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Modulation of antisaccade costs through manipulation of target-location probability: Only under decisional uncertainty

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ABSTRACT

Latencies of *antisaccades* made in the direction opposite to a peripheral target are typically slower longer than of *prosaccades* towards such a target by 50–100 ms. Antisaccades have proved to be an important tool for diagnostic purposes in neurology, psychology and psychiatry, providing invaluable insights into attentional function, decision making and the functionality of eye movement control. Recent findings have suggested, however, that latency differences between pro- and antisaccades can be eliminated by manipulating target-location probabilities. Pro- and antisaccades were equally fast to locations where a target rarely appeared, a finding that may be of promise for more elaborate diagnoses of neurological and psychiatric illness and further understanding of the eye movement system. Here, we tested probability manipulations for a number of different pro- and antisaccade tasks of varied difficulty. Probability only modulated antisaccade costs in a difficult antisaccade task involving decisional uncertainty with low target saliency. For other tasks including standard ones from the literature, target-location probability asymmetries had minimal effects. Probability modulation of antisaccade costs may therefore reflect effects upon decision making rather than saccade generation. This may limit the usefulness of probability manipulations of antisaccades for diagnostic purposes in neurology, psychology and related disciplines.

1. Introduction

Visual acuity is by far the best at the fovea and declines quickly with increased retinal eccentricity. For high visual resolution stimuli of interest must be projected onto the fovea. Here the eye movement system plays a central role, generating saccades that shift the center of gaze to targets of interest. Two types of saccades are often compared. Prosaccades are made towards a target while antisaccades are made in the opposite direction (e.g. to the right if a stimulus is displayed on the left). Antisaccade latencies are typically considerably longer than prosaccade latencies (Everling & Fischer, 1998; Hallett, 1978; Kristjánsson, 2007), a difference called the antisaccade cost.

Antisaccades are an important diagnostic tool in neurology, psychiatry and psychology since they can be predictive of various neurological disorders and are easy to administer (Antoniades et al., 2013). While predictive of neurological dysfunction, they are, however, not always discriminative for different disorders. Findings where the antisaccade cost can be manipulated are therefore of great interest, since they open up the possibility that differential effects might be seen for different disorders. Recent findings indicate that modulation of target-location probability[1] can eliminate antisaccade costs (Liu et al., 2010; see also Liu et al., 2011). Liu et al. found that for saccades made to low-probability locations, there was little or no difference in latency between pro- and antisaccades. However, their task was not a typical antisaccade task but involved target uncertainty where the correct location needed to be determined with odd-one-out visual search once the task to be performed had been determined from a central saccade-type indicator.

Probabilities of saccade target-locations have been manipulated before. Carpenter and Williams (1995) tested prosaccade performance with probability ratios ranging from .50/.50 to .95/.05 finding that saccades towards high-probability locations had shorter latencies than towards low-probability locations. Dorris and Munoz (1998) found that latencies of prosaccades performed by rhesus monkeys were shorter (by ≈19 ms) towards high- than

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[1] Here we define probabilities by ratios. For example, .75/.25 means that the target appears on 75% of the trials to the left of central fixation, and consequently, the remaining 25% of the trials the target appears to the right of central fixation. Of the total prosaccades 75% are made to the left while 75% of the total antisaccades are made to the right. The opposite ratio is denoted in our terminology with .25/.75 and equal probabilities by .50/.50.

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low-probability locations. Koval, Ford, and Everling (2004) tested antisaccades using 3 different probability ratios (.80/.20, .50/.50, .20/.80). The antisaccade latencies were significantly shorter for high- than low-probability target-locations and the number of erroneous prosaccades (saccades towards rather than away from the target) increased. Further support for the effects of probability manipulations comes from Noorani and Carpenter (2012). In their experiment they used the same probabilities as Koval, Ford, and Everling (2004) and found that latency decreased and error rates increased in the high, compared to the low probability condition.

1.1. Current aims

In addition to providing information about brain mechanisms for saccade generation, saccadic probability effects are of interest for another reason. The antisaccade is an important part of the toolbox of neurologists, neuropsychologists, and psychiatrists to name a few (Antoniades et al., 2013; Hutton & Ettinger, 2006; Kristjánsson, 2007; Leigh & Kennard, 2004). New paradigms (e.g. Liu et al., 2010; ; Liu et al., 2011) where differences in latencies between antisaccades and prosaccades are modulated therefore rightly generate great interest. A drawback is that the task tested by Liu et al. may be very challenging for a number of patient groups. Their task differs from typical saccade tasks since when the task display appears, the odd-one-out target must be found, and an anti- or prosaccade (based on a central saccade-type indicator) made consequently. With this in mind we investigated under what conditions such probability effects occur. We conducted 5 experiments, increasing task complexity gradually experiment by experiment to find conditions where probability manipulations affect pro- and antisaccade latencies. Experiments (4A and B) were more or less exact replications of experiment 2 in Liu et al. (2010). Our aim was to test effects of target-location probability on pro- and antisaccades and whether such effects occur in simpler tasks that are easier to administer to patient groups in an effort to develop paradigms that may more accurately probe different disorders or distinguish between them.

2. General method

2.1. Equipment

A high-speed video eyetracker (250 Hz) from Cambridge Research Systems (2006) with a spatial accuracy of 0.125–0.25° and a horizontal range of ±40° and a vertical range of ±20° measured eye position. The eyetracker uses infrared technology and dual first Purkinje reflection to keep track of gaze. The observers' head was stabilized with a head and chin rest. Viewing distance was 53 cm. The stimuli appeared on a 100 Hz 19″ Hansol CRT screen (model: 920D resolution: 1280 × 1024) controlled by a 2.33 GHz PC. Experiments were run in a soundproof booth where the only illumination came from stimulus screen and the LCD screen used by the experimenter. Experimental programs were written in Matlab utilizing the Psychtoolbox (Brainard, 1997; Kleiner, Brainard, & Pelli, 2007; Pelli, 1997). Extensions from the Video Eyetracker Toolbox (2008) controlled the eyetracker and recorded eye movements. The observers were not trained in the experimental tasks but the task was explained to them by running demos showing all the experimental conditions but, importantly, the observers were not informed of the probability manipulations beforehand.

2.2. Analyses

A saccade was considered to have started at time point $N-1$ when eye velocity at time point N exceeded 30 deg/s (Leigh & Zee, 2006) and the angular distance between N and $N-1$ exceeded 1° (Rolfs, Knapen, & Cavanagh, 2010). If the initial amplitude of a saccade exceeded 1° in direction opposite to what it should be, the saccade was considered invalid. Saccades with landing-points within 4° around the intended target location were considered valid. The first point after the velocity of the saccade dropped below 30 deg/s defined the landing-point (Leigh & Zee, 2006; Walker et al., 1997). The dominant eye (determined by the pointing method; Greenberg, 1960) of each participant was tracked. Saccadic latency was defined as the time from stimulus onset until saccade onset. Saccades with latencies shorter than 80 ms (100 ms in experiments 4A and B) were excluded from statistical analyses (Becker, 1991; Edelman, Kristjánsson, & Nakayama, 2007; Rolfs & Vitu, 2007). In experiments 1 through 3, trials with latencies deviating more than 3 SD from each participants mean were excluded (see procedure and results of experiment 4A and 4B for their criteria). Besides using traditional repeated measures ANOVAs in our analyses we used a random effects model (Bates, 2010) which takes into account individual variability and has more power than ANOVA, especially when there is variability in latency distributions between observers (Bates, 2010). In the random effects model we used the .50 probability as baseline. Furthermore we fitted our data to ex-Gaussian distributions (Ratcliff, 1993) since response time distributions tend to be positively skewed. We used the egfit.m (Lacouture & Cousineau, 2008) function in Matlab to fit the data and to estimate the three parameters of the ex-Gaussinan distribution. The μ-parameter is the mean, and σ the standard deviation, of the normal part. The τ-parameter is the mean of the exponential part of the distribution (Matzke & Wagenmakers, 2009; Ratcliff, 1993). All participants were volunteers from the University of Iceland, receiving course credit for participation, and gave written informed consent before participation. The research was approved by The Icelandic National Bioethics Committee (11-054).

3. Experiment 1 – testing probability effects upon pro- and antisaccades in a standard task

3.1. Method

3.1.1. Participants

Twenty naïve students (15 female, aged from 20 to 53 years, $M = 26.6$ years, $SD = 7.4$ years) participated.

3.1.2. Stimuli

The color and shape of the fixation point indicated whether observers were to make anti- or prosaccades. For half of the observers the fixation point (a red square; 0.7°, 8 cd/m^2; RGB = [202 2 2]) indicated that a prosaccade should be made while a blue circle (0.7°; 6 cd/m^2; RGB = [0 0 255]) signaled an antisaccade.[2] This was reversed for the other observers. Both stimuli had a smaller dark-gray (<1 cd/m^2; RGB = [0 0 0]) square in the middle. The target was a white square (0.7°; 39 cd/m^2; RGB = [255 255 255]) with a smaller dark-gray (<1 cd/m^2; RGB = [0 0 0]) square at center.

3.1.3. Procedure

The fixation point was visible for 600–1600 ms (randomly determined for each trial) after which the experimental program automatically checked if the observer was fixating the fixation point or not. When fixation on the fixation point was confirmed, the fixation point disappeared and the target stimulus appeared

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[2] In the blocked task the color of the fixation point followed the same rule as in the interleaved task but the observers were told at the beginning of each block whether to make anti- or prosaccades.

randomly 8° to the right or left for 950 ms. We used 3 probabilities in the prosaccade task and the same 3 probabilities in the antisaccade task whether the trials were run in blocks or interleaved. The probability that the target was left of the fixation point was .25, .50 and .75 and consequently the rightward probability was .75., .50 and .25, respectively. In the interleaved blocks half of the trials were prosaccade trials and the other half antisaccade trials (randomly decided for each trial). Following a random ITI of 100–600 ms, the next trial began. Each observer participated in 6 blocks of 36 trials of prosaccades, antisaccades and interleaved trials (always in this order, but a latin square determined the order of different probabilities); a total of 18 blocks and 648 trials.

3.2. Results

A three-way repeated-measures ANOVA with probability, saccade-type and task-type (blocked or interleaved) showed only a significant effect of saccade-type, ($F(1,19) = 270.1$, $p < .001$; all other p's > .1). Effects of target-locations probability upon latency were tested separately for blocks of prosaccades, antisaccades and interleaved blocks with one-way repeated-measures ANOVAs. No effects of probability were found (all F's < 1.3 and all p's > .3; see Fig. 1B and C). No differences were found between left and right probabilities of .25 nor .75 so these conditions were collapsed. The percentage of excluded trials (from signal loss, incorrect saccade direction and latencies or landing-points outside criteria) varied between observers from 2.2% to 11.6% so 573 to 634 trials were analyzed. There were no significant differences in error rates by probability (all p's > .06; see Table A1 in Appendix A for a detailed overview of error rates). Plots of the observers mean latency and probability effects are shown in Fig. B1 in Appendix B.

3.2.1. Results: random effects model

A model with random effects of subject on task-type, saccade-type and probability revealed a significant intercept (173 ms, $t = 41.5$) and slope differences for antisaccades with respect to prosaccades (101 ms, $t = 18.1$). The slope of task was also significant with a steeper slope in the interleaved task than in the blocked task (11 ms, $t = 3.2$) but the slopes of probability were not significant (both t's < 0.6). Furthermore the slope of interaction between task-type and saccade-type was significant (−15 ms, $t = -2.95$; all other t's < 1.7). Further analyses of anti- and prosaccades blocks and interleaved blocks revealed only significant intercepts (all t's > 25) but no significant slopes (all t's < 1.8). As in the ANOVA results the effect of saccade-type was significant but the effect of task-type was also significant, suggesting the interleaved task was more difficult than the blocked task. Otherwise the two analyses are in good accordance.

3.2.2. Results: parameters of ex-Gaussian distributions

A three-way repeated measures ANOVA with probability, saccade-type and task-type as factors and μ (τ and $\mu + \tau$) as dependent variable revealed significant effects of saccade-type on μ ($F(1,18) = 442.63$, $p < .001$), τ ($F(1,18) = 6.02$, $p = .025$) and $\mu + \tau$ ($F(1,18) = 331.43$, $p < .001$). Effects of probability were never significant (all p's > .12) but the effect of task-type on μ was significant ($F(1,18) = 6.54$, $p = .019$) but neither on τ nor $\mu + \tau$ (both p's > .13). The two-way interaction of saccade- and task-type on τ was significant ($F(1,18) = 10.14$, $p = 0.005$) and also on $\mu + \tau$ ($F(1,18) = 8.92$, $p = .008$). The only significant interaction was between probability and saccade-type on $\mu + \tau$ ($F(1,18) = 5.49$, $p = .009$, all other p's > .06). The effect of probability was never significant in the blocked tasks (all p's > .29). The only significant effect in the interleaved prosaccade trials was the effect of probability on τ ($F(2,38) = 3.91$, $p = .029$; both other p's > .06). In

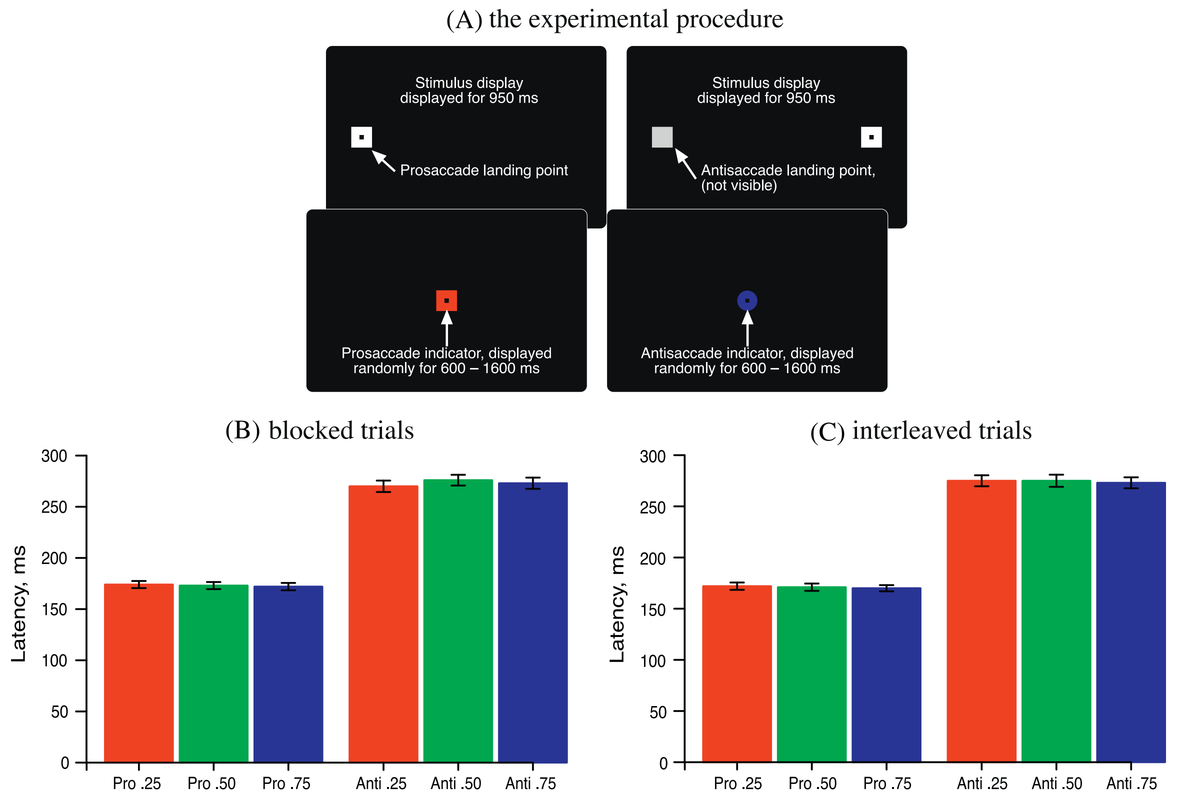

Fig. 1. Experimental procedure and results from experiment 1. (A) The experimental design. (B) latencies of anti- and prosaccades run in separate blocks. (C) Latencies of anti- and prosaccades in the interleaved blocks. Error bars represent the standard error of the mean (SEM).

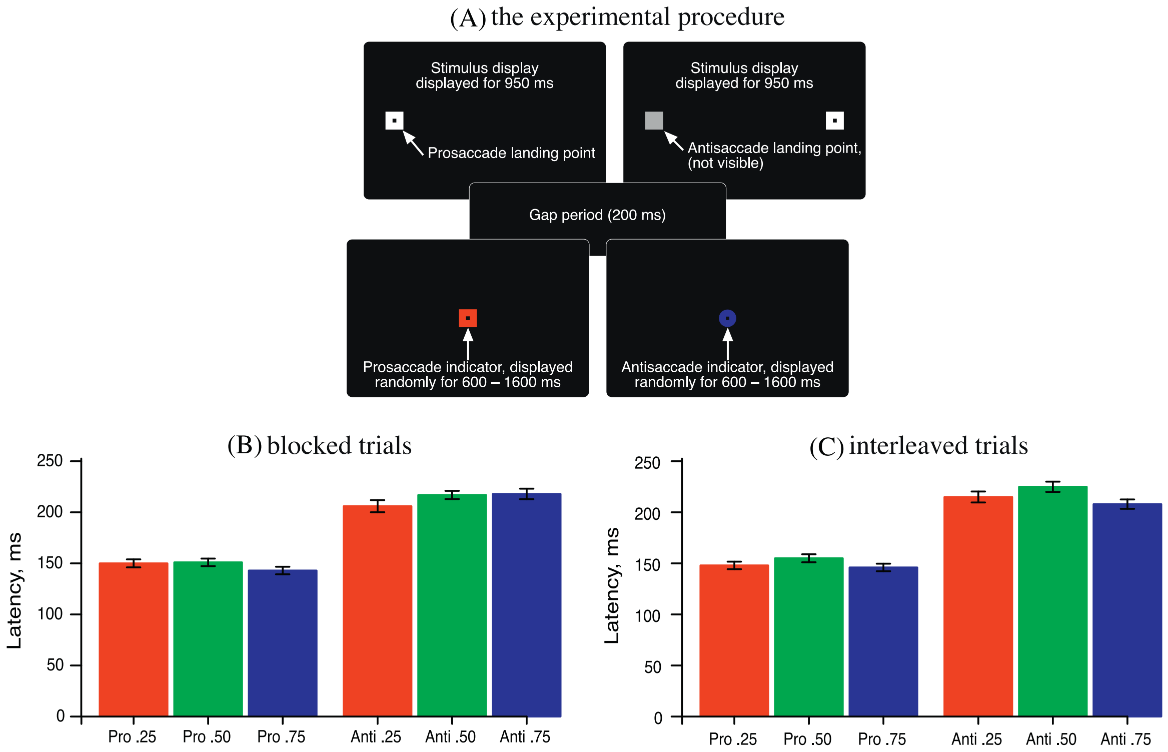

Fig. 2. The design and results from experiment 2. (A) Experimental design. (B) Latencies of anti- and prosaccades run in separated blocks. (C) Latencies of anti- and prosaccades interleaved. Error bars represent the standard error of the mean (SEM).

the interleaved antisaccade trials the effect of probability on $\mu + \tau$ was significant ($F(2,38) = 5.49$, $p = .008$) but not on μ or τ (both p's > .35). The only significant effects of probability involved the τ-parameter suggesting that probability might influence longer latencies but this did not differ for the interleaved anti- and prosaccades tasks.

3.3. Conclusions from experiment 1

No effects of target-location probability were found in experiment 1, but the well-known antisaccade cost (difference in latency between pro- and antisaccades) was large.

Koval, Ford, and Everling (2004) and Noorani and Carpenter (2012)reported evidence for effects of target-location probability upon antisaccades when the fixation point disappeared shortly before saccade target appearance (the gap paradigm, Saslow, 1967). Experiment 2 tested effects of manipulating target-location probabilities in the gap paradigm.

4. Experiment 2 – probability effects in the gap paradigm

4.1. Method

4.1.1. Participants

Five[3] naïve female volunteers (aged from 23 to 48 years, $M = 29.8$ years, SD = 10.3 years) participated.

4.1.2. Stimuli and procedure

Stimuli and procedure were similar to experiment 1 except that the central fixation point disappeared 200 ms before the task stimuli appeared (the gap paradigm, Fig. 2A). Each observer participated in 648 trials in 18 blocks of 36 trials.

4.2. Results

A three-way repeated-measures ANOVA with probability, saccade-type and task-type again showed only a main effect of saccade-type, ($F(1,4) = 43.27$, $p = .003$) and the interaction of probability, saccade-type and task-type was not far from significance ($F(2,8) = 3.53$, $p = .061$) but all other p's > .088. A one-way repeated measure ANOVA tested effects of target-location probability upon latency, separately for prosaccades, antisaccades and interleaved blocks. The main effect of probability was significant in the antisaccade block ($F(2,8) = 4.86$, $p = .042$) and in the interleaved antisaccade task ($F(2,8) = 4.61$, $p = .047$) but not for the prosaccade tasks (both F's < 1.5 and both p's > .2). Posthoc t-tests with Bonferroni corrected p-values revealed no significant differences between saccadic latencies with respect to target-location probability (all p's > .09). Excluded trials varied between observers from 3.8% to 19.7% for each observer. No significant differences in error rates were found between probability conditions (all p's > .2). A detailed overview of error rates can be found in Table A2 in Appendix A.

4.2.1. Results: random effects model

In a model with random effects of subjects on saccade-type, probability and task-type the intercept (151 ms, $t = 20.4$) and the slope of saccade-type (65 ms steeper for anti- than for prosaccades, $t = 6.9$) was significant. No other slopes were significant (all t's < 1.9). In the prosaccade tasks, blocked and interleaved, the intercept was significant (151 ms, $t = 20.0$ and 147 ms, $t = 15.8$, respectively) but not the slope of probability (both t's < 1.7). In the blocked antisaccade task the intercept was significant (216 ms, $t = 23.0$) and the slope of probability of .25 was also significant (4 ms, $t = -2.6$) but not the slope of .75 probability ($t = 0.3$). In the interleaved antisaccade task the intercept was significant

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[3] Experiment 1 showed that not many observes were needed for reliable answers to our experimental questions so 5 to 6 observers were tested in experiments 2–4 instead of the large number tested in experiment 1.

(207 ms, $t = 24.6$) but the slope of probability was not significant (both t's < 0.9). As before, the effect of saccade-type was significant but here we found a slight significant effect of probability in the blocked antisaccade task suggesting that the latency of low probability antisaccades is slightly higher (4 ms) than of equal probability. This difference is so miniscule, however, that it is doubtful that it is meaningful.

4.2.2. Results: parameters of ex-Gaussian distributions

A three-way repeated measures ANOVA with probability, saccade- and task-type as factors and μ (τ and $\mu + \tau$) as dependent variables revealed significant main effects of saccade-type on μ ($F(1,4) = 107.6$, $p < .001$), τ ($F(1,4) = 18.21$, $p = .013$) and on $\mu + \tau$ ($F(1,4) = 64.84$, $p = .001$). The effects of probability and task-type were not significant (all p's > .12). The two-way interaction effect of probability and saccade-type on μ was significant ($F(2,8) = 7.09$, $p = .017$) and on $\mu + \tau$ ($F(2, 8) = 5.05$, $p = .038$). The effect of interaction between task- and saccade-type on μ was significant ($F(1,4) = 8.31$, $p = .045$). The two-way interaction of probability and task-type on $\mu + \tau$ was significant ($F(2,8) = 7.14$, $p = .017$). None of the other two-way, and three-way interactions were significant (all p's > .19). The effect of probability was never significant in the blocked and interleaved tasks, neither on anti- or prosaccade latencies (all p's > .08). Here we only found significant effect of probability in interaction with saccade-type and task-type, suggesting that any effects are not due to probability but rather an effect of saccade- and task-type.

The latencies of both anti- and prosaccades were short in comparison with experiment 1 similar to results from other experiments (Koval, Ford, & Everling, 2004; Kristjánsson, 2007, and as measured with the same equipment, e.g. Jóhannesson & Kristjánsson, 2013; Jóhannesson, Ásgeirsson, & Kristjánsson, 2012). Most importantly, however, there were no modulation of anti- versus prosaccade latencies from target-location probability manipulation, which seems to be at odds with the probability effects upon antisaccade latency previously found (Koval, Ford, & Everling, 2004; Noorani & Carpenter, 2012). But Koval, Ford and Everling found only significant effects in 2 of 3 probability conditions and Noorani and Carpenter told their observers about the probability manipulations beforehand, which we did not do. At the very least, this suggests that any probability effects upon antisaccades is not particularly robust (see also Clark, Bogacz, and Gilchrist (2013) for preliminary evidence supporting this conclusion).

5. Experiment 3 – is the antisaccade cost affected by target-location probability in a saccade task involving visual search?

Probability manipulations affected antisaccade performance in Liu et al. (2010) in a task involving both vertical and horizontal saccades. In experiment 3 we tested a modified version of their task, involving horizontal saccades only, again in an attempt at simplifying their task.

5.1. Method

5.1.1. Participants

Five naïve volunteers participated (3 female, aged from 22 to 37 years, $M = 27.4$ years, SD = 5.8 years).

5.1.2. Stimuli

The fixation point was a white cross at screen center. Simultaneously with the central saccade-type indicators (prosaccades: a red square 0.7°, 8 cd/m^2; RGB = [202 2 2], antisaccades: a green circle 0.7°; 2.7 cd/m^2; RGB = [0 255 0]), four stimuli appeared on the screen; 3 white squares (distractors; 0.7°; 39 cd/m^2; RGB = [255 255 255]) and 1 blue square (the target stimulus; 0.7°, 6 cd/m^2; RGB = [0 0 255]) all with a dark-gray (<1 cd/m^2; RGB = [0 0 0]) square at center.

5.1.3. Procedure

The fixation cross was presented for 800–1400 ms (decided randomly) and when the experimental program confirmed automatically that the observer was fixating the fixation cross, the experimental display appeared for 1500 ms. The stimuli were presented in a straight horizontal line (see Fig. 3A), the saccade-type indicator at screen center and two stimuli at left and right away from center (by 6° and 8°). The oddly colored item was the target and it appeared with the same probability at outer and inner positions. Probability ratios between left and right were the same as in previous experiments, which means that when the probability of a left target was .25, the probability of the outer and inner left positions was .125 in both cases. There were 40 trials in 6 blocks of each of the 3 parts (prosaccades, antisaccades and pro- and antisaccades interleaved), 720 trials in total. Whether pro- or antisaccades were to be made (in interleaved blocks), and whether a saccade was to be made to the left or right and to the inner or outer target stimuli was randomly determined for each trial. In all other respects methods were similar to preceding experiments.

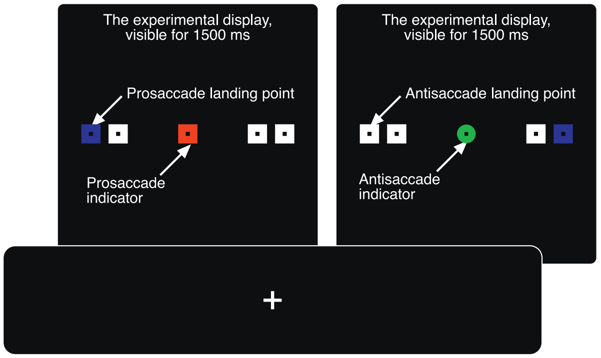
5.2. Results

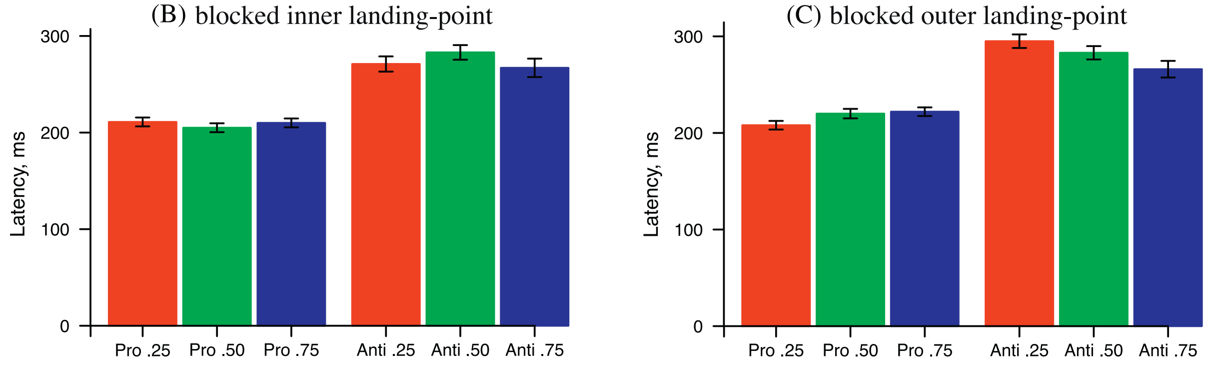
Latencies were higher than in experiments 1 and 2 with a proportionally smaller antisaccade cost, especially in the interleaved task. A four-way repeated-measures ANOVA with probability, saccade-type, task-type and amplitude (6° or 8°) as factors reveled significant main effects upon latency of saccade-type ($F(1,4) = 21.4$, $p = .01$), of task-type ($F(1,4) = 14.4$, $p = .02$) and marginally of amplitude ($F(1,4) = 6.9$, $p = .06$). The main effect of probability was, however, far from significant ($F(2,8) = 0.4$, $p = .67$). The only significant interaction was between saccade-type and task-type ($F(1,4) = 387$, $p < .001$; all other p's > .08) suggesting that task-difficulty depends on both saccade-type and task-type but Fig. 3 suggests that task-type is mainly involved as the latencies in the interleaved task are ≈50% longer than in the blocked task (in contrast to previous experiments where the differences were minimal).

A one-way repeated-measures ANOVA tested the effect of target-location probability separately for blocks of prosaccades, antisaccades and interleaved blocks with respect to inner and outer target-locations. There was a significant effect of probability for blocked antisaccades away from outer stimuli ($F(2,8) = 5.14$, $p = .028$) between the probabilities of .50 and .75 (17 ms; $p = .032$, Bonferroni corrected). There were also significant effects of probability for antisaccades in the interleaved conditions away from inner stimuli ($F(2,8) = 8.6$, $p = .01$) again between the .50 and .75 probabilities (37 ms; $p = .027$, Bonferroni corrected). There were no other significant effects of probability (all p's > .08). No significant differences in error rates were found as a function of probability (all p's > .25). Further exploration of the error rates revealed that they were mainly found in the antisaccade task (58.7%) but 7.8% in the prosaccade (see Table A3 in Appendix A).

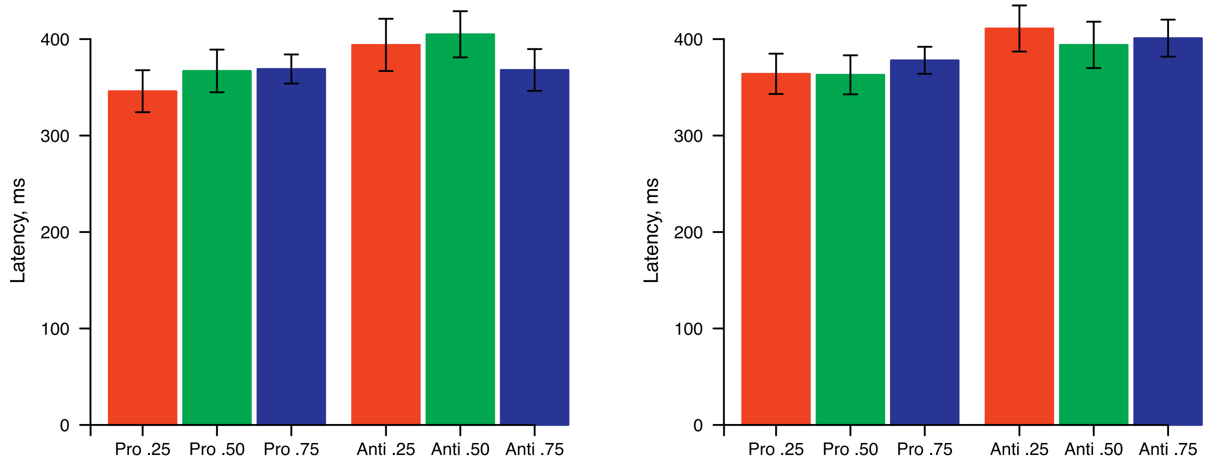
5.2.1. Results: random effects model

In a model with random effects of subjects on saccade-type, task-type, probability and amplitude the intercept was significant (286 ms, $t = 18.1$) as were the slopes of saccade- and task-type were significant (prosaccades: −77 ms, $t = -5.2$ and 111 ms, $t = 3.4$, respectively). The two-way interaction of saccade- and task-type was significant (36 ms, $t = 2.4$) as was the three-way interaction of saccade-type, task-type and probability (.75, 50 ms, $t = 2.4$). Furthermore, the four-way interaction of saccade-type, probability (.75), amplitude (inner stimuli) and task-type (inter-


(A) the experimental procedure


(B) blocked inner landing-point

(C) blocked outer landing-point


(D) interleaved inner landing-point

(E) interleaved outer landing-point

Fig. 3. Experimental procedure and results from experiment 3. (A) Experimental procedure. (B) Results for blocks of anti- and prosaccades made towards the inner stimuli (see panel A). (C) Results for blocks of anti- and prosaccades made towards the outer stimuli. (D) Results for anti- and prosaccades towards the inner stimuli in interleaved blocks. (E) Results from interleaved anti- and prosaccades made towards the outer stimuli. Error bars represent the standard error of the mean (SEM).

leaved) was significant (-98 ms, $t = -3.0$). No other slopes were significant (all t's < 1.8). In the blocked and interleaved prosaccade task the intercept was significant both towards the inner (215 ms, $t = 29.2$ and 375 ms, $t = 8.0$, respectively) and outer stimuli (209 ms, $t = 21.6$ and 356 ms, $t = 9.6$, respectively) but none of the slopes were significant (all t's < 1.6). In the antisaccade task the intercept was significant in the blocked and interleaved, low amplitude task (279 ms, $t = 23.3$ and 391 ms, $t = 6.4$, respectively) and also in the high amplitude task (287 ms, $t = 18.3$ and 398 ms, $t = 9.5$, respectively). The slope of probability of .75 in the high amplitude, interleaved antisaccade task was significant (-40 ms, $t = -2.3$) but no other slopes were significant (all t's < 1.9). The results show a significant effect of probability in the interleaved high probability, high amplitude antisaccade task. Any other evidence for probability effects is weak, only seen in interaction with saccade- and task-type, which both had significant slopes which probability did not.

5.2.2. Results: parameters of ex-Gaussian distribution

The only significant effects of task-type, saccade-type, probability and amplitude on μ revealed by a four-way repeated measures ANOVA was the main effect of saccade-type ($F(1,4) = 16.0$, $p = .016$) and of the interaction between saccade- and task-type ($F(1,4) = 15.9$, $p = .016$; all other p's > .14). An ANOVA with the same factors as in previous analyzes but with τ as the dependent variable revealed no significant effects (all p's > .06). The same AN-

OVA with $\mu + \tau$ as dependent variable revealed a significant main effect of task-type ($F(1,4) = 33.97$, $p = .004$) and a significant interaction of task-type and amplitude ($F(1,4) = 94.68$, $p < .001$) but no other effects were significant (all p's > .19). When a one-way repeated measures ANOVA was run within the experimental condition no significant effects were found (all p's > .13). These analyses showed no significant main effects of probability on the three ex-Gaussian parameters with the only significant effects on μ and $\mu + \tau$ when saccade-type, task-type and amplitude were involved.

5.3. Conclusions of experiment 3

There were only very limited modulation of antisaccade costs from probability manipulations in experiment 3. The very high error rates for the antisaccades indicate that observers found the task very difficult and this limits the conclusions that can be drawn. But most importantly, we still have no clear evidence that target-location probability manipulations modulate antisaccade costs.

It is interesting to compare latencies in experiments 1 and 3. On average, the latency of prosaccades in experiment 1 was 172 ms (SD = 31.1 ms), but 289 ms in experiment 3 (SD = 95.4 ms) a difference of 117 ms. Average antisaccade latencies in experiment 1 were 274 ms (SD = 49.1 ms), 337 ms (SD = 93.1 ms) in experiment 3, a difference of 63 ms. This result (along with the large increase in error rates), suggests that the task in experiment 3 is far more difficult than in experiment 1. This is perhaps not surprising since in previous experiments the decision of whether to make anti- or prosaccades was taken before the target appeared and there were no effects of task-type. The interleaved part of experiment 3 involves a decision stage where the task must be determined from the central fixation stimulus that appears simultaneously with the target and the distractors and – as in the blocked parts – observers had to find the target among three distractors.

6. Experiments 4A and 4B – replication of Liu et al. (2010)

We are yet to find any effects of probability upon the antisaccade cost. Our preceding efforts have been aimed at simplifying the task used by Liu et al. (2010), in part with the aim of making it more suitable for testing patient populations. In experiment 4A we closely followed their procedure to replicate their probability effects. The only difference between experiments 4A and 4B was that experiment 4A was self-paced while each trial in experiment 4B ended with a random ITI followed automatically by the next trial. In self-paced experiments observers can take breaks between trials, which may lead to better performance. The error rates in experiment 3 increased sharply from experiments 1 and 2, probably because of increased task difficulty, and in an attempt to manipulate error rates we ran these two versions.

6.1. Method

6.1.1. Participants

Six naïve volunteers (5 female, aged from 20 to 27 years, $M = 24.6$ SD = 2.8 years) participated in experiments 4A and B, (the same in both, but on different occasions).

6.1.2. Stimuli

The fixation point was a white cross at screen center. The experimental display consisted of a dark gray circle (the saccade-type indicator; 1°, 8 cd/m^2; RGB = [100 100 100]) centered inside a lighter one (2°, RGB = [200 200 200]) when prosaccades were to be made and a light gray circle inside a darker one for antisaccades (see Fig. 4A). On 50% of trials there were 3 blue distractor circles (1°, 6 cd/m^2; RGB = [0 140 210]) and the target was a green circle (1°; 2.7 cd/m^2; RGB = [0 165 66]) and on the other 50% this was reversed. The color of the target and the distractors changed randomly so observers only knew that the target was the "odd-one-out" on any given trial. All stimuli had a central small white dot (39 cd/m^2; RGB = [255 255 255]).[4]

6.1.3. Procedure

The fixation cross appeared for 400 ms followed immediately by the experimental display consisting of the central saccade-type indicator, the target and 3 distractors which were presented 6.5° away from center at the N, S, W and E positions (see Fig. 4A). The display was visible until a saccade was made towards one of the stimuli, or for 2500 ms max. Following each trial in experiment 4A a message telling the observer to press any key when ready to continue was presented while in experiment 4B each trial finished with a random ITI of 400–1000 ms after which the next trial started automatically.

As in Liu et al. (2010), the probability manipulation was only applied to horizontal prosaccades and in one of the two blocks the horizontal prosaccade target appeared 120 times (74.1%) to the left and 14 times in each of the 3 other location (25.9% or 8.6% in each location) while antisaccades were evenly distributed between all four stimulus positions (40 times in each). In the other block the distribution of anti- and prosaccades was the same, except that the high-probability position was to the right. The order of locations within blocks was counterbalanced across observers. Whether observers started by participating in the self-paced (4A) or automatized (4B) version was determined randomly. Each observer participated in 2 blocks of 322 trials in each experiment.

6.1.4. Statistical analyses

We used a two-way repeated measures ANOVA with probability (high/low) and saccade type (antisaccades/prosaccades) as factors and latency as dependent variable. To follow the method of Liu et al. (2010) we split the data into two groups according to probability using a one-way repeated-measures ANOVA to test for effects upon latencies. The high-probability part included prosaccades towards and antisaccades away from high-probability locations (74.1% of prosaccades trials, 25% of antisaccades trials). The low-probability part included prosaccades towards and antisaccades away from low-probability locations (25.9% of prosaccades trials; 75% of antisaccades trials). Trials with signal loss and saccadic latencies shorter than 100 ms or longer than 2500 ms were 10.1% and 11.7% of the data, in experiments 4A and B, respectively. Trials with saccades outside exclusion criteria were 18.4% and 22.1% of the pro- and antisaccade data, respectively, in experiment 4A, while in experiment 4B they were 23.2% and 26.7%. Furthermore, trials with latencies 1.5 × the interquartile range below the first quartile or above the third quartile were also removed from the data (experiment 4A: 291 trials or 7.5% of the total data; experiment 4B: 184 trials or 4.8%). The results, based on 62.1% of the data in experiment 4A and 58.5% in experiment 4B, are shown in Fig. 4. A detailed overview of error rates is provided in Table A4 in Appendix A.

6.2. Results, experiment 4A

The two-way ANOVA reveled a significant main effect of saccade-type ($F(1,5) = 12.48$, $p = .017$), probability ($F(1,5) = 31.31$, $p = .003$) and an interaction of probability and saccade type

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[4] In a pilot test we found out that by adding a white dot at the center of the stimuli (not the saccadic indicator) decreased errors. This is different from the stimuli Liu et al. (2010) used but it is doubtful that this modification will significantly affect the results.

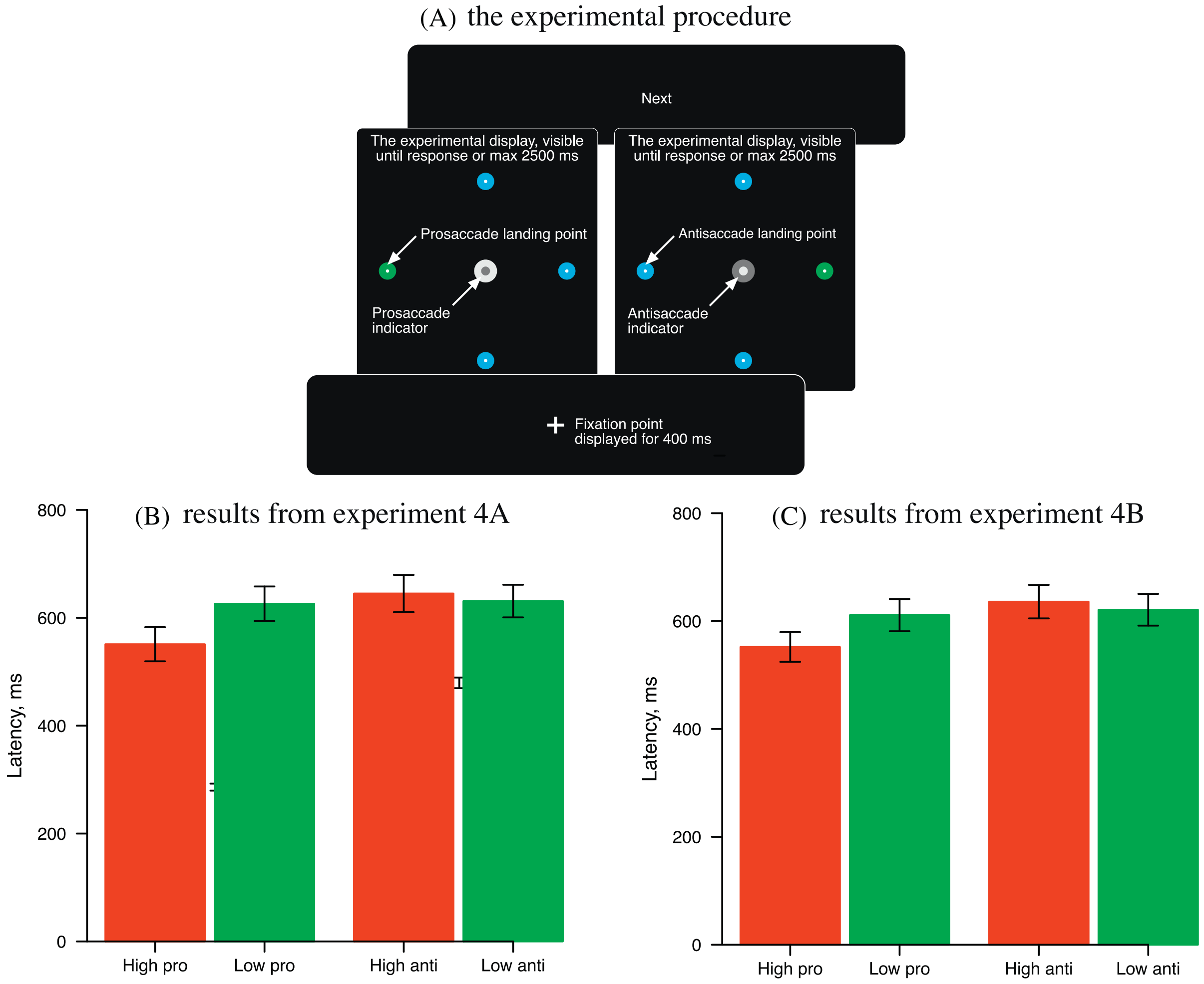

Fig. 4. Experimental procedure and results from experiments 4A and B. (A) Experimental procedure in experiments 4A and B. (B) The results from experiment 4A. (C) The results from experiment 4B. Error bars represent the standard error of the mean (SEM).

($F(1,5) = 10.72$, $p = .022$). In the high-probability condition the main effect of saccade-type was significant ($F(1,5) = 19.9$, $p = .006$; $M_{\mathrm{pro}} = 551$ ms (SD = 155), $M_{\mathrm{anti}} = 645$ ms (SD = 169 ms)) but not for the low-probability condition ($F(1,5) = 0.36$, $p = .732$; $M_{\mathrm{pro}} = 626$ ms (SD = 157), $M_{\mathrm{anti}} = 631$ ms (SD = 148 ms)). Prosaccade latencies in the high-probability condition were 75 ms shorter than of prosaccades in the low-probability condition ($F(1,5) = 25.98$, $p = .003$). This replicates the results of Liu et al. (2010) in that there is no antisaccade cost for low-probability locations where the pro- and antisaccades are equally slow.

6.2.1. Results, experiment 4A: random effects model

All parameters were significant in a model with random effects of subjects on saccade-type and probability. The intercept was 543 ms ($t = 15.2$), the slope of saccade-type was 107 ms (antisaccade, $t = 5.5$) and the slope of probability was 67 ms (low, $t = 7.2$). The slope of the interaction between saccade-type and probability was −92 ms and significant ($t = -5.1$). The intercept of 543 ms in the high-probability condition was significant ($t = 15.1$) as was the 108 ms slope of saccade-type (antisaccade, $t = 5.3$). In the low-probability condition the slope of saccade-type was not significant ($t = 0.6$) but the intercept was (611 ms, $t = 16.2$). The slopes of probability, saccade-type and interaction were significant in accordance with the ANOVA results in 6.2. Furthermore the slope of saccade-type was significant in the high, but not in the low, probability condition, again replicating the results in 6.2.

6.2.2. Results, experiment 4A: parameters of ex-Gaussian distributions

A two-way repeated measures ANOVA with saccade-type and probability as factors and μ (τ and $\mu + \tau$) as dependent variables revealed significant main effects of saccade-type on μ ($F(1,5) = 5.29$, $p = .069$) and $\mu + \tau$ ($F(1,5) = 45.15$, $p = .001$) but not on τ ($p = .64$). The main effect of probability on $\mu + \tau$ was significant ($F(1,5) = 77.51$ $p < .001$) but not on μ and τ (both p's > .3). The interaction between saccade-type and probability was significant for μ ($F(1,5) = 10.14$, $p = .024$) and $\mu + \tau$ ($F(1,5) = 10.47$, $p = .023$) but not for τ ($p = .346$). In the high-probability data the effect of saccade-type on μ ($F(1,5) = 8.68$, $p = .032$) and $\mu + \tau$ ($F(1,5) = 28.44$, $p = .003$) was significant but not on τ ($p = .445$). In the low probability data the effect of saccade-type was never significant (all p's > .5). These results are similar to the results in Sections 6.2 and 6.2.1except that the main effects of probability were not significant on μ and τ in the two-way analyses and the interaction between saccade-type and probability did not significantly affect τ. The results from the one-way analyses are in accordance with the results in Sections 6.2 and 6.2.1except that the effect of saccade-type in the high probability condition on τ was not significant.

6.3. Results, experiment 4B

The main effects of saccade-type ($F(1,5) = 38.3$, $p > .002$), and of probability ($F(1,5) = 130.8$, $p < .001$) and the interaction of saccade-type and probability ($F(1,5) = 109.72$, $p < .001$) were all significant.

In the high-probability condition the main effect of saccade-type was significant ($F(1,5) = 42.3$, $p = .001$; $M_{\mathrm{pro}} = 552$ ms (SD = 135 ms), and $M_{\mathrm{anti}} = 636$ ms (SD = 152 ms)) but again not in the low probability condition ($F(1,5) = 1.97$, $p = .219$; $M_{\mathrm{pro}} = 611$ ms (SD = 146), $M_{\mathrm{anti}} = 621$ ms (SD = 144 ms)). The latency of prosaccades in the high-probability condition was 59 ms shorter than for prosaccades in the low-probability condition and the difference was significant ($F(1,5) = 17.67$, $p = .008$). Again the antisaccade cost is eliminated for the low-probability condition because the anti- and prosaccades are equally slow as in Liu et al. (2010, 2011).

6.3.1. Results, experiment 4B: Random effects model

A model with random effects of subject on saccade-type and probability revealed a significant intercept (632 ms, $t = 19.8$). The slopes of saccade-type (antisaccade: 82 ms, $t = 7.6$) and probability (55 ms, $t = 6.4$) were significant and the interaction of saccade-type (antisaccade) and probability (low) was also significant (−69 ms, $t = -5.4$). In high-probability condition the intercept (550 ms, $t = 19.7$) and the slope of saccade-type (antisaccade: 82 ms, $t = 6.6$) were significant. In the low-probability condition the intercept was significant (604 ms, $t = 22.1$) but not the slope of saccade-type ($t = 1.1$). As in Section 6.2.1these results replicate the results from the ANOVA analyses (in Section 6.3) lending further support to the results of Liu et al. (2010, 2011).

6.3.2. Results, experiment 4B: parameters of ex-Gaussian distributions

A two-way repeated measures ANOVA with saccade-type and probability as factors and μ (τ and $\mu + \tau$) as dependent variable revealed significant main effect of saccade-type on μ ($F(1,5) = 18.52$, $p = .007$), on $\mu + \tau$ ($F(1,5) = 40.77$, $p = .001$) but not on τ ($p = .194$). The effect of probability on $\mu + \tau$ was significant ($F(1,5) = 77.51$ $p < .001$) but not on μ nor τ (both p's > .4). The effect of the interaction between saccade-type and probability was significant on μ ($F(1,5) = 7.86$, $p = .038$) and $\mu + \tau$ ($F(1,5) = 8.25$, $p = .035$) but not on τ ($p = .95$). For the high-probability data the effect of saccade-type on μ was significant ($F(1,5) = 37.34$, $p = .001$) and on $\mu + \tau$ ($F(1,5) = 35.98$, $p = .001$) but not on τ ($p > .27$). For the low probability data the effect of saccade-type was never significant (all p's > .18). As in Section 6.2.1the experimental conditions appear not to interact with the τ-parameter and these results are consistent with what was seen in Section 6.2.1and supports the results in both Sections 6.3 and 6.3.1.

6.4. Conclusions from experiments 4A and 4B

In sum, we replicate the disappearance of the antisaccade cost for the low probability target-locations from Liu et al. (2010, 2011). But the long latencies for both pro- and antisaccades are very notable (compare, for example Figs. 4B and C to Figs. 1B and C). This shows that the task in experiments 4A and B is very difficult. The task may therefore not only measure saccadic execution. Determining which stimulus is the target may be a lengthy process, one that is unrelated to saccade generation. This opens up the possibility that the probability manipulation may affect this decision process rather than processes involved in saccade preparation, per se.

7. Experiment 5. addressing the potential role of block length

The blocks in experiments 4A and 4B, where some effects of probability were found, were much longer than in experiments 1 through 3 and one might argue that the probability effect might show up if the blocks are long enough. Koval, Ford, and Everling (2004) and Noorani and Carpenter (2012)found some evidence of probability in blocks of 200 and 400 trials respectively. To test if longer blocks would reveal effects of probability manipulations we ran a 5th experiment with 300 trials in each block using the same task as in experiment 1.

7.1. Participants

Five naïve female volunteers (aged from 22 to 30 years, $M = 26.8$ SD = 3.6 years) participated in experiments 5 and all of them had participated in other eye-tracking experiments in our lab.

7.1.1. Stimuli and procedure

The stimuli used in the experiment were similar to the stimuli used in experiment 1 as was the procedure with the exception that each of the 6 blocks (3 blocks of antisaccades, 3 blocks of prosaccades) consisted of 300 trials.

7.2. Results

A two-way repeated measures ANOVA with probability and saccade-type as factors revealed strong main effect of saccade-type ($F(1,4) = 406.8$, $p < .001$) and a small effect of probability ($F(2,8) = 5.15$, $p = .037$) but no interaction between the two (($F(2,8) = 2.78$, $p = .165$). To investigate the main effect of probability further we split the data into anti- and prosaccades and ran one-way repeated measures ANOVAs with probability as factor. For the prosaccades there was no probability effect ($F(2,8) = 0.42$, $p = .67$) but for the antisaccade data it was significant ($F(1,4) = 4.9$ $p = .041$). Since the probability effect only shows up in the antisaccade task the results supports our previous conclusions in that, that the probability lends its effect upon the decision process behind the saccades, but not the saccadic preparation per se. Most importantly, however, the probability manipulations had no effect upon the antisaccade cost. There was a strong and similar antisaccade cost at all probability levels: 90, 83 and 78 ms in the .25, .50 and .75 probability conditions, respectively. The percentage of excluded trials (from signal loss, incorrect saccade direction and latencies or landing-points outside criteria) varied between observers from 1.6% to 17.5% so 1484 to 1790 trials were analyzed. There were no significant differences in error rates by probability (all p's > .1; see Table A5 in Appendix A for detailed overview of error rates).

7.2.1. Results, experiment 5: random effects model

In a model with random effects of subjects on saccade-type and probability the intercept of 244 ms was significant ($t = 27.48$) and the slope of saccade-type (latency of antisaccades 83 ms longer than of prosaccades) was also significant ($t = 29.8$). The latency in the low probability condition was numerically 11 ms longer than of it in the median probability and close to significance ($t = 1.99$) but no difference were found between the high- and median probability conditions ($t = 0.16$). The interactions were not significant (both $ps > .17$). It seems when the individuals' differences are taken into account the probability effect found in the repeated ANOVA results disappear, which is perhaps not unexpected since they were miniscule.

7.2.2. Results, experiment 5: parameters of ex-Gaussian distributions

A two-way repeated measures ANOVA with probability and saccade-type as factors and μ (τ and $\mu + \tau$) as dependent variables revealed significant main effects of saccade-type on μ and on $\mu + \tau$ ($F(1,4) = 228.8$, $p < .001$; $F(1,4) = 266.9$, $p < .001$;) but not on τ ($F(1,4) = 6.26$, $p = .067$). The main effect of probability was never significant (all $Fs < 2.5$ and all $ps > .18$) and no interaction was significant (all $Fs < 2.4$ and all $ps > .2$). The results suggest that the probability manipulations do not have any effect on the ex-Gaussian parameters, in good accordance with our previous results. In sum, the results from experiment 5 show that the absence of probability effects in the simple tasks tested in experiments 1 and 2 cannot be traced to the block length.

8. General discussion

The antisaccade task is an important diagnostic tool for various neurological and psychiatric disorders (see e.g. Antoniades et al., 2013; Hutton, 2008; Leigh & Kennard, 2004; Smyrnis, 2008) and has shed light upon decision processes and saccade execution mechanisms (Everling & Fischer, 1998; Kristjánsson, 2007, 2011). Development of new procedures, such as any that may decrease costs connected with performing antisaccades rather than prosaccades is therefore very exciting, potentially allowing greater insights into saccade generation systems and the nature of psychiatric and neurological disorders. The probability effects observed by Liu et al. (2010, 2011) are one such example. It is therefore disappointing if their findings do not generalize well to simpler versions of antisaccade tasks, as our results indicate (see also Clark, Bogacz, & Gilchrist, 2013). In experiments 1 through 3 we did not find any effects of probability but as the task became more difficult antisaccade cost was reduced. In experiments 4A and B we found no antisaccade cost in the low-probability condition replicating Liu et al. (2010; see our Fig. 4).

Latencies of both anti- and prosaccades were shortest in the experiments with the simplest tasks (experiment 1 and 2) and became longer with increasing task complexity as in experiment 3 and were longest in experiments 4A and B (the most difficult tasks). Prosaccade latencies increased from about 172 ms (experiment 1, equal probability of left and right stimuli) to 626 and 611 ms in the low-probability conditions from experiments 4A and B, respectively. Under similar conditions the latency of antisaccades increased from 274 ms in experiment 1 to 631 and 621 ms in experiments 4A and B, respectively. Saccades can be initiated as quickly as in 80–130 ms (express saccades; see e.g. Delinte et al., 2002; Edelman, Kristjánsson, & Nakayama, 2007; Fischer & Boch, 1983) and the latency of regular prosaccades is typically between 170 and 200 ms (Delinte et al., 2002; Leigh & Zee, 2006), as in experiment 1 here. The only cognitive effort in the task of experiment 1 is to decide whether to make a saccade or not and whether to make anti- or prosaccades on interleaved trials – a decision made before the target stimuli appeared – and this is reflected in saccadic latency. It is therefore worth considering whether the critical effects in Liu et al. (2010) do indeed involve processes considered to be the hallmark of antisaccades (disengagement from the target followed by saccade generation; see e.g. Antoniades et al., 2013; Hutton, 2008; Kristjánsson, 2007, 2011; Munoz & Everling, 2004).

In experiment 3, task complexity increased. After deciding which saccade-type to make, observers had to find the target among 3 distractors. The task is therefore a combination of a saccade task and a visual search task. The same applies to experiments 4A and B but in those last 2 experiments the task was even more complex, since observers made either horizontal or vertical saccades depending on target's position. The increased complexity of experiments 3, 4A and 4B, compared to experiments 1 and 2 is clearly reflected in higher latencies. This may simply mean that the probability manipulations affected the visual search, or decision components of the task rather than saccade preparation and execution.

Finally, the tasks in Liu et al. (2010) are probably too complicated for many patient groups severely limiting the appeal of the paradigm for application in clinical settings (Antoniades et al., 2013).

Further evidence regarding effects of task complexity on the antisaccade cost comes from dual-task experiments. Kristjánsson, Chen, and Nakayama (2001; see also Kristjánsson, Vandenbroucke, & Driver, 2004; Mitchell, Macrae, & Gilchrist, 2002; Pashler, Carrier, & Hoffman, 1993; Stuyven et al., 2000, for some converging findings) showed that the antisaccade cost decreases if discrimination stimuli are displayed shortly before the target appears on the screen (their experiment 1). When the discrimination stimuli and target appeared simultaneously, antisaccade latencies were only slightly increased but the increase in prosaccade latency was substantial (as in Jóhannesson, Ásgeirsson, & Kristjánsson, 2012; experiment 3 vs. experiments 4A and B), similar to our experiment 3 where prosaccade latency was about 70% longer, but antisaccade latency only about 30% longer in the interleaved than the blocked task (see Fig. 3). In Kristjánsson, Chen, and Nakayama (2001) the task was to discriminate between two sinusoidal gratings but in our interleaved task the observer had to “discriminate” between whether to make anti- or prosaccades based on color or shape of a central target (see Fig. 3A). This reinforces our proposal that cognitive effort is greatly increased in experiment 3 compared to experiments 1 and 2.

9. Conclusions

Since probability manipulations were only found when decisions based on visual search were to be made, our results suggest that probability manipulations of saccadic latencies and modulation of the antisaccade cost observed by Liu et al. (2010) do not affect saccadic latency, per se, but rather the time taken to discern which stimulus is the target and which saccade-type to make. This may severely limit the usefulness of the findings in clinical settings.

Acknowledgments

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Appendix A.

See Tables A1–A5.

Table A1
Overview of error rates in experiment 1. A three-way ANOVA (factors: block/interleaved; saccade type; probability, .25, .50, .75; dependent variable error ratio) revealed a significant main effect of saccade type ($F(1,19) = 55.04$, $p < .001$) but all other F's < 2.6 and all p's > .095. Comparison within blocks are shown below and in all cases the degrees of freedom were 2, 32.

	F-value	*p*-Value	Probability		
			0.25	0.5	0.75
Prosaccades, blocked	0.83	.446	0.3	0.6	0.9
Antisaccades, blocked	0.08	.925	28.7	35.0	29.5
Prosaccades, interleaved	1.61	.216	3.5	2.6	3.7
Antisaccades, interleaved	0.22	.803	31.3	33.9	28.3

Table A2
Overview of error rates in experiment 2. The main effect of saccade type was significant ($F(1,4) = 13.07$, $p = .022$) but all other effects in a three-way ANOVA factors: block/interleaved; saccade type; probability, .25, .50, .75; dependent variable error ratio) were not significant (all F's < 3.0 and all p's > .11). An overview of more detailed analyses is presented in the table and in all cases the degrees of freedom were 2, 8.

	F-value	*p*-Value	Probability		
			0.25	0.5	0.75
Prosaccades, blocked	0.69	.527	2.5	1.1	2.5
Antisaccades, blocked	2.09	.187	22.3	31.4	27.5
Prosaccades, interleaved	0.33	.730	3.8	3.7	1.9
Antisaccades, interleaved	3.07	.103	23.7	26.9	33.5

Table A3
Overview of error rates in experiment 3. A four-way repeated measure ANOVA (factors: block/interleaved; short/long saccade; saccade type; probability, .25, .50, .75; dependent variable error ratio) revealed a significant main effect of saccade type ($F(1,4) = 22.64$, $p = .009$) but all other F's < 3.0 and all other p's > .16. In the table a more detailed analysis of error rates are shown. In all cases the degrees of freedom were 2, 8.

	F-value	*p*-Value	Probability		
			0.25	0.5	0.75
Long prosaccades, blocked:	2.34	.158	16.2	8.3	16.0
Short prosaccades, blocked	0.17	.884	13.8	13.4	11.9
Long antisaccades, blocked	0.33	.730	56.2	56.5	52.6
Short antisaccades, blocked	3.55	.079	62.3	49.5	50.7
Long prosaccades, interleaved	0.89	.449	4.1	8.6	6.1
Short prosaccades, interleaved	3.18	.096	8.7	3.6	6.1
Long antisaccades, interleaved	0.63	.557	60.0	63.3	54.0
Short antisaccades, interleaved	0.32	.735	59.1	59.4	55.7

Table A4
Overview of error rates in experiments 4A and 4B. A two-way repeated measure ANOVA (factors: saccade-type; probability; dependent variable error ratio) revealed a significant main effect of saccade type (exp 4A: $F(1,5) = 48.69$, $p < .001$; exp 4B: $F(1,4) = 36.69$, $p = .002$) but all other F's < 3.2 and all other p's > .13. In the table more detailed analyses of error rates are shown. In all cases the degrees of freedom were 1, 5.

	F-value	*p*-Value	High prob.	Low prob.
E 4A: Prosaccades	20.56	.006	18.3	32.9
E 4A: Antisaccades	0.19	.667	61.7	56.7
E 4B: Prosaccades	4.19	.096	21.2	35.1
E 4B: Antisaccades	0.61	.469	55.4	61.7

Table A5
Overview of error rates in experiment 5. A two-way ANOVA (factors: saccade type; probability, .25, .50, .75; dependent variable error ratio) revealed significant main effect of saccade type ($F(1,4) = 7.88$, $p = .049$) but both other F's < 2.5 and both p's > .14. Comparisons within blocks are shown below and in all cases the degrees of freedom were 2, 8.

	F-value	*p*-Value	Probability		
			0.25	0.5	0.75
Prosaccades	3.04	.104	5.9	5.7	8.2
Antisaccades	1.48	.284	10.8	6.7	10.7

Appendix B.

See Fig. B1.

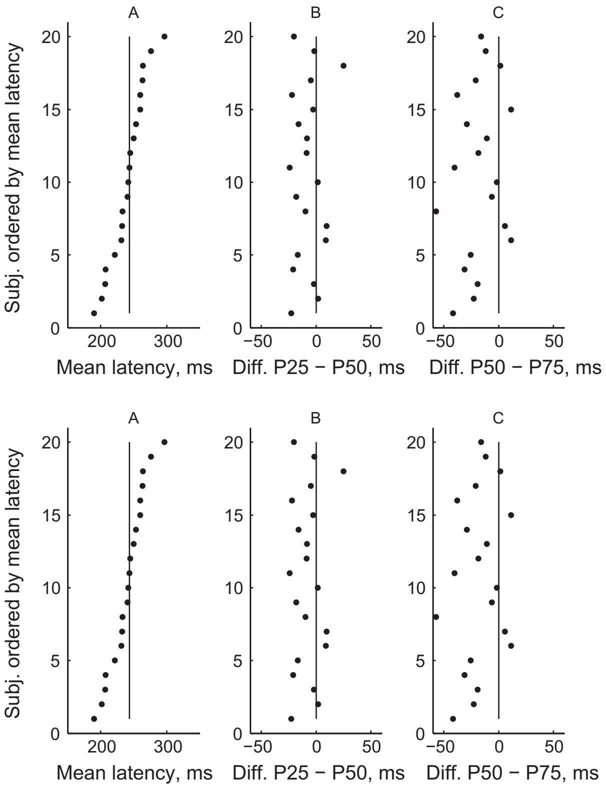

Fig. B.1. Probability effects of anti and prosaccades in experiment 1. The probability effects of antisaccades are shown in the upper row and prosaccades in the lower row. The data points are all sorted with respect to mean latency. In panels A and D the solid line represent the mean and in the other panels it represent no difference. As can be seen in the figure the individual differences are considerable but seem not to be related to latency.

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