixels in size to more closely replicate the viewing conditions of Experiments 1 and 2 with the new larger monitor size and resolution.

**Procedures and data analysis.** Experiment 4 proceeded in a similar manner to Experiment 3 apart from the following changes. Participants were seated in individual enclosable cubicles in front of a 24in monitor with a screen resolution of 1920×1080 pixels and a refresh rate of 60Hz. The images from Experiment 3 were replaced with the new stimulus set. As the images were larger, the search array took up a larger portion of the screen than in Experiment 3. The data were processed in the manner described in Experiment 3. Data from two participants were not included in analysis as more than 40% of their responses were incorrect or missing in either the visual search or the categorization task[2].

**Results**

**Visual search task.** Despite the use of a completely new set of stimuli, participants were significantly faster to search through older adult backgrounds and detect young adult targets than vice versa, $F(1,89)=75.70$, $p<.001$, $\eta_p^2=.46$, 90% CI[.33–.55]. Participants were also faster to respond on target present than on target absent trials, $F(1,89)=161.76$, $p<.001$, $\eta_p^2=.65$, 90% CI[.54–.71]. These differences were moderated by a significant Background age × Trial type interaction, $F(1,89)=25.80$, $p<.001$, $\eta_p^2=.23$, 90% CI[.11–.34]. Participants were faster to search

[2] Task order did not moderate performance on the age categorization task, $F(1,88)=2.52$, $p=.116$, $\eta_p^2=.03$, 90% CIs [.00–.10]. There was, however, a significant influence of task order on visual search performance. A significant Background age × Task order interaction, $F(1,88)=5.68$, $p=.019$, $\eta_p^2=.06$, 90% CIs [.01–.15], was further moderated by a significant Trial type × Background age × Task order interaction, $F(1,88)=4.88$, $p=.030$, $\eta_p^2=.05$, 90% CIs [.00–.14]. Participants were faster to detect young adult targets and search through older adult backgrounds regardless of task order, all *t*s>2.92, *p*s<.005, $d_z$s>0.40, $M_D$S>43.99, 95% CIs [0.10–1.45]. This interaction emerged as the other-age background search advantage was larger for participants who completed the search task first than for participants who completed it second on target absent trials, $t(88)=2.76$, $p=.007$, $d_z=0.58$, 95% CI [0.15–1.01] but not on target present trials, $t(88)=0.59$, $p=.557$, $d_z=0.12$, 95% CI[-0.30–0.54]. Task order did not significant influence the direction or magnitude of the correlations between search and categorization performance, *z*s<1.09, *p*s>.279.

through older adult backgrounds on target absent trials, $t(89)=8.37$, $p<.001$, $d_z=0.88$, 95% CI[0.63–1.12], $M_D=138.46$ms, and faster to detect young adult targets on target present trials, $t(89)=4.69$, $p<.001$, $d_z=0.49$, 95% CI[0.27–0.71], $M_D=49.86$ms; however, this search advantage was larger on target absent trials (See Figure 5).

**Categorization task.** Participants were significantly faster to categorize older adult ($M=517.96$, $SD=75.41$) than young adult faces ($M=533.79$, $SD=89.15$) by their age, $t(89)=4.22$, $p<.001$, $d_z=0.44$, 95% CI[0.22–0.66], $M_D=15.83$ms.

**Relationship between visual search and categorization performance.** Similar to Experiment 3, there was a marginal positive relationship between the magnitude of the other-age categorization advantage and the other-age background search advantage on target absent trials, $r(88)=.19$, $p=.075$, 95% CI[-.02–.38]. Also in line with Experiment 3, although a significant own-age detection advantage was observed in the visual search task, the magnitude of this detection advantage was not significantly related to the other-age categorization advantage, $r(88)=.03$, $p=.813$, 95% CI[-.18–.24], (See Figure 6 for a combined scatterplot from Experiments 3 and 4).

**Discussion**

The aim of Experiment 4 was to investigate the relationship between performance on visual search and categorization tasks to provide indication of whether the own-age detection advantage observed in previous studies reflected faster rejection of other-age background faces. Consistent with previous experiments there was a significant own-age detection advantage and a significant other-age categorization advantage. Despite the own-age detection advantage being significant in the current experiment, its magnitude was not related to the other-age categorization advantage. However, as in Experiment 3, there was some evidence that search performance on target absent trials was related to performance on the categorization task.

## Combined Analyses

As there were some discrepancies across studies we conducted fixed effects mini meta-analyses for each effect of interest using the Metafor package 2.0-0 (Viechtbauer, 2010) in R 3.4.3

(R Core Team, 2017). This was done to more closely estimate the size and likelihood of each effect across studies taking advantage of a larger combined sample size. Data from all experiments ($N$=225) were included in the mini meta-analysis of visual search effects and data from Experiments 3 and 4 ($N$=173) were included in the mini meta-analysis of the categorization effect and the correlations between categorization and search performance.

**Visual Search and Categorization Advantages**

Despite some discrepancies across studies, the own-age detection advantage was highly significant, mean weighted $d_z$=0.27, 95% CI[0.13–0.41], $SE$=0.07, $z$=3.82, $p$<.001, as was the advantage for searching through other-age backgrounds, mean weighted $d_z$=0.47, 95% CI[0.33–0.61], $SE$=0.07, $z$=6.59, $p$<.001. Similarly, the other-age categorization advantage was highly significant, mean weighted $d_z$=0.51, 95% CI[0.35–0.67], $SE$=0.08, $z$=6.32, $p$<.001.

**Relationship between Categorization and Visual Search**

There was evidence of a significant relationship between the magnitude of the other-age categorization advantage and the other-age search advantage on target absent trials, mean weighted $r$=0.21, 95% CI[.06–.35], $SE$=0.07, $z$=2.87, $p$=.004, but not on target present trials, mean weighted $r$=0.08, 95% CI[-.07–.23], $SE$=0.08, $z$=1.04, $p$=.299. This finding suggests that the larger the other-age categorization advantage, the faster participants were to search through other-age relative to own-age backgrounds on target absent trials but not on target present trials.

As a non-significant effect does not provide evidence for the absence of an effect, we conducted a supplementary Bayesian linear regression analysis using JASP software (Love et al., 2015; Morey & Rouder, 2015; Rouder, Morey, Speckman, & Province, 2012). This method of analysis produces Bayes Factors (BFs) which can be interpreted as a likelihood of the alternate hypothesis (a significant relationship between the two variables exists) over the null hypothesis (no significant relationship between the two variables exists) given the observed data. Although the Bayesian approach does not recommend the use of cutoffs in interpreting BFs, labelling conventions have been proposed (e.g., Jeffreys, 1961; Wetzels & Wagenmakers, 2013). A BF between 1 and 3 is considered anecdotal evidence and between 3 and 10 is considered substantial evidence for the alternate over the null model. A BF between 0.33 and 1 is considered anecdotal evidence, and between 0.33 and 0.10 is considered substantial evidence for the null over the alternate model. The results of the Bayesian analysis indicated anecdotal evidence for the presence of a relationship between categorization and visual search performance on target absent trials. The presence of a relationship was around 3 times more likely than the absence of a relationship, $BF_{10}$=2.98. There was substantial evidence against the presence of a relationship between categorization and visual search performance on target present trials as the absence of a relationship was almost five times more likely than the presence of a relationship, $BF_{10}$=0.22.

## General Discussion

The current study had two main aims. Firstly, to determine whether the previously reported own-age detection advantage would be observed for different other-age groups and secondly to investigate whether the own-age detection advantage could be explained by faster processing of other-age background faces rather than attentional capture by own-age targets. These two aims are discussed separately below.

### Own-Age Detection Advantage

As predicted, young adult participants were faster to detect young adult targets in backgrounds of early adolescent faces and older adult faces. They were also faster to search through early adolescent and older adult backgrounds. The own-age detection advantage held for both younger and older other-age faces and across different stimulus sets derived from different face databases. This suggests that the search advantage is independent of the other-age group used as a reference and of the unique characteristics of the faces used in a particular experiment; however, this remains to be confirmed by showing a detection advantage for young adult faces in a young adult sample and for older adult faces in an older adult sample using the same stimuli and procedures.

Finding an own-age detection advantage is consistent with the findings of Macchi Cassia et al. (2015), and finding an own-age detection advantage in reference to older and younger other-age faces is consistent with previous studies investigating different age-related face processing biases. For example, an other-age categorization advantage has been observed in young adult participants categorizing young adult and older adult faces (Craig & Lipp, 2017) or child faces (Johnston et al., 1997). Similarly, an own-age recognition advantage has been observed in young adult participants recognizing older adult faces (Anastasi & Rhodes, 2006) and child faces (Hills & Lewis, 2011).

Finding both an own-age detection advantage and an other-age categorization advantage is also broadly consistent with findings from the literature investigating processing of another social category, race. Similar to the other-age categorization advantage, an other-race categorization advantage has been observed across a range of different racial outgroups (Ge et al., 2009; Levin, 1996, 2000). Similar to the own-age detection advantage, an own-race detection advantage has been observed with Caucasian participants searching for Caucasian faces in heterogeneous backgrounds of Chinese and African American faces (Lipp et al., 2009; though, see Levin, 1996, 2000, and Lipp et al., 2009 for evidence of an other-race detection advantage when searching through homogenous search backgrounds composed of the same face presented repeatedly).

Although the own-age detection advantage and the other-age categorization advantage are consistent with some previous studies, they are inconsistent with studies that have found an attentional bias for other-age faces, like the attentional bias towards infant faces (Brosch et al., 2007; Thompson-Booth et al., 2014) or the accuracy advantage for detecting older adult faces observed by Neumann et al. (2015). At this point, it is unclear why some studies produce evidence for an attentional bias towards own-age faces and others an attentional bias towards other-age faces. One possibility is that infant faces are a special class of stimuli that attract or hold attention through an evolved mechanism to promote infant survival (Lorenz, 1943). This would explain why young adult participants were faster to respond to probes that were preceded by an infant face than a young adult face in the dot probe paradigm (Brosch et al., 2007; Hodsoll et al., 2010); however, this explanation cannot account for the absence of a detection advantage for infant faces in a visual search experiment using infant and young adult faces as targets and distractors (Macchi Cassia et al., 2015). Also, it cannot explain the finding that young adult participants more accurately detected older adult than young adult targets (Neumann et al., 2015).

Another possibility is that differences in the methods adopted to look at attentional biases influenced whether an own-age or other-age detection advantage was observed. As mentioned above, the methods adopted in the current study, those used by Macchi Cassia et al. (2015), and those used by Neumann and colleagues (2015) differed in a number of ways. In particular, in the current study and in the study by Macchi Cassia et al., search arrays were presented until a response was made, whereas they were presented for a limited duration of 200ms by Neumann and colleagues. This may have led participants to adopt different strategies to perform the search task. When participants had limited time to process each face, they may have relied more on particular features or textural information in the images (e.g., skin wrinkling) to perform the task which may have allowed more accurate detection of older adult singletons than young adult singletons under conditions of limited visual input. This is just one possible explanation. As the methods adopted by Neumann et al., Macchi Cassia et al., and the current study differed in several ways, further research is required to determine which methodological differences led to the observation of different age-related search biases.

**Relationship between Visual Search and Categorization**

The second aim of the current study was to investigate whether the own-age detection advantage could be accounted for by faster categorization and rejection of other-age backgrounds rather than capture by own-age targets. As one way to investigate this, we looked at the relationship between detection advantages observed in visual search and the magnitude of the other-age categorization advantage (e.g., Craig & Lipp, 2017; Johnston et al., 1997). Across two experiments, relatively faster categorization of other-age faces was related to relatively faster search through other-age backgrounds on target absent, but not target present trials. One possibility to explain the absence of a relationship between categorization and visual search on target present trials is that differences in the processing of different types of backgrounds do not contribute to the own-age detection advantage.

As set size was not varied, we could not calculate search slopes to provide evidence that target detection slowed with an increase in the number of background items. Despite this, the data suggest that processing of background faces was highly likely. Firstly, previous research suggests that pop-out search, where targets are detected without the need to process background items separately, is fast with the perceptual component requiring around 200ms and the motor response occurring around 500ms (Olds, Cowan, & Jolicoer, 2000). With target detection times over 1500ms in Experiments 1, 2, and 3, and at around 1000ms in Experiment 4, pop-out of targets seems unlikely. Further, we analysed average target detection time at each target position (excluding the centre [location of fixation]) in Experiments 3 and 4 where sample sizes provided ample power to do so. These analyses indicated that target detection times differed across locations, $F(7,574)=6.71$, $p<.001$, $\eta_p^2=.08$, (Experiment 3), and $F(7,623)=7.51$, $p<.001$, $\eta_p^2=.08$ (Experiment 4). This suggests that participants' attention was not automatically captured by the target but that participants tended to search through the backgrounds systematically. Although there are a number of reasons why pop-out search was unlikely in the current investigation, varying search array size to assess search efficiency rather than search speed may serve to clarify the process/es underlying the own-age detection advantage. Given the additional information that can be gleaned from varying search array size, it is recommended for future research.

As it is likely that background faces were processed to some extent on target present trials, the failure to find a relationship between categorization and search on target present trials may be due to response times on target present and target absent trials reflecting different processes. To determine that there was no target on target absent trials, the participant had to process each of the nine faces to determine that they were all the same age on every trial. On target present trials, search could be terminated as soon as two faces differed in age. On some trials, participants may have only needed to look at two faces before search was terminated. As such there may have been a variable role of background processing with little influence when the target was fixated early, but a larger influence when it was fixated later. As such, condition means on target present trials would reflect background processing to a lesser extent than on target absent trials. This may have limited the magnitude of the relationship between search and categorization performance on target present relative to target absent trials even though faster processing of other-age faces could have contributed to the own-age detection advantage.

Further, although difference scores have been used successfully to examine relationships between person perception processes (e.g., Ge et al., 2009), using difference scores could have limited our ability to detect a relationship between categorization and search performance. This is because the reliability of a difference score depends on the reliability of the initial scores as well as the correlation between these scores (e.g., see Trafimow, 2015). The reliability of the difference scores matters because the magnitude of a correlation is limited by the reliability of the measures being correlated. When the reliability of the individual scores is good and the correlation between the individual scores is low, the difference scores themselves can have good reliability (Trafimow, 2015). In the current study, the estimated reliability of the initial scores used to calculate the difference scores was good to excellent (αs range from .88-.97); however, the correlation between scores was also high (*r*s range from .89-.92). As a result, the reliability of the difference scores was at times acceptable (>.70 for search through target absent trials in Experiment 3), but at other times unacceptable (<.50; for search on target present trials in both Experiments 3 and 4). Acceptable reliability of the difference scores calculated from target absent trials but unacceptable reliability of difference scores calculated from target present trials could explain why a correlation between categorization and search performance was observed on target absent but not on target present trials.

**Implications for Future Research**

Although difference scores can be reliable under some circumstances, at this point, the possibility that the own-age detection advantage is at least partly driven by processing of other-age background faces cannot be clearly confirmed nor ruled out. The findings of the current study highlight the need to further examine the source/s of the own-age detection advantage using a different methodological approach. For example, eye-tracking technology may be applied to determine whether own-age targets are detected with fewer fixations or whether less time is spent fixating on other-age distractors to distinguish between these accounts.

Future research may also investigate why these age related categorization and search biases occur. The current study cannot speak to whether the own-age detection advantage is due to differences in perceptual expertise, differences in motivation to process own-age vs. other-age faces, differences in implicit evaluations, a combination of these, or something else (Hugenberg et al., 2010; Macchi Cassia et al., 2015; Tanaka, Kiefer, Bukach, 2004; Young & Hugenberg, 2012). As the current study used only young adults as participants and we did not take any measures of identity, motivation, liking, or contact with other-age groups, we could not determine what caused the biases. At this point, the own-age bias could be explained by either perceptual expertise or socio-cognitive processes or both.

In line with the perceptual expertise explanation, Hershler and Hochstein (2009) found a search advantage for objects of greater perceptual expertise. In this study, bird experts and car experts were faster to detect bird and car targets respectively in arrays of objects. Assuming our young adult participants have greater experience processing young adult faces, the finding of an own-age detection advantage is consistent with a detection advantage for objects of greater expertise. Macchi Cassia et al. (2015) also proposed that experience drives this effect, as participants with little experience interacting with children showed the bias but preschool teachers with greater experience did not. Given the quasi-experimental nature of their experiment there were potentially other differences between the groups such as differences in motivation or liking of infants/children which may have contributed to the bias.

Finding age processing biases that resemble race processing biases and finding a relationship between visual search and categorization performance is also consistent with socio-cognitive accounts. They propose that when a face is first encountered, social categorization occurs and this categorization determines the extent to which the face is subsequently processed. Cues indicating ingroup membership or social relevance lead the observer to pay greater attention to the face and process it more deeply (see e.g., Brewer, 1988; Levin, 2000; Hugenberg et al., 2010). In line with this, the own-age detection advantage may reflect quicker and less detailed processing of each of the other-age faces in the background. If these models are accurate, then the own-age detection advantage should generalize to participants of other-age groups to the extent that they perceive the faces as own- or other-age group members. Future research may examine the own-age bias in other-age groups to determine whether effects generalize beyond young adult participants.

The current findings highlight a limitation of some types of visual search designs in understanding attentional capture. As discussed above, when other-age faces act as the background for own-age targets and own-age faces are used as the background for other-age targets, it is difficult to disambiguate whether a ‘detection advantage’ is a target capture effect, a background processing effect, or a combination of both. To address this, future studies may consider alternative designs where the set of faces comprising the background of the search arrays is held constant and only the age of the target faces is varied. This recommendation has been applied in studies investigating visual search for targets defined by emotional expression. In these studies, participants search through a set of neutral faces for either happy or angry targets (Becker, Anderson, Mortensen, Neufeld, & Neel, 2011; Frischen, Eastwood & Smilek, 2008; Savage, Lipp, Craig, Becker, & Horstmann, 2013). In the context of search for own- and other-age faces, participants may search through a constant set of middle aged faces for young adult and older adult targets. Using this method, the background is fixed and differences in target detection times more closely reflect the allocation of attention to the target face rather than differences in background processing (Becker et al., 2011; Frischen et al., 2008).

Finally, it was interesting to note that no own-age detection advantage was observed in Experiment 3 when the search array occupied a smaller portion of the visual field than in the other experiments. This may suggest a boundary condition to the own-age detection advantage. Perhaps participants adopted slightly different scanning strategies when scanning smaller or larger arrays. Future research could more systematically vary image size/search array size to investigate how these factors influence the own-age detection advantage and also use techniques like eye-tracking to better understand why these differences may arise.

## Conclusion

The current study confirms the own-age detection advantage in young adult participants relative to two other-age groups, early adolescents and older adults, in a search paradigm different to those used previously. In addition, the study provided evidence that the processes underlying the other-age categorization advantage and visual search for other-age faces are related. This relationship was significant for target absent trials, but not for target present trials, and more research is required to investigate this relationship further. Overall, the current results suggest some contribution of background face processing to the own-age detection advantage (and are inconsistent with the view that other-age targets pop-out in visual search).

*Figure 1*. Examples of faces used across experiments - Early adolescent (left), young adult (middle), and older adult (right).

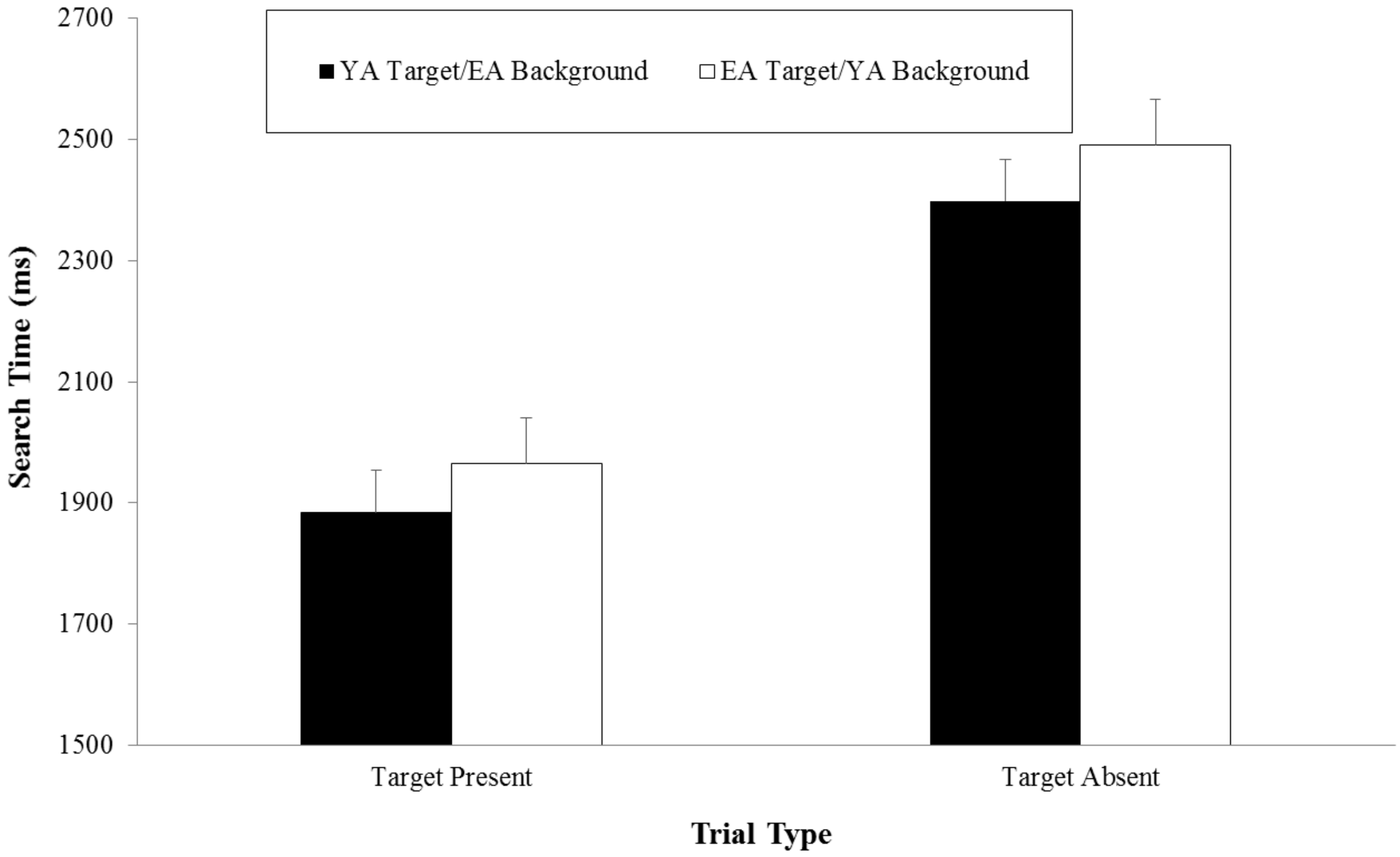


*Figure 2*. Search times for detecting the presence or absence of young adult (YA) targets in backgrounds of early adolescent (EA) faces or early adolescent targets in young adult backgrounds in Experiment 1. Error bars represent one SEM.

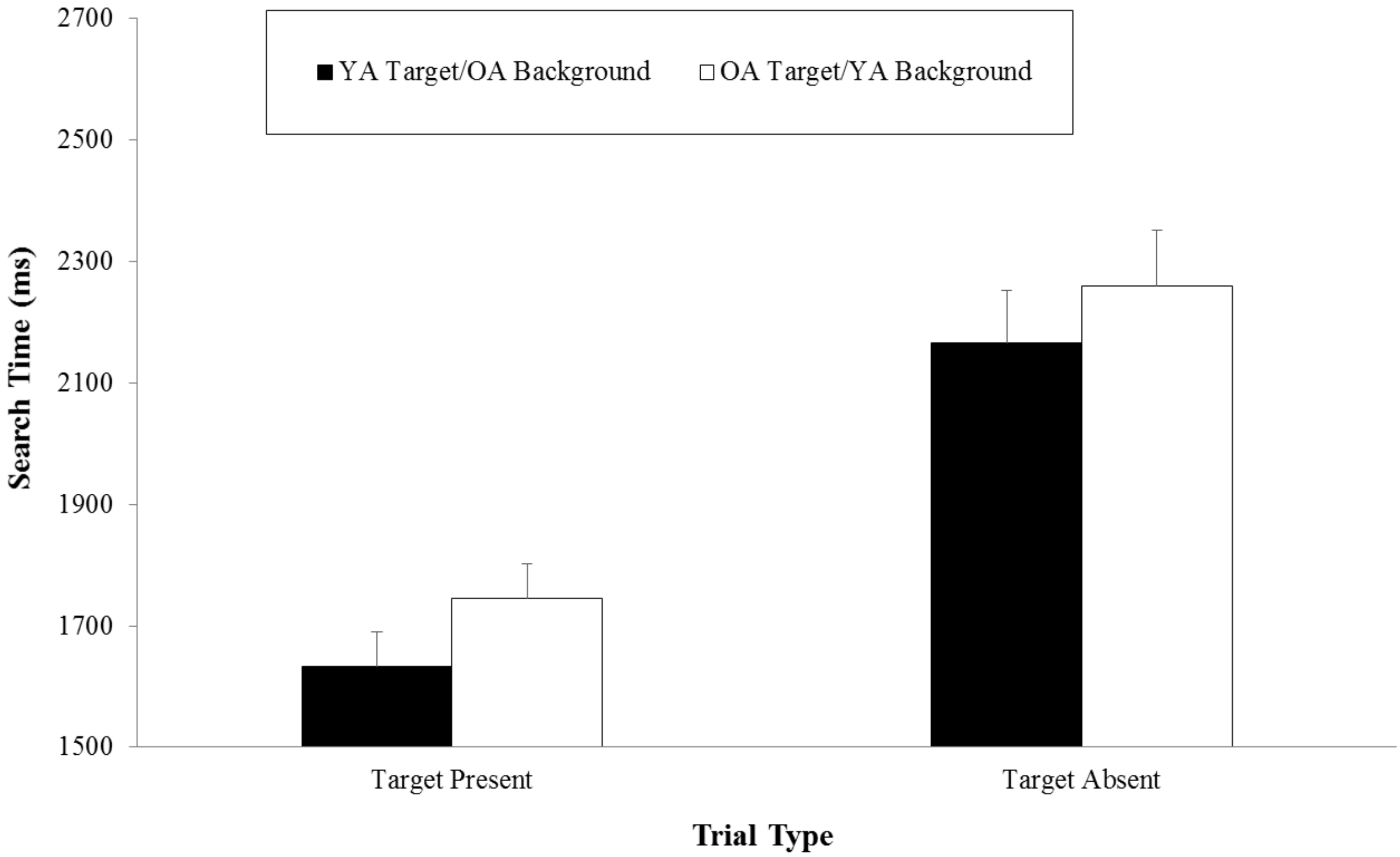


*Figure 3*. Search times for detecting the presence or absence of young adult (YA) targets in backgrounds of older adult (OA) faces or older adult targets in young adult backgrounds in Experiment 2. Error bars represent one SEM.

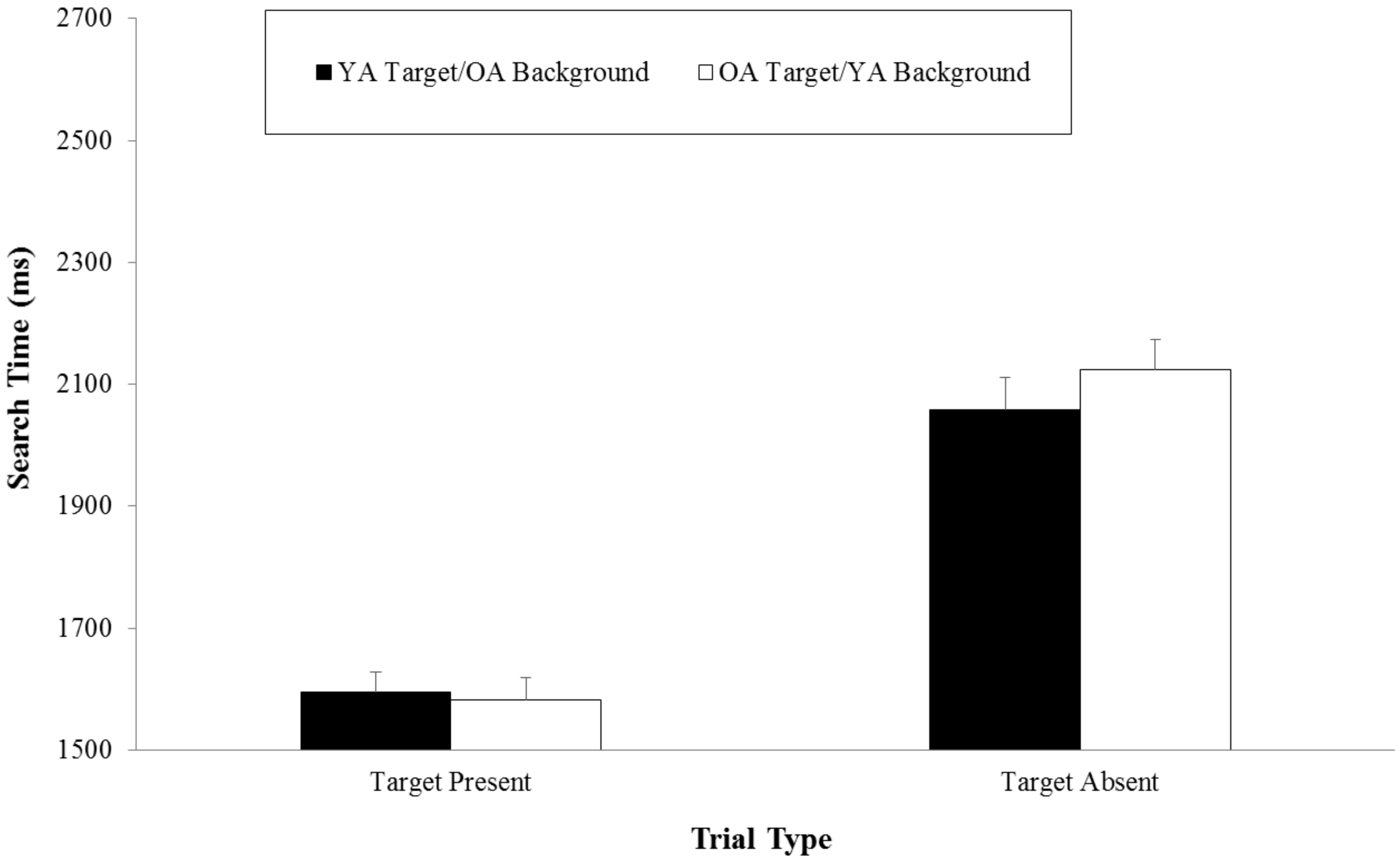


*Figure 4*. Search times for detecting the presence or absence of young adult (YA) targets in backgrounds of older adult (OA) faces or older adult targets in young adult backgrounds in Experiment 3. Error bars represent one SEM.

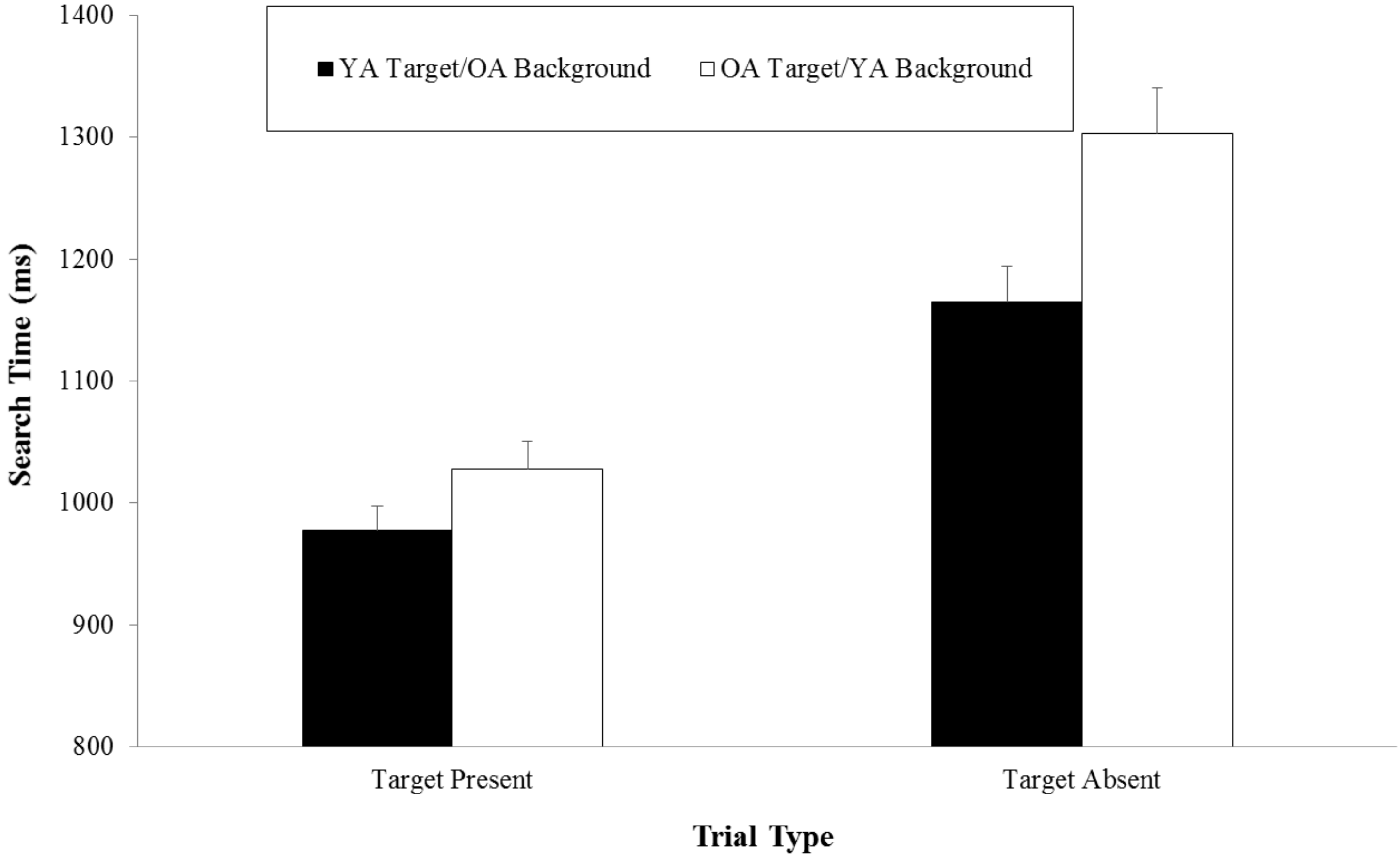


*Figure 5*. Search times for detecting the presence or absence of young adult (YA) targets in backgrounds of older adult (OA) faces or older adult targets in young adult backgrounds in Experiment 4. Error bars represent one SEM.

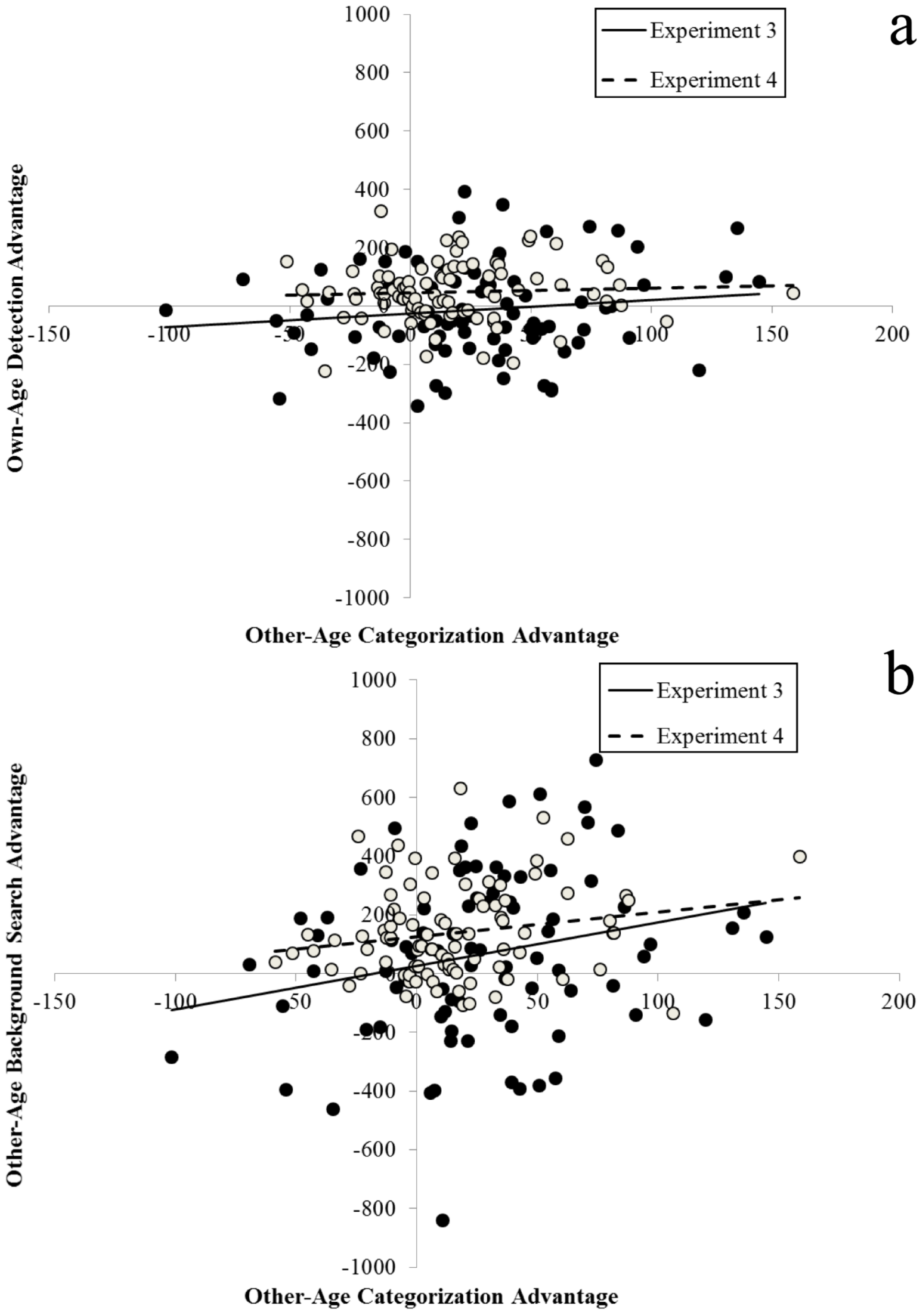


*Figure 6.* Scatter plots depict the relationship between the magnitude of the other-age categorization advantage and the magnitude of the own-age detection advantage/other-age background search advantage on target present trials (a) and target absent trials (b). Closed circles denote participants from Experiment 3 and open circles are participants from Experiment 4

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