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Self-bias modulates saccadic control

A. Yankouskaya, D. Palmer, Stolte, M., J. Sui, G.W. Humphreys

Department of Experimental Psychology University of Oxford

Alla Yankouskaya, PhD
Cognitive Neuropsychology Centre
Department of Experimental Psychology
University of Oxford
9, South Parks Road,
OX1 3UD
UK
alla.yankouskaya@psy.ox.ac.uk

Diahann Palmer, MD,
Cognitive Neuropsychology Centre
Department of Experimental Psychology
University of Oxford
9, South Parks Road,
OX1 3UD
UK
diahann.palmer@psy.ox.ac.uk

Moritz Stolte, PhD
Cognitive Neuropsychology Centre
Department of Experimental Psychology
University of Oxford
9, South Parks Road,
OX1 3UD
UK
moritz.stolte@psy.ox.ac.uk

Jie Sui, PhD
Cognitive Neuropsychology Centre
Department of Experimental Psychology
University of Oxford
9, South Parks Road,
OX1 3UD
UK
jie.sui@psy.ox.ac.uk

G.W. Humphreys, Professor
Cognitive Neuropsychology Centre
Department of Experimental Psychology
University of Oxford
9, South Parks Road,
OX1 3UD
UK

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Abstract

We present novel data on the role of attention in eliciting enhanced processing of stimuli associated with self. Participants were required to make pro- or anti-saccades according to whether learned shape-label pairings matched or mismatched. When stimuli matched participants were required to make an anti-saccade and when the stimuli mismatched a pro-saccade was required. We found that anti-saccades were difficult to make to stimuli associated with self when compared to stimuli associated with a friend and a stranger. In contrast, anti-saccades to friend-stimuli were easier to make than anti-saccades to stranger-stimuli. In addition, a correct anti-saccade to a self-associated stimulus disrupted subsequent pro-saccade trials, relative to when the preceding anti-saccade was made to other stimuli. The data indicate that self-associated stimuli provide a strong cue for explicit shifts of attention to them, and that correct anti-saccades to such stimuli demand high levels of inhibition (which carries over to subsequent pro-saccade trials). The self exerts an automatic draw on attention.

Introduction

It is known that human cognition is strongly modulated by self-bias. Information encoded in relation to the self tends to be better remembered and recollected than other information (Turk, Cunningham, & Macrae, 2008); people respond faster to their own faces rather than to those of others (Ma & Han, 2010; Theeuwes, Van der Stigchel, & Olivers, 2006); responses to their own objects are faster and more accurate compared to responses to objects owned by others (Turk, van Bussel, Waiter, & Macrae, 2011). Recently, the effects of self-biases have been found even in simple perceptual tasks (Sui, He, & Humphreys, 2012; Sui, Sun, Peng, & Humphreys, 2014). Specifically, in a task where participants associate simple geometric shapes with personal labels (you, friend, or stranger) and then immediately judge whether subsequent label–shape pairings matched, there are faster responses and higher perceptual sensitivity to self-associations compared with other-associations (Sui et al., 2012). Previous research provides strong evidence that the effects of self: (i) are stable over time (Stolte, Yankouskaya, Humphreys, & Sui, 2015); (ii) mimic behavioural and neural responses generated by stimuli with high perceptual saliency (Sui, Liu, Mevorach, & Humphreys, 2013); (iii) are automatic and not easily overruled even if participants set an expectation for another stimulus (friend or stranger) on the trial (Sui, et al., 2014); (iv) alter perceptual processing even when the shape is subsequently presented without the label (Sui, Yankouskaya, & Humphreys, 2015)

Although the effect of self-prioritization in perceptual matching is robust, it remains unknown where the effect comes from. Recent studies have shown that the self-prioritization effect may reflect attentional biases to self-related stimuli (Alexopoulos, Muller, Ric, & Marendaz, 2012; Bredart, Delchambre, & Laureys, 2006). The results in behavioural studies are also supported by neuroimaging work demonstrating that self-associated stimuli as distractors elicit increased activation over the attentional neural

network (Sui, Liu, et al., 2015). There is also evidence of self-related attentional biases from ERP studies. For example, researchers have reported that when an item is cued as being relevant to the self, the amplitude of P300 component was increased compared to an other-relevant cue, indicating an enhanced attentional processing to the item. This has been attributed to self-related stimuli narrowing the range of spatial attention, indexed by reduction of the amplitude of the occipital P1 component elicited by task-irrelevant probes when participants responded to self-relevant objects (Turk, van Bussel, Brebner, et al., 2011).

However, a number of other studies provide contradictory evidence (Devue, Laloyaux, Feyers, Theeuwes, & Bredart, 2009; Devue, Van der Stigchel, Bredart, & Theeuwes, 2009; Gronau, Cohen, & Ben-Shakhar, 2003; Kawahara & Yamada, 2004). For example, Devue et al. (2006) measured eye-tracking movements in visual search for self-faces among other faces and suggested that the self-prioritization effect reflects a difficulty in disengaging attention from highly familiar faces, rather than differential attentional engagement. Bundesen et al. (1997) reported that presenting the participant's own name as a distractor did not cause more interference than other names, but participants were more accurate in reporting their own name presented as targets. These authors suggested that the advantage for the participant's own name as a target was not attentional, but rather reflected a better identification of the participant's own name compared with other names. Other researchers have argued that self-related stimuli capture attention only when they are presented within the participant's attentional focus (i.e., at fixation) and when the stimuli are task-relevant (Gronau et al., 2003; Kawahara & Yamada, 2004). Notably visual search tasks typically use complex stimuli (e.g., faces) which may involve several stages of information processing, and hence these studies do not rule out the possibility that self-related stimuli can capture attention with simple displays.

In the present study we assessed whether stimuli associated with the self can capture attention with simple displays using a measure of explicit attention based on eye tracking. To do this we had participants carry out a perceptual matching task similar to that previously used to elicit self-bias (Sui, Liu, et al., 2009; Sui et al., 2012), but required eye movements to be made to signal the response. Participants first associated three different shapes (e.g., circle, triangle, square) with three labels (letters represented You, Friend, Stranger). By having people associate the shapes with social labels, the neutral geometric shapes are ‘tagged’ with social relevance (Sui et al., 2012). This procedure allows us study how basic perceptual processing for that shape changes when compared with other matched shapes (e.g., Sui, et al., 2014). They then saw displays in which the label appeared at fixation and the shape was presented at a peripheral location in either left or right visual field. If the label and the shape matched, the participants had to make an anti-saccade. If the label and shape mismatched, a pro-saccade had to be made. This task, which required voluntary control of attention, allows a precise assessment of the effects of self information on top-down cognitive control. Specifically, comparing the accuracy of eye-movements for conditions that involved competition between a reflexive saccadic response and the voluntary inhibition of the reflexive tendency (on anti-saccade trials) enabled us to test: (i) whether it is more difficult to make an anti-saccade to self-related compared to other-related stimuli; (ii) what is the cost of voluntary attentional control for self compared to friend and stranger associations.

METHOD

Participants

Thirty four healthy participants (18 to 35 years, $M = 25.18$, $SD = 5.32$) were recruited for the study. Data from one participant were excluded from later analyses due to data lost for three out of five experimental blocks. The remaining sample of 33 participants (18

females) were right handed, had normal or corrected-to-normal vision and had no neurological history. This experiment was approved by Central University of Oxford Research Ethics Committee (CUREC). All participants provided informed consent.

Materials

The experiment comprised a 3 shapes x 3 labels x 2 conditions (matching, mismatching) design. The assignment of label and shape was balanced across participants following a Latin square. The letters Y, F and S were used to represent ‘you’, ‘friend’ and ‘stranger’ respectively and were paired with three out of four simple geometric shapes (a square, triangle, circle or diamond). Each display consisted of a dark grey background with a centrally presented white letter and a shape placed on the left or on the right from the letter at visual degrees of 6.8° . Both the letters and the shape were of 2.8° in size. Stimulus sets, randomized across participants, were consisted of pairings of three of the four geometric shapes with the letters Y, F and S.

The experiment was implemented and run in Matlab (32-bit version R2012a; The MathWorks, Natick, MA) Psychtoolbox and conducted with the Tobii TX300 eye tracker, running at 300 Hz on a 22-inch screen (51×32 degree of visual angle, 1920×1080 pixels, 100ppi). To minimize head movement and maintain the distance between eyes and the centre of monitor constant (60 cm), participants’ heads were secured in a chin-rest. The eye-tracking system was calibrated for each participant using a 9-point calibration scheme. Verification of each point calibration involved ensuring that fixation of the eye was within 2° of each calibration point. The calibration was repeated if a participant failed to fixate on less than seven out of nine points within the defined accuracy limit. Following the acceptance of the calibration, the task instructions appeared on screen.

Procedure

First, participants were asked to make associations between a shape and self

(represented by the letter Y¹), a shape and a close friend (represented by the letter F), and a shape and a complete stranger (represented by the letter S)². Based on previous studies showing that participants can rapidly gain associations between the shapes and labels just after an association instruction (Sui et al., 2012, 2014), we had participants perform 24 practice trials to reinforce associations between the letters and shapes trials where they indicated their responses ('match' or 'mismatch') by pressing buttons on a keyboard. After each trial they were provided with feedback on accuracy.

After the initial associations, participants were asked to make a saccadic response ('look at the shape presented') for mismatching pairings between a letter and a shape, and an anti-saccadic response ('look in the direction opposite the shape presented') for matching trials. The participants then performed eight practice trials followed by five blocks of 48 trials each (24 required anti-saccadic responses) yielding a total of 240 experimental trials. The experiment lasted around 1.2 hour.

Each trial started with a black fixation cross (1° of visual angle) which appeared for 500 ms in the centre of the screen which participants were instructed to focus on. If a participant was unable to focus on the fixation cross during this time, a display stimulus was not presented, the trial was recorded as a miss, and added to the end of the block. This criterion was set up to ensure that participants focused at the centre of the screen before the stimuli appeared in order to accurately and consistently record eye-movements. On valid trials, when the fixation cross disappeared, the stimulus pairs were presented for 800 ms followed by a 700ms blank screen before the start of the next trial (Figure 1). After each block participants were given a 5 min break.

¹ Our previous work showed that there were no significant differences in the magnitude of self-biases elicited by an association to a shape with a label 'you' or a label 'me' or 'myself'.

² For each participant we carefully checked whether the participant's initials might interfere with the labels. Two out of 34 participants' surnames started with the letter 'S', and one participants' first name started with the letter 'F'. We found no evidence for interference.

(Figure 1 about here)

We first flagged data (0.15% across all trials) where the eye tracker lost the eye data momentarily. The flagged data were replaced with last known good value. Blink (3.1%) and missed (0.42%) trials were identified and excluded from the analysis. Saccade onset was defined as the time point at which the eye moved 30° of visual angle or faster per second (with minimum amplitude of 1.5°). When eye velocity went down again below 30°/s, the time point immediately after this sample was regarded as the termination of the saccade. Saccadic landing positions was specified for pro-saccade as 2° window around a shape, for anti-saccade as 2° window around mirrored shape location. We excluded 2.2% of anti-saccade trials and 1.34 % of pro-saccade trials that were outside the landing positions.

The first saccade after target onset was considered the saccadic response. To exclude anticipatory responses, trials with latencies of saccadic responses less than 80 ms (2.13 % of valid saccadic trials) and greater than 500 ms (0%) were excluded from consequent analysis. Each trial was classified by the condition: stimulus type and saccade type (anti-saccade, pro-saccade). There were two measures for the pro-saccade and anti-saccade trials respectively: saccadic directional accuracy³ (whether the initial saccade moved in the correct direction) and saccade latency (the difference in time between the presentation of the stimulus to make an eye movement and the beginning of the initial saccade). An incorrect saccade direction was defined as the first saccade after a stimulus onset towards a shape (on anti-saccade trials), or away from the shape (on pro-saccade trials).

³ We emphasize here the term ‘saccadic directional accuracy’ to avoid confusion with saccadic accuracy that typically refers to the spatial error between intended and actual saccade landing point

RESULTS

Saccadic directional accuracy for anti- and pro-saccade trials

To examine the effect of the stimulus on saccadic directional accuracy in anti-saccade and pro-saccade trials, a two way repeated measures ANOVA was calculated with the factors being the saccade type (anti-saccade, pro-saccade) and stimulus (self, friend, stranger associations). There was a main effect of saccade type ($F(1,32)=18.56$, $p<0.001$, $\eta_p^2=.65$; 90% CI [0.47, 0.75]) indicating that saccadic directional accuracy on anti-saccade trials ($M=61.6$, $SD=4.3$) was lower than on pro-saccade trials ($M=75.9$, $SD=3.21$) (Figure 2). There was a main effect of stimulus ($F(2,64)=6.78$, $p=0.007$, $\eta_p^2=.34$; 90% CI [0.019, 0.43]) and an interaction of saccade type *stimulus ($F(2,64)=8.52$, $p=0.002$, $\eta_p^2=.42$, 90% CI [0 .023, 0.59]). Two separate ANOVAs were performed to test the interaction effect (Figure 2). The results show that there was a main effect of stimulus on anti-saccade ($F(2,64)=8.59$, $p=0.001$, $\eta_p^2=.39$; 90% CI [0.026, 0.48]); there was lower saccadic directional accuracy for self compared to friend ($t(32)=3.27$, $p=0.005$; $d_z = 0.56$; 95% CI for d_z [0.35, 0.67]), and for stranger compared to friend stimuli ($t(32)=3.5$, $p=0.004$; $d_z = 0.60$; 95% CI for d_z [0.49, 0.74]). No significant differences were found between anti-saccades for self and stranger although the trend was for responses to be more errors in saccadic direction for stranger stimuli ($t(32)=1.4$, $p=0.09$, $d_z = 0.24$; 95% CI for d_z [0.09, 0.23]). There was no effect of stimulus on saccadic directional accuracy of pro-saccades ($F(2,64)=2.1$, $p=0.16$).

(Figure 2 about here)

We further examined anti-saccade and pro-saccade saccadic directional accuracy by testing whether correct eye-responses for self, friend and stranger stimuli differed from chance. One sample t-tests (chance level 50%) showed that saccadic directional accuracy

for all stimuli except anti-saccades for self ($t(32)=0.92$) were significantly higher than chance level ($t(32)=2.58$, $p=0.017$, $d_z = 0.44$, 95% CI for d_z [0.29, 0.52]; $t(32)=10.26$, $p<0.001$, $d_z = 1.78$, 95% CI for d_z [1.24, 1.93] for friend and stranger anti-saccades respectively; $t(32)=4.76$, $p<0.001$, $d_z = 0.82$, 95% CI for d_z [0.67, 1.05]; $t(32)=9.36$, $p<0.001$, $d_z = 1.62$, 95% CI for d_z [1.47, 1.63]; $t(32)=6.56$, $p<0.001$, $d_z = 1.14$, 95% CI for d_z [1.03, 1.37] for self, friend, stranger pro-saccades respectively).

The cost of voluntary control

To verify above self-biases in saccadic directional accuracy and reduce the variations of conditions, the difference between pro-and anti-saccades in saccadic directional accuracy were contrasted for each condition as a measure of the voluntary control of saccades. There was a main effect of stimulus type ($F(2,64)=7.87$, $p=0.002$, $\eta_p^2 = .32$, 90% CI [0.26, 0.43]) showing that the contrast between the two types of saccade was larger for self relative to friend ($t(32)=3.23$, $p=0.016$, $d_z = 0.56$, 95% CI for d_z [0.39, 0.68]) and stranger stimuli ($t(32)=2.95$, $p=0.031$, $d_z = 0.51$, 95% CI for d_z [0.26, 0.66]) (Figure 3). There was no difference between voluntary control for friend and stranger stimuli ($t(32)=1.05$, $p=0.84$, $d_z = 0.18$, 95% CI for d_z [0.01, 0.16]). The data indicate that the increased difficulty of making an anti-saccade relative to pro-saccade was exacerbated for self-related stimuli.

(Figure 3 about here)

Inter-trial effect comparisons

Further analyses were performed to test the cost of voluntary control by examining inter-trial effects of pro-saccades and anti-saccades. We calculated saccadic directional accuracy for correct anti-saccade trials (for the self, friend and stranger) preceding correct pro-saccade trials (averaged across self, friend and stranger shapes), along also with saccadic directional accuracy for correct pro-saccade trials for each shape preceding correct anti-saccade trials (averaged across self, friend and stranger stimuli). A two way repeated

measures ANOVA with preceding saccade (anti-saccade, pro-saccade) and preceding shape type (self, friend, stranger) as within subject factors was carried out to examine the inter-trial effects. There was a main effect of preceding saccade ($F(1,32)=76.79$, $p<0.001$, $\eta_p^2=.78$, 90% CI [0.59, 0.89]); a main effect of shape type ($F(2,64)=10.23$, $p<0.001$, $\eta_p^2=.37$, 90% CI [0.21, 0.54]) and an interaction of preceding saccade* preceding shape type ($F(2,64)=11.68$, $p<0.001$, $\eta_p^2=.39$; 90% CI [0.22, 0.57]).

To explore the interaction effect, two separate ANOVAs were performed for each type of preceding saccade. In the first ANOVA we examined whether anti-saccades for self, friend and stranger on trial N-1 had a differential effect on saccadic directional accuracy of the next pro-saccade trial (trial N). The results showed significantly lower accuracy in pro-saccade trials preceded by correct self-anti-saccades compared to pro-saccades preceded by correct anti-saccades to friend stimuli ($t(32)=5.9$, $p<0.001$, $d_z = 1.03$, 95% CI for d_z [0.66, 1.29]) and to stranger stimuli ($t(32)=7.1$, $p<0.001$, $d_z = 1.23$, 95% CI for d_z [1.02, 1.44]) (overall, $F(2,64)=11.47$, $p<0.001$, $\eta_p^2=.39$; 90% CI [0.11, 0.52]). There was no difference in saccadic directional accuracy of pro-saccades preceded by correct friend and stranger-anti-saccades ($t(32)=0.85$) (Figure 4, a). The second ANOVA tested whether making a preceding correct pro-saccade to self, friend and stranger shapes affected saccadic directional accuracy for the next anti-saccade trial. The result indicated that there was no differential effect of the preceding pro-saccade on anti-saccade saccadic accuracy ($F(2,64)=0.41$) (Figure 4, b).

(Figure 4 about here)

Saccade latencies

In addition to measuring saccadic directional accuracy, we calculated the latency of the first correct and incorrect eye-movement⁴. First, a two way repeated measures ANOVA was carried out to examine the effect of saccade type (anti-saccade, pro-saccade) and stimulus (self, friend, stranger) on latency of correct responses (Figure 5). There was a main effect of saccade type ($F(1,32)=12.95$, $p=0.001$, $\eta_p^2=.39$, 90% CI [0.19, 0.56]) indicating that latencies for pro-saccade trials were shorter compared to anti-saccade trials. No other terms were found significant (no main effect of stimulus ($F(2,64)=0.79$; no interaction of saccade type*stimulus ($F(2,64)=0.88$)).

(Figure 5 about here)

Then, a similar two-way repeated measures ANOVA was performed on the latency of incorrect responses. There were no main effects of saccade type ($F(1,32)=0.25$) and stimulus ($F(1,32)=0.404$). However, the interaction between saccade type and stimulus ($F(2, 64)=3.26$, $p=0.044$, $\eta_p^2=.09$, 90% CI [0.07, 0.18]) was significant (Figure 6). Paired sample t-test showed that latency of incorrect responses for self anti-saccade condition was significantly shorter compared to incorrect responses for self saccade condition ($t(32)=2.63$, $p=0.031$, $d_z = 0.43$, 95% CI for d_z [0.23, 0.57]). No reliable differences were found between friend anti-saccade and friend saccade trials ($t(32)=0.036$, and between stranger anti-saccade and stranger saccade conditions ($t(32)=0.12$).

(Figure 6 about here)

Our inter-trial comparisons showed significantly lower accuracy in pro-saccade trials preceded by correct self-anti-saccades compared to pro-saccades preceded by other-anti-saccades (Figure 4). If the preceding correct self-anti-saccade are required more control (inhibition) to be generated, we may expect that the subsequent pro-saccades are also

⁴ We also examined the effect of stimuli on the amplitude of saccadic responses, but no significant differences were found between the conditions.

delayed⁵. To test this assumption, we calculated saccadic latency for correct anti-saccade trials (for the self, friend and stranger) preceding correct pro-saccade trials (averaged across self, friend and stranger shapes), along with saccadic latency for correct pro-saccade trials for each shape preceding correct anti-saccade trials (averaged across self, friend and stranger stimuli).

A two-way repeated measures ANOVA with preceding saccade (anti-saccade, pro-saccade) and preceding shape type (self, friend, stranger) as within subject factors was carried out to examine the inter-trial effects on saccadic latency (Figure 7). There was a main effect of preceding shape type ($F(2,64)=4.4$, $p=0.016$, $\eta_p^2=.12$, 90% CI [0.06, 0.23]) indicating that preceding self-shape slowed down saccadic latency on the subsequent pro-saccades. There was no effect of preceding saccade ($F(1,32)=0.22$) or interaction effect ($F(2,64)=1.78$, $p=0.17$). To explore the effect of preceding shape type, two separate ANOVAs were performed on the saccadic latency for anti-saccades and pro-saccades. There was a main effect of preceding shape type in anti-saccade trials ($F(2,64)=5.11$, $p=0.009$, $\eta_p^2=.14$, 90% CI [0.08, 0.41] showing significant delays in pro-saccades preceded by self-shape compared to friend-shape ($p=0.003$) and stranger-shape ($p=0.037$) (adjusted for multiple comparisons using Bonferroni correction). No effect of preceding shape type in pro-saccade trials was found ($F(2,64)=0.41$).

(Figure 7 about here)

DISCUSSION

In line with previous findings, our results show that anti-saccadic responses elicit more saccadic errors compared to pro-saccades (Barton, Raouf, Jameel, & Manoach, 2006; Nieuwenhuis, Broerse, Nielen, & de Jong, 2004; Hallett, 1978). More pertinently,

⁵ Thanks to the anonymous reviewer who pointed this out.

however, this effect was stronger for self than friend stimuli. In addition, relative to stranger stimuli, self stimuli showed a significantly greater contrast between pro- and anti-saccade trials and anti-saccades only for self-stimuli. Furthermore, our data showed greater disruption on pro-saccades when the preceding trial required an anti-saccade to self-stimuli compared with other stimuli. Taken together, both findings indicate (i) an increase in the relative difficulty of anti-saccades for self-related items, (ii) larger disruption in pro-saccade responses (in both saccadic directional accuracy and latency) preceded by self-anti-saccades. This latter finding may stem from the requirement to inhibit a pro-saccade to the self stimulus when an anti-saccade was required on trial N-1, which may then make it more difficult to generate a pro-saccade on trial N. Furthermore, our data of the latency of incorrect responses showed that only for 'self' condition incorrect responses for the anti-saccade trials were significantly shorter compared to pro-saccade trials. The results suggest that there are qualitative differences in the ability to generate an anti-saccade away from a stimulus associated with the self compared with other people. Note that this result is highly unlikely to reflect the difficulty of matching self-related stimuli since a strong advantage for matching self-related items has been consistently demonstrated in the literature (e.g., Sui et al., 2012).

Current views on anti-saccadic responses (e.g., Barton, Raoof, Jamel, & Manoach, 2006; Munoz & Everling 2004) propose an involvement of two processing stages that are linked to two independent mechanisms: (1) suppressing an automatic pro-saccade eye-movement and (2) generating instead a voluntary saccade in the opposite direction. Presumably, the higher cost of voluntary control for self-associated responses may reflect either or both stages together. If the cost of voluntary control is linked to the suppression of reflexive saccades (e.g., if the inhibition of pre-target activity for the self takes longer compared to that for others due to stronger attentional capture), but the generation of a

voluntary saccade remains the same for all stimuli, then we should expect longer latencies for self-anti-saccades compared to others. However, we found no significant differences in correct anti-saccade latency between the conditions. On the other hand, there may need to be more inhibition of the pro-saccade to self stimuli, even if the time to generate effective inhibition (e.g., to enable an anti-saccade to be made) does not differ for the contrasting stimuli. It would then follow that it may be more difficult to generate a subsequent pro-saccade, since the pro-saccade will be strongly inhibited. This is what we observed. Our results on inter-trial effects support the idea that there is greater suppression of pro-saccades to make an anti-saccade to a self-related stimulus. We also observed longer latency on pro-saccades preceded by self-anti-saccades. This finding further support the idea that the correct anti-saccades for self-associated stimuli require more control (inhibition) to be generated.

In contrast to the effects of self-related stimuli, anti-saccades to friend-related stimuli were easier to make than those to stimuli related to a stranger. This result is interesting since it indicates a dissociation between effects of self-association (disrupting anti-saccades) and effects of familiarity (the association to a friend). We propose that familiar stimuli (friend associations) are processed more efficiently than unfamiliar stimuli (stranger associations) and exert a reduced cost on difficult responses (anti-saccades). Self-related stimuli, on the other hand, cue attention to themselves, disrupting anti-saccades. Our results provide strong support for the attentional draw of self-associated stimuli and suggest that voluntary saccadic responses away from a self-related item demand greater inhibition than is the case for stimuli related to other people.

In addition, a recent eye-tracking study (Siebold, Weaver, Donk, & van Zoest, 2016) using an oculomotor visual search paradigm did not find the effects of self on an early perceptual level. In this study, participants were required to form associations between two

orientation lines (right- and left-tilted) and two labels ('you' and 'stranger'), and then make a speeded eye-movements to one of the two lines without any task instruction (Experiment 1), to dot probe target located on one of the two lines (Experiment 2), or to the line that was cued by its associated label (Experiment 3). Similar to our finding, there was no effect of self-prioritization on involuntary eye-movements. Furthermore, the study suggests that top-down information affects detection responses, but not localization of socially salient stimuli, providing indirect support for our conclusion that once a 'self-cued' stimulus is detected, it is more difficult to control involuntary eye-movement.

The results of the present study raise an important question for further studies: what is the relationship between individual differences in the magnitude of self-biases (i.e., the response time advantage for stimuli associated with self compared to other) and the cost of voluntary control of saccades for self. If the magnitude of the facilitation effect for self-associated stimuli can predict the cost of self-related attentional control, this may have important implications in neuropsychological studies (e.g., in patients with lesions affecting brain regions shown to be related to self-biases (van den Bos & Güroğlu, 2009) and the frontal eye fields (Machado & Rafal, 2003), patients suffering from depression (Koenigs & Grafman, 2009).

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Figure 1. Trial sequence

Figure.2 Saccadic directional accuracy for anti-saccades and pro-saccades for self, friend and stranger stimuli. Error bars represent +/- 1SEM. The stars indicate significant differences between a pair of conditions (adjusted for multiple comparisons using Bonferroni correction).

Figure 3. Saccadic directional accuracy difference between pro- and anti-saccades. Error bars represent +/- 1SEM. The stars indicate significant differences between a pair of conditions (adjusted for multiple comparisons using Bonferroni correction).

Figure 4. Inter-trial effects of preceding self-, friend-, stranger-anti-saccades on the accuracy of the next pro-saccade trials (a); and effects of preceding self-, friend- stranger-pro-saccades on the directional accuracy of the next anti-saccade trial (b). Error bars represent +/- 1 SEM. The stars indicate significant differences between a pair of conditions (adjusted for multiple comparisons using Bonferroni correction).

Figure 5. Latency for correct anti-saccade and pro-saccade trials. Error bars represent +/- 1SEM.

Figure 6. Latency for incorrect anti-saccade and pro-saccade trials. Error bars represent +/- 1SEM.

Figure 7. Inter-trial effects of preceding self-, friend-, stranger-anti-saccades on the latency of the next pro-saccade trials (a); and effects of preceding self-, friend- stranger-pro-saccades on the latency of the next anti-saccade trial (b). Error bars represent +/- 1 SEM. The stars indicate significant differences between a pair of conditions (adjusted for multiple comparisons using Bonferroni correction).

Figure 1

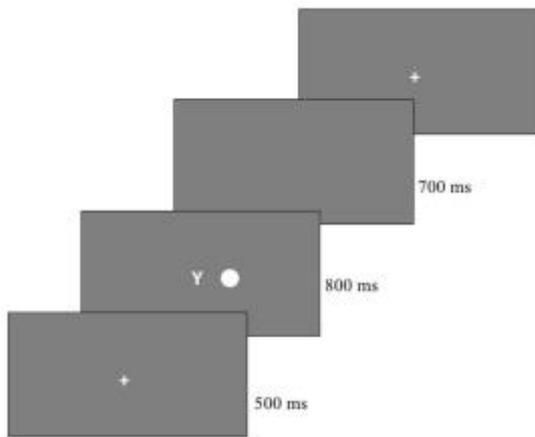


Figure 2

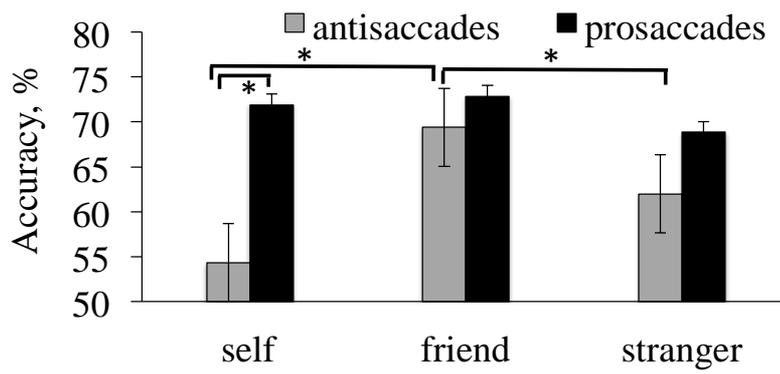


Figure 3

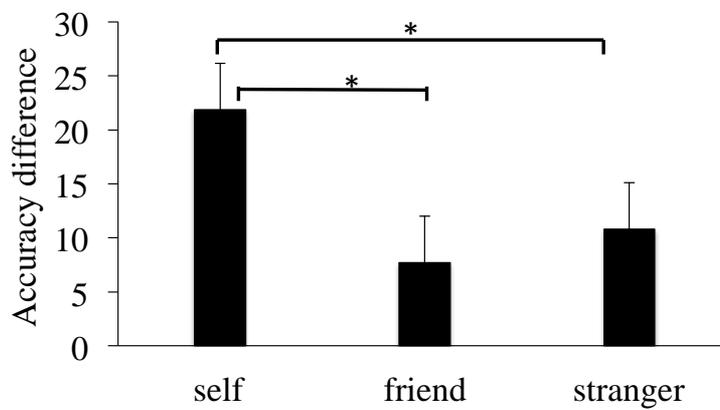


Figure 4

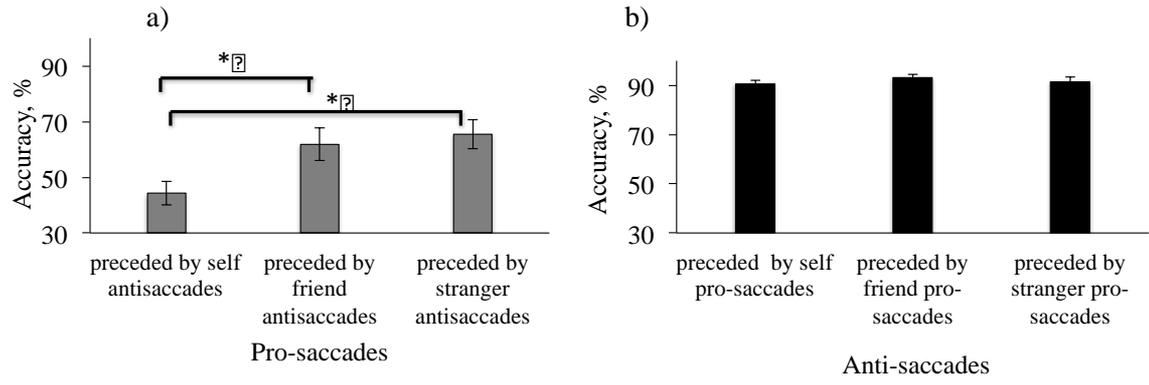


Figure 5

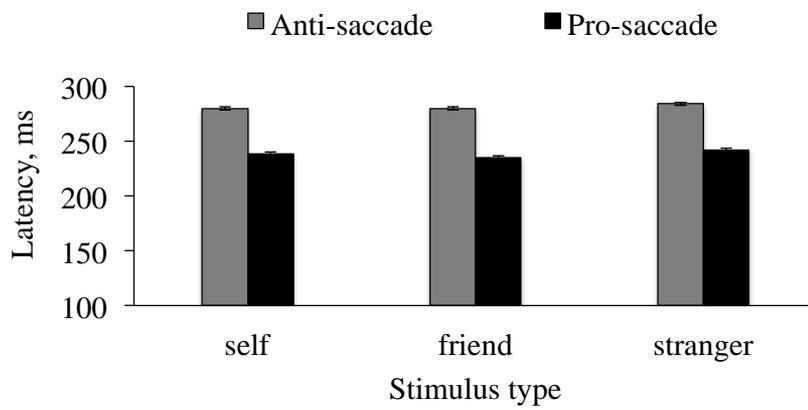


Figure 6

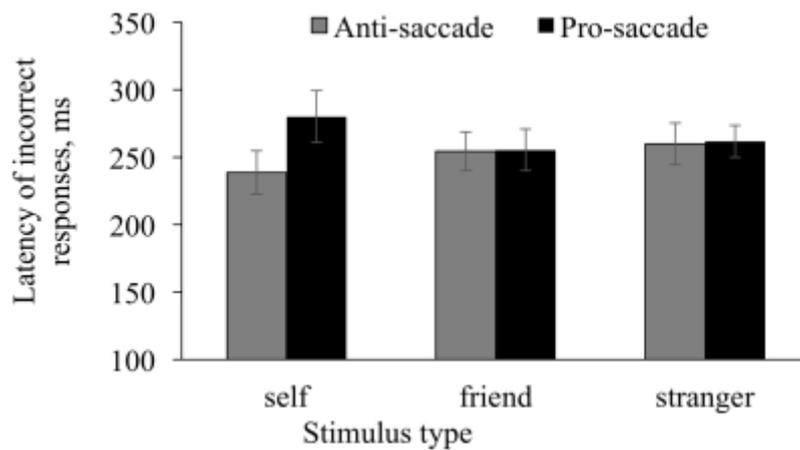


Figure 7

