Dual Target Search is Neither Purely Simultaneous nor Purely Successive.

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Abstract

Previous research shows that visual search for two different targets is less efficient than search for a single target. Stroud, Menneer, Cave and Donnelly (2012) concluded that two target colours are represented separately based on modeling the fixation patterns. Although those analyses provide evidence for two separate target representations, they do not show whether participants search simultaneously for both targets, or first search for one target and then the other. Some studies suggest that multiple target representations are simultaneously active, while others indicate that search can be voluntarily simultaneous, or switching, or a mixture of both. Stroud *et al.'s* participants were not explicitly instructed to use any particular strategy. These data were revisited to determine which strategy was employed. Each fixated item was categorised according to whether its colour was more similar to one target or the other. Once an item similar to one target is fixated, the next fixated item is more likely to be similar to that target than the other, showing that at a given moment during search, one target is generally favoured. However, the search for one target is not completed before search for the other begins. Instead, there are often short runs of one or two fixations to distractors similar to one target, with each run followed by a switch to the other target. Thus, the results suggest that one target is more highly weighted than the other at any given time, but not to the extent that search is purely successive.

Keywords: target representations, attention, visual search, search guidance, eye movements.

Visual search often requires a mental representation specifying the characteristics of the search target in order to guide attention. In search for two dissimilar targets, however, there is often serious difficulty in representing both items, leading to costs in performance over single-target search (Hout & Goldinger, 2015; Menneer, Barrett, Phillips, Donnelly, & Cave, 2004, 2007; Menneer, Cave, & Donnelly, 2009). This cost in search guidance can take the form of extra fixations to colours that are dissimilar to either target (Grubert & Eimer, 2013; Menneer, Stroud, Cave, Li, Godwin, & Liversedge, 2012; Stroud et al., 2012; Stroud, Menneer, Cave, Donnelly, & Rayner, 2011).

There is evidence that the two search targets can be represented separately, with both representations simultaneously guiding attention (Barrett & Zobay, 2014; Grubert & Eimer, 2015; 2016; Irons et al., 2012). However, other evidence indicates that the search strategy can be influenced voluntarily, creating simultaneous active representations or a switching between representations (Beck et al., 2012). In some cases a mixture of both may be used, with search being biased towards the previous target (Cain & Wolfe, 2015; Wolfe, Aizenman, Boettcher, & Cain, 2016). In addition, guidance can vary depending on the attentional demands of the task (Kristjánsson, Jóhannesson, & Thornton, 2014).

Beck et al. (2012, Experiment 2) asked participants to search for a particular Landolt C. The target C was always one of two colours, and distractors Cs were one of four colours, including the target colours. Half of the participants were instructed to search for both colours simultaneously and the other half to search first for items of one colour and then switch to the other colour (the switch condition). In the switch condition, participants fixated multiple items of one colour, then multiple items of the other colour, with long run lengths of each colour, and a switch cost in time between runs. In the simultaneous condition, participants had much shorter runs, with multiple runs for each colour, and exhibited no switch cost. The results show that there is voluntary control over the strategy used, and that participants can decide to keep two target representations active simultaneously. These results contrast with those of Wolfe et al. (2016), who used many targets in a foraging task, and showed more efficient behaviour when searching for one target-type than when switching between targets.

To get a clearer view of how participants search for two dissimilar targets, we reexamine data from Stroud et al. (2012), a dual-target search study in which participants were not instructed to use any particular strategy (simultaneous search or switching between two targets). Based on their original analyses and modelling, Stroud et al. (2012) concluded that the two target colours are represented separately; however they did not test whether participants searched simultaneously for both targets (simultaneous search) or searched first for one target and then search for the other (successive search).

We approach the issue of simultaneous versus successive search in two different ways. To assess the possibility of simultaneous search, we look at the probability that each fixation is guided by the same target colour as the previous fixation. If both target colours are actively guiding search simultaneously, then the colour selected for one fixation should be unrelated to the colour of the previous fixation. To assess the possibility of successive search, we examine the order in which different colours are fixated. Under successive search, there should be a run of fixations to objects similar to one of the targets, and then a switch that starts a run to objects similar to the other target. The results are not consistent with either purely successive or purely simultaneous search.

Method

The current data are from the condition in Stroud et al. (2012) in which participants searched for two targets that were 4 steps apart in stimulus colour space. The description below summarises the method in Stroud et al. (2012), with a focus on information relevant to the current re-examination.

Participants

Sixteen University of Massachusetts students with normal colour vision (Ishihara, 1917) and normal or corrected-to-normal acuity (self-reported) participated for course credit.

Stimuli

Stimuli were Ts (targets) and offset Ls (distractors) each constructed from two rectangles 2.5° x 0.5° of visual angle, which were joined with a symmetrical offset of 1° for the T and joined asymmetrically for the L with offsets of 0.3° and 1.7°, with the aim that difficult discriminability should encourage fixations. Each object appeared in one of sixteen colours spaced in a ring in CIExyY space (See Figure 1, top panel; Menneer et al., 2007).

Each display contained ten objects on a white background. All were Ls, except one that was a T on target-present trials. Objects were placed in a circle with a radius of 7.3° visual angle, and appeared at orientations of 0°, 90°, 180°, or 270°(See Figure 1, bottom panel).

Each participant was assigned a different pair of coloured Ts as targets, with the two colours being 4 steps apart in the stimulus colour space (See Figure 1, top panel). All colour pairs were used across the 16 participants. Each distractor's colour was selected randomly from the 16 colours, including the two target colours. Target and distractor orientations were also chosen randomly, with each colour-orientation combination being represented equally often among the distractors across the set of trials.

Apparatus

The stimuli were presented on a 17-inch Vision Master Pro 514 iiyama CRT monitor attached to a computer interfaced with an SR Research Limited Eye-Link II eye tracking system operating at a sampling rate of 250 Hz. Participants viewed the stimuli binocularly, but only the right eye was tracked. Participants were seated 57 cm from the monitor with the entire display subtending 39.2° x 29.0° of visual angle. Pupil position and corneal reflections were tracked to no more than .40° of error, while participants kept their head stationary in a chin rest. Participants responded on a Microsoft game controller.

Procedure

Each trial comprised 1) a dot at the centre of the screen, 2) presentation of the two possible target Ts for 1000 ms, 3) a central fixation point, 4) presentation of the search array until response. The task was to indicate whether or not a T was present or absent in the display. One target at most was present on each trial. There were 5 practice trials followed by 256 experimental trials. Each target was presented on 64 experimental trials.

Analyses and Results

First we present the overall patterns of eye movements (number of fixations, distance of fixations from objects, saccade lengths, and number of objects fixated) from the data aggregated across participants in order to characterise search behaviour and identify any patterns that emerge during the course of a trial. We then examine the key question of whether participants use simultaneous or successive search. In order to address this question, each of the 16 colours was categorised according to whether it was more similar to one target or the other. Under successive search, there should be a run of fixations guided by one target colour, followed by a run guided by the other target colour. Under simultaneous search, there should be many switches between target colours throughout the trial, and the colour of the previous fixation should not affect the colour of the current fixation.

General Pattern of Fixations and Saccades

The number of fixations on each trial varied across a wide range, as shown in the left panels of Figure 2. For target-absent trials, the overall mean of subject means was 9.5, and the overall mean of individual subject medians was 9.4. For target-present trials, the mean was 5.7, and using medians it was 5.2. All data presented and all analyses exclude the first fixation recorded for the search task (fixation 1), which was centrally located, and began either before (during the drift correct) or very shortly after the display was presented. The saccade data also exclude the first recorded saccade, which originated at fixation 1 at the centre of the display. The data presented here include trials with erroneous responses, but the results are very similar if those trials are removed.

Each fixation was assigned to the nearest object. The top panel of Figure 3 shows the distribution of the distances between fixations and their assigned objects. These distributions are plotted separately for each of fixations 2-8. Overall, the distributions are very similar whether they occur early or later in a trial, but fixation 2 of each trial stands out as different. That fixation is generally the endpoint of a saccade that goes from the centre of the display to a part of the stimulus array. The distribution for fixation 2, shown by the red line in the top panel of Figure 3 with error bars added, is shifted to the right relative to the others, indicating that this fixation tended to fall farther away from the object than the later fixations. Some of these initial fixations may not have been guided to a single object, but to a group of two or more objects, so that they landed close to the "centre of gravity" of the group.

The distance from one fixation to the next tends to be fairly short. The bottom panel of Figure 3 shows the distribution of saccade lengths for the 2^{nd} through the 8^{th} saccades. For a saccade from one stimulus item to either of the two items that are closest to it in the circular search array, the length will be 4.51 degrees of visual angle, which is indicated by the leftmost grey dashed vertical line on the graph. The other dashed lines indicate the distances for objects that are 2, 3, 4, or 5 positions away around the stimulus circle.

The distribution of lengths for saccade 2 is shown in the reddest line in the graph (Figure 3, bottom panel). It includes more very short saccades of just one or two degrees, suggesting that many of these initial saccades were small positional adjustments from the centre-of-gravity fixations mentioned above. For the saccades after saccade 2, the modal length was a bit less than the distance from one object to its nearest neighbours. There are relatively few saccades that travel long distances across the display.

Given that there were more than 10 fixations on a number of trials (Figure 2, left panels), it is clear that many objects were fixated repeatedly. When the target was absent, a mean of only 6.6 of the 10 objects were fixated at least once (Using medians, the value is also 6.6.) In a number of target-absent trials, all 10 items are fixated. When a target was present, the mean number of objects fixated at least once was 4.0 (3.8 with medians). If search was self-terminating, we would not expect the mean to be above 5 for target-present trials, even if it was unguided; thus a rather large proportion of the potential maximum of 5 objects are being fixated. See the right panels of Figure 2 for the distributions of these values.

Classification of Stimulus Colours

In order to address the main question regarding successive or simultaneous search, each fixation had to be classified in terms of the relationship between the colour of the object being fixated and the target colours. The similarity of each of the 16 stimulus colours to the two targets was quantified in terms of steps around the stimulus colour circle. For instance, consider the reddish-orange square at the top of the circle in Figure 4, just to the right of centre. It is one step away from the orange target to its left, as indicated by the “1” above it, and it is three steps away from the pink target to its right, as indicated by the “3” below it. A score was calculated by subtracting these two distance values for this colour and every other colour. For the reddish-orange square, 1 – 3 = -2, which is the score shown in the middle of the square. It indicates that it is two steps closer to the orange target than to the pink target. Negative values are closer to the orange target than the pink, and positive values are closer to the pink target. For each target-colour pair, there are two colours with a score of zero, meaning the colour is equally similar to both target colours. These two colours are referred to below as “neither-target colours”. The remaining 14 colours were assigned to one target category or the other, depending on which target is more similar. Of these 14 colours, there are four colours that are weakly more similar to one target than the other, with scores of ±2, and there are ten colours that are strongly more similar to one target than the other, with scores of ±4.

Are Both Targets Searched For Simultaneously With Equal Weighting?

We tested whether participants searched for both targets simultaneously. If both targets were equally weighted throughout search, then each fixated colour should be unrelated to the previously-fixated colour. The results instead show that each fixated colour was more likely to be in the same target category as the previously-fixated colour than the other target category.

Each fixated colour was first categorised as either strongly similar (±4) or weakly similar (±2) to one of the targets, or equally similar (0) to both targets (“Neither-Target”). In the top panel of Figure 5, the proportions of strongly similar fixated colours are on the left of the graph, and the weakly similar fixated colours are on the right. The fixations within these two categories are further categorised according to whether its target category matches the target category for the previous fixation. For fixated colours that are strongly similar to a target, the target colour guiding the fixation is likely to be the same target colour that guided the previous fixation, $t(23.1) = 4.6, p < 0.001, d = 1.6$. For fixated colours that are weakly similar to a target, the effect is also significant, $t(25.7) = 2.4, p < .05, d = 0.8$. These analyses include some fixations that are to the same object as the previous fixation; if those refixations are removed, then the result is still significant for fixations to colours that are strongly similar to a target, $t(29.6) = 2.4$, $p < 0.025$, $d = 0.8$. For colours that are weakly similar to a target, the difference is still in the same direction, but it is no longer significant, $t(30.0) = 0.8$, $p = 0.405$, $d = 0.3$. Thus, even this conservative measure indicates that one target is often favoured over the other in the course of search.

It is the results with the refixations removed that are shown in the top panel of Figure 5, and also in the bottom panel, which presents additional evidence that the colour chosen for each fixation tends to match the target-colour category that guided the previous fixation. All fixations were categorised according to the target category of the *previous* fixation, represented by the two lines on the graph. One target has the colour at position 3 on the x-axis of the bottom graph in Figure 5, which would correspond to the pink target in the example in Figures 1 (top panel) and 4. The other has the colour at position 15, which corresponds to the orange target in the previous figures. There were more fixations to colour 3 and neighbouring colours when the previously-fixated colour was similar to this target colour, and more fixations to colour 15 and neighbouring colours when the previously-fixated colour was similar to this target colour. This graph shows only data from the target-absent trials. There is a similar pattern in the target-present trials, but interpretation is complicated by the high number of fixations to the target, which might reflect guidance by shape as well as colour.

Is Search Successive?

The preference for the previously-fixated target category suggests that search is guided primarily by one target at any given time. However, switches between targets do occur, as reflected by the fixations falling in the “Different from Previous Category” type in the top panel of Figure 5. In this section, we ask whether the switch to the other target occurs only after search for the first target is complete.

A run is defined as a series of fixations to colours that are all similar to the same target: that is, they are in the same target category. When one of the neither-target colours is fixated in the course of a run, it is considered part of that run. If two consecutive fixations both select the same object, they are counted as two separate fixations within the run. A switch is a transition from fixating one target category to fixating the other. A switch marks the end of one run and the beginning of another.

We focus on target-absent trials, because search could be terminated before a switch once the target is found in target-present trials. When the target is absent, the mean run length is 2.4 fixations (1.9 based on medians). The mean number of switches per trial is 2.8 (2.9 based on medians). (Note that the number of runs in a trial is one more than the number of switches e.g., 3 switches leads to 4 runs.) Some trials begin with one or more fixations to neither-target colours; these fixations are not included in a run and are not part of a switch.

If participants were searching exhaustively for one target before switching to the other (i.e., purely successive search), we would expect one switch together with runs of 4 to 5 fixations on average. This value is predicted because, of the 16 colours, 7 of them are similar to one target, 7 to the other target, and 2 are neither-target colours. Therefore, on average, 7/16 of the 10 display items are in a given target category, giving 4.4 items to fixate before switching.[1] The observed run length (mean = 2.4, see above) is significantly below this prediction, $t(15) = -34.1$, $p < .0001$, $d = 8.5$.

The left side of Figure 6 shows that there are many runs with just one or two fixations. Given that the distractor colours were assigned randomly, there will be some trials with only a small number of items that are similar to a particular target, but the large number of short runs here is inconsistent with successive search in which the entire display is searched for one target before search shifts to the other target. However, these histograms do not show what proportion of the search is conducted with short runs and what proportion is conducted with long runs, because a single long run includes many fixations (i.e., a relatively high proportion of search). Figure 7 shows the proportion of search that occurred within runs of each length by totalling fixations for each run length. When organized this way, the mean

[1] The value of 4.4 is conservative, because it does not take into account the neither-target colours that were included as part of a run, which would make the actual prediction somewhat higher.

run length is 3.7 (3.1 based on medians). Even after this adjustment, it is clear that a large proportion of the searching was conducted within short runs of 1-3 fixations.

Given the large number of short runs, there must be more than one switch in most trials, which is confirmed in the graphs on the right side of Figure 6. The high number of switches shows that search is not purely successive; search for one target is usually not completed before search for the other target begins.

It seems intuitive that run length should decrease as the number of switches increases, a pattern that is not immediately apparent by comparing the left and right sides of Figure 6. However, the relationship between run length and number of switches also depends on the total number of fixations in a trial, which varies over a wide range. Also, each trial can include runs of very different lengths. Note that for target-absent trials, the mean number of fixations per trial (9.5) divided by the mean run length (2.4) produces 4.0 runs per trial, which is consistent with the mean number of switches of 2.8 per trial.

Discussion

The results of our reanalysis of the data from Stroud et al. (2012) show that this search task usually elicits a number of fixations that cover a large proportion of the objects in the search array, and that the distance from one fixation to the next is usually short, suggesting relatively thorough search. Perhaps the most important finding is that search in that experiment is not purely successive: there are too many switches and the runs are too short. Neither is search purely simultaneous: the objects selected for fixations are biased towards the target category of the previously-fixated item, showing that at a given moment during search, one target is generally favoured over the other. Consistent with the findings of Wolfe et al. (2016), the data instead show a short run on one target followed by a switch and a short run on the other.

We suggest four possible non-mutually-exclusive explanations for our findings. The first is that search is driven by two target representations that are not always equally weighted, such that one guides search more than the other at a given moment in time, but does not dominate attentional guidance to the extent that search for one target is completed before the next one begins. Such unequal guidance has been found when targets differ in prevalence (Godwin, Menneer, Riggs, Cave, & Donnelly, 2015; Hout, Walenchok, Goldinger, & Wolfe, 2015). Here, unequal weighting of activation may be driven by priming from the previously-fixated colour or the target colour on the previous trial. However, Beck & Hollingworth (2014) found no evidence for priming of the currently fixated object colour in selection of the next object to fixate.

The second account is that different participants use different strategies (successive versus simultaneous), or that strategies change across trials. However, if there was a clear distinction between the two types of search, then we would expect a high number of very short runs accompanied by many switches, as well as a high number of long runs accompanied by few switches. The graphs in Figure 6 show no evidence of a bimodal pattern in numbers of runs and switches.

The third possibility is that participants may serially shift from one spatial region to another during search (e.g., Findlay & Brown, 2006), with each region containing a few items. Within a region, they might search first for one target and then the other. Such behaviour would result in short runs, many switches, and evidence of weighting one target colour more strongly than the other at any given time, consistent with our observations. Using this strategy would have the advantage of limiting long saccades. However, our stimulus circle was <20° diameter; for these short distances, we would not expect saccade latency to increase with eccentricity (Findlay, 1983), so time to program saccades should not be a motivation to limit long saccades. There are also previous data from other studies suggesting that the cost of performing eye movements is not a strong motivation to limit them: Wu, Kwon, and Kowler (2010) found that increasing the rate of producing saccades is favoured over time spent planning saccades. In addition, Cain and Wolfe (2015) found that participants skipped over targets that were of a different type to the previously fixated item in favour of targets of the same type, suggesting that spatial location has less of an influence on item selection than featural properties do. In the current study, the data show that participants tended to make relatively short saccades (Figure 3, bottom panel).

The fourth account is based on colour grouping within each spatial region. If there are regions with adjacent items that are similar in colour to each other and to one of the targets, then the activation map created to guide search (Guided Search: Wolfe, Cave, & Franzel, 1989) would have a strong activation in this area, thereby attracting attention to search those items before moving to the next colour group. This possibility could be tested with displays that have controlled regions of similar-colour items. The account would be supported by short saccades between similar colours and fewer long saccades between dissimilar colours.

It is interesting that the modal number of switches is 2 (in target-absent trials). By definition, participants must be searching for one target, then the other, then returning to the first target, which suggests a reconfirmation of evidence for the first target. The need for such checking behaviour is consistent with increased load in dual-target search (Hout & Goldinger, 2010; Menneer, Kaplan, Stroud, Cave, & Donnelly, 2014, Menneer et al., 2009; Mestry, Menneer, Cave, Godwin & Donnelly, under revision, Stroud et al., 2012).

Foraging studies have often observed optimisation of search strategies to obtain high rewards (Cain, Vul, Clark, & Mitroff, 2012; although see Wolfe, 2013). Future experiments could test for adaptability and optimisation of the search strategy in dual-target search by manipulating display characteristics to favour one strategy over the other.

In conclusion, in this dual-target search task, with items of many different colours and no instructions about search strategy, items are fixated in a pattern that reflects neither a single simultaneous search nor two successive searches. While previous research has found that multiple target representations can be used simultaneously (Barrett & Zobay, 2014; Beck et al., 2012; Grubert & Eimer, 2015; 2016; Irons et al., 2012) or successively (Beck et al., 2012), participants without explicit instruction actually favour one target over the other at any given time, but not to the extent that they search for it exclusively.

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Figure Captions

Figure 1: *Top: The stimulus colour space, comprising 16 colours. The squares with black borders indicate one example target-colour pair, 4 steps apart in the stimulus colour space. Each colour is numbered. The numbers on the outside of the circle represent the distance of each colour from target-colour 15, and the numbers on the inside represent the distance of each colour from target-colour 3. Distance is measured in steps around the stimulus colour circle. Bottom: A sample search display, comprising 9 L distractors and 1 T target.*

Figure 2: *Left: The number of trials with a given number of fixations. As would be expected, there were generally more fixations on target-absent trials (top graph) than target-present trials (bottom graph). Right: The number of trials with a given number of objects that were fixated at least once.*

Figure 3: *Top: Distributions of the distances between each of the fixations 2-8 in each trial and the center of the object nearest each fixation. Fixation 1 is omitted because it is at the centre of the display. The distribution for the 2^{nd} fixations are shown by a red line; the distributions for the 8^{th} fixations are shown by a blue line, and the lines for the fixations between 2^{nd} and 8^{th} are in corresponding shades of red and blue, as shown in the legend in the upper right corner. Fixations after the 8^{th} on each trial are omitted. Distances tend to be somewhat longer for the 2^{nd} fixation, but the distributions appear to be fairly consistent across the other trials. Error bars showing the standard error of the mean have been added to the line for the 2^{nd} fixation to allow comparison. Bottom: Distributions of the saccade lengths for saccades 2-8. The 1^{st} saccade is omitted, because it will originate from the initial fixation at the centre of the display. The line for saccade 2 is in red, and the line for saccade 8 is blue, and the saccades in between are corresponding combinations of*

red and blue. The dashed vertical lines indicate the distances from a stimulus item to other items that are 1-5 positions away on the stimulus circle. Error bars showing the standard error of the mean have been added to the line for the 2nd saccade to allow comparison.

Figure 4: *Each of the 16 colours is assigned a number calculated by subtracting the distance to one target from the distance to the other target. Targets are indicated by a black border around the colour square. The numbers on the outside of the circle represent the distance of each colour from the orange target-colour (at the top of the circle), and the numbers on the inside represent the distance of each colour from the pink target-colour (on the right of the circle). The difference between the two distances is given within the colour square. This value dictates the target category into which the colour falls, with negative values falling into the orange target category, positive values falling into the pink target category, and values of zero falling into the "neither-target" category.*

Figure 5: *Top: Each fixation is categorised by the relationship between its object's colour and the more similar target colour. The more similar target colour presumably reflects the target representation that guided the fixation. The "strongly similar" colours on the left are much more similar to one target than the other, while the "weakly similar" colours on the right are only slightly more similar to one target than the other. Each of these groups is further segregated according to whether the target colour guiding this fixation is the same as that for the previous fixation. The proportion of fixations to colours that are equally similar to both targets (10%) is shown by the dashed horizontal line. Target-absent and target-present trials are combined. Fixations to the target are included. Bottom: Frequency of fixations to each distractor colour split by the target category of the previously-fixated colour.*

Target-absent trials only. The two target colours are marked by vertical bars. As indicated by the labels, Target A corresponds to the pink target in the examples shown in Figures 1 (top) and 4, and Target B corresponds to the orange target.

Figure 6: *Left: Frequency of runs of a given length. There are more fixations overall, and thus more runs, for the target-absent trials (top graph) than for the target-present trials (bottom graph). Right: Frequency of number of switches in target-absent (top graph) and target-present trials (bottom graph).*

Figure 7: *The total number of fixations in runs of each length, which captures the proportion of search conducted by runs of each length.*

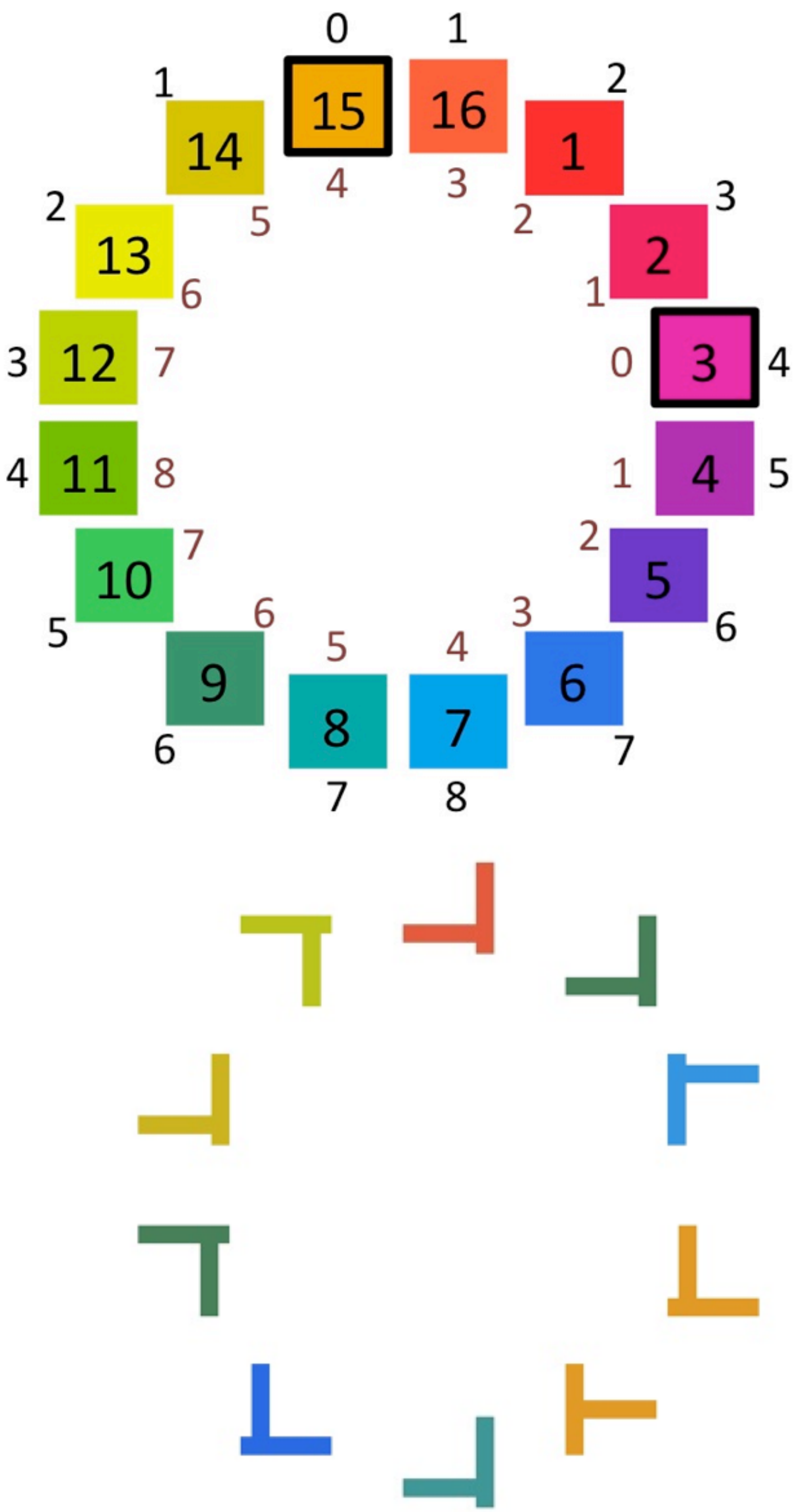

0 1
1 2
15 16
14 1
4 3
2 5 2 3
13 2
6 1
3 12 7 0 3 4
4 11 8 1 4 5
7 2
10 5
5 6 3 6
9 5 4 6
8 7
6 7
7 8

Figure 1

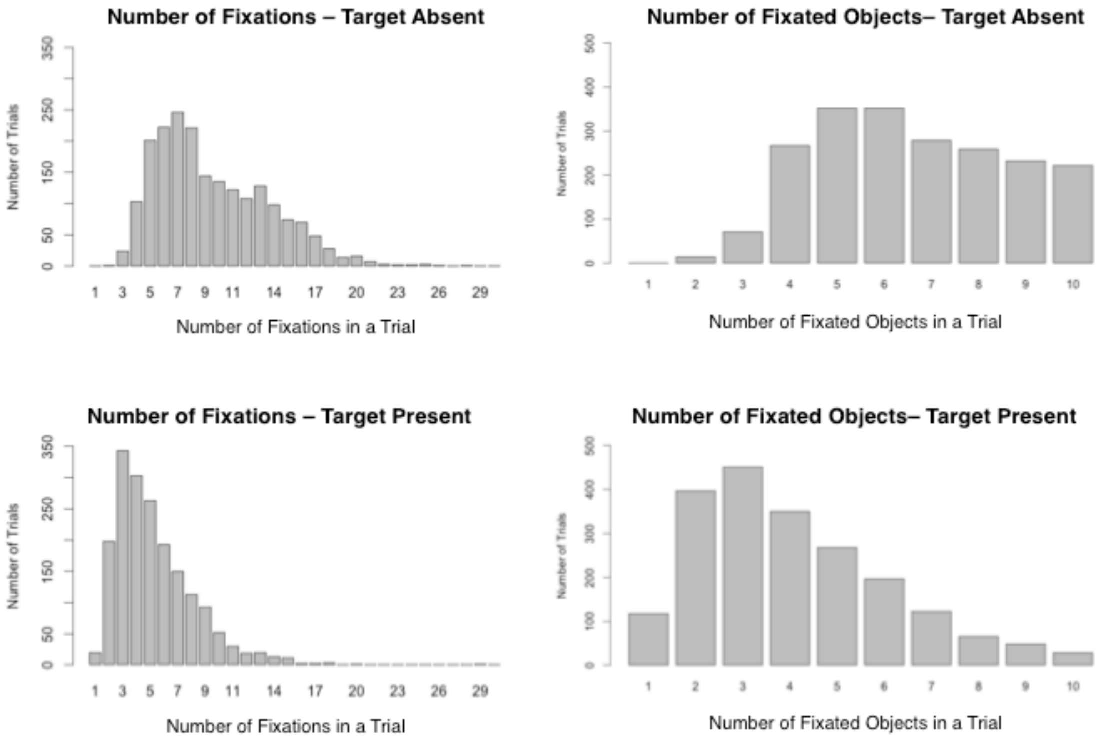

Number of Fixations – Target Absent
Number of Trials
Number of Fixations in a Trial
Number of Fixated Objects– Target Absent
Number of Fixated Objects in a Trial
Number of Fixations – Target Present
Number of Trials
Number of Fixations in a Trial
Number of Fixated Objects– Target Present
Number of Fixated Objects in a Trial

Figure 2

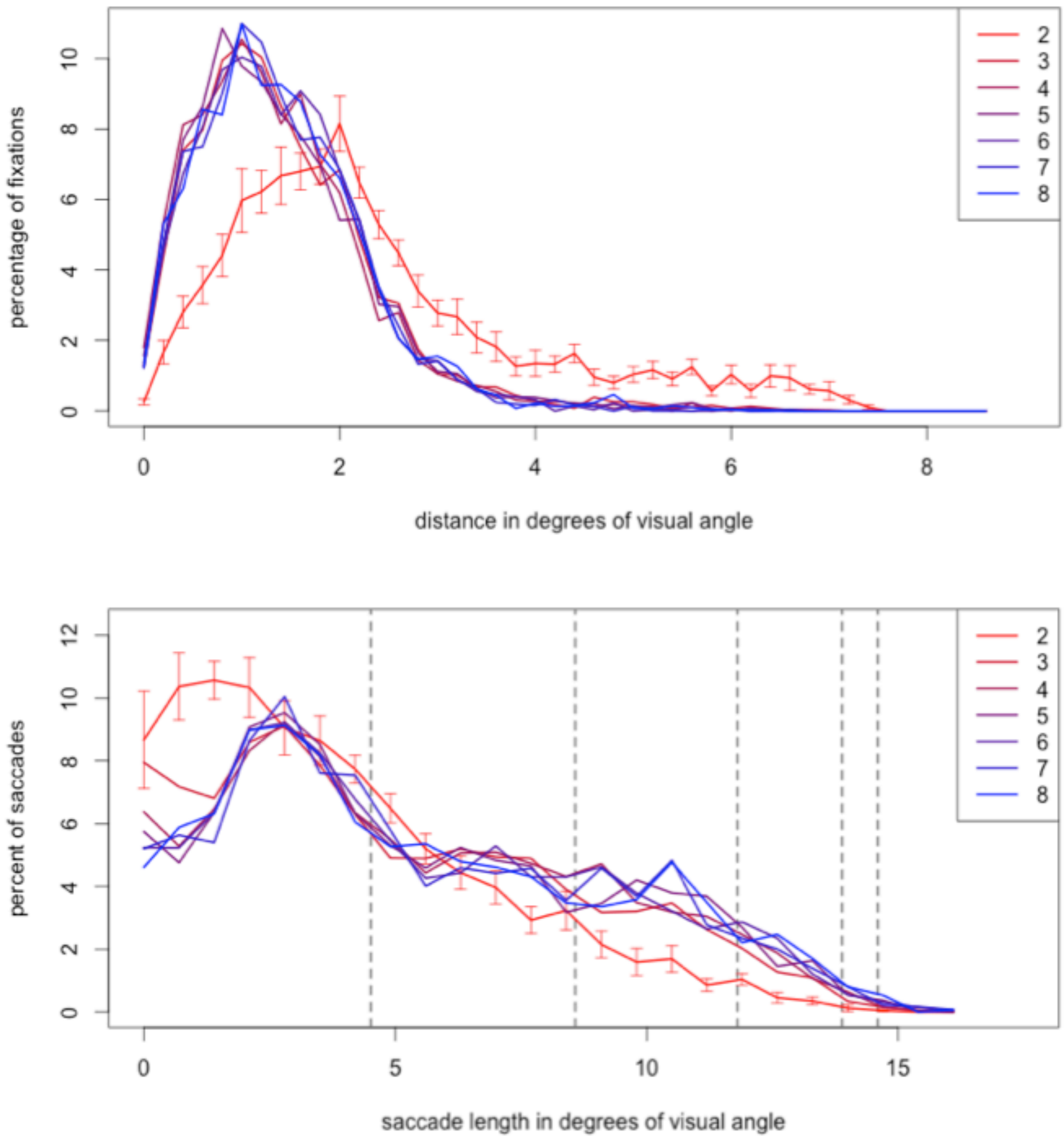

percentage of fixations
distance in degrees of visual angle
percent of saccades
saccade length in degrees of visual angle
0
2
4
6
8
10
12
5
15
3
7

Figure 3

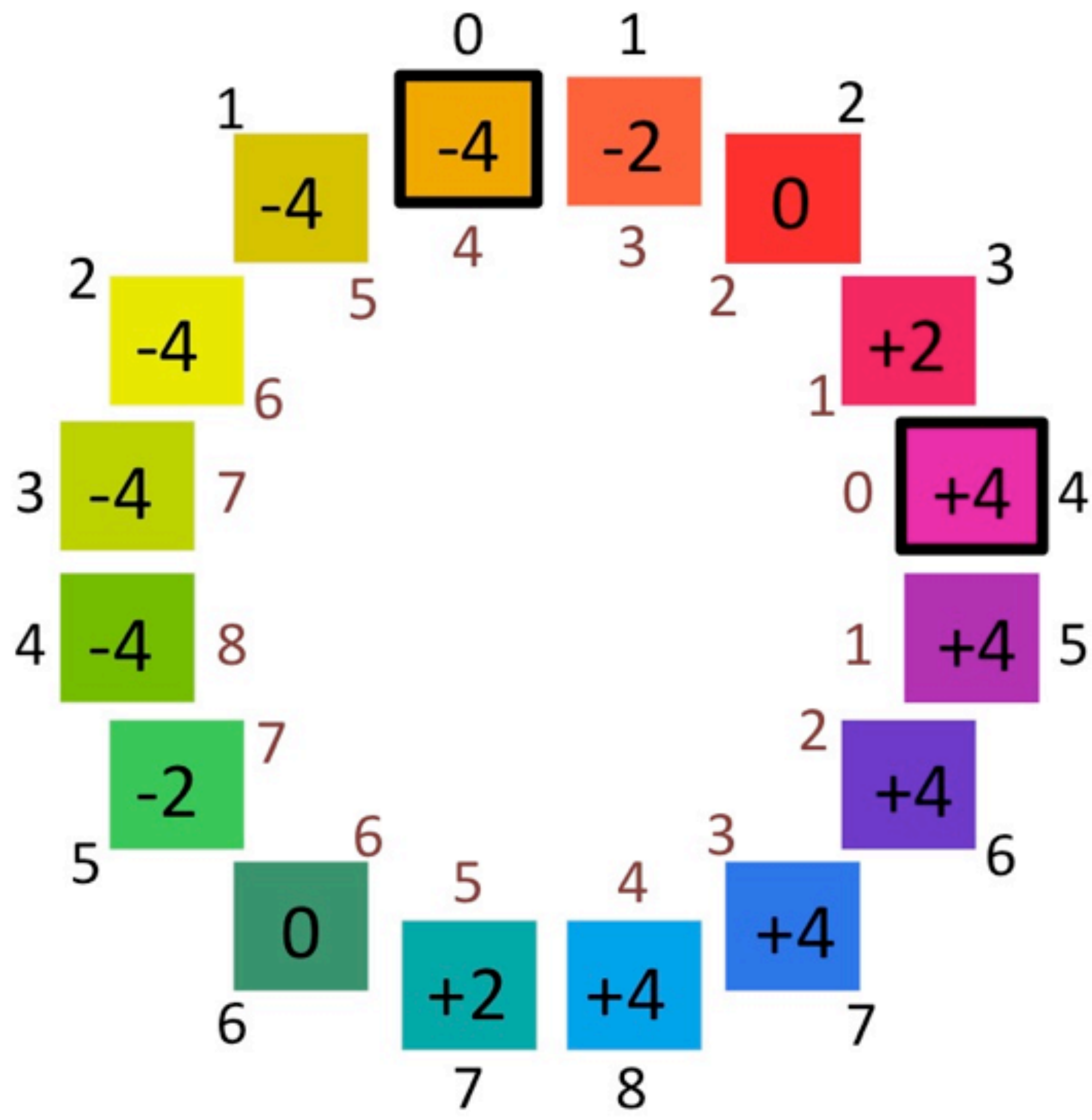
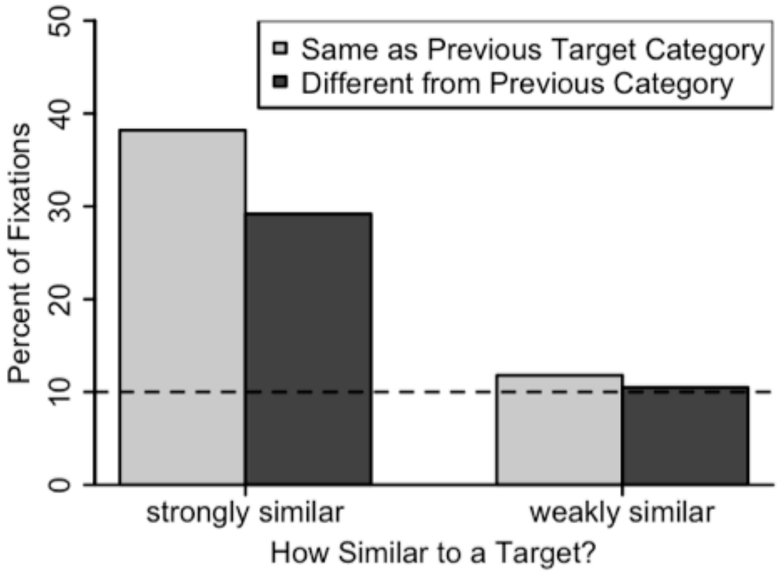


Figure 4


Same as Previous Target Category
Different from Previous Category
Percent of Fixations
0
10
20
30
40
50
strongly similar
weakly similar
How Similar to a Target?

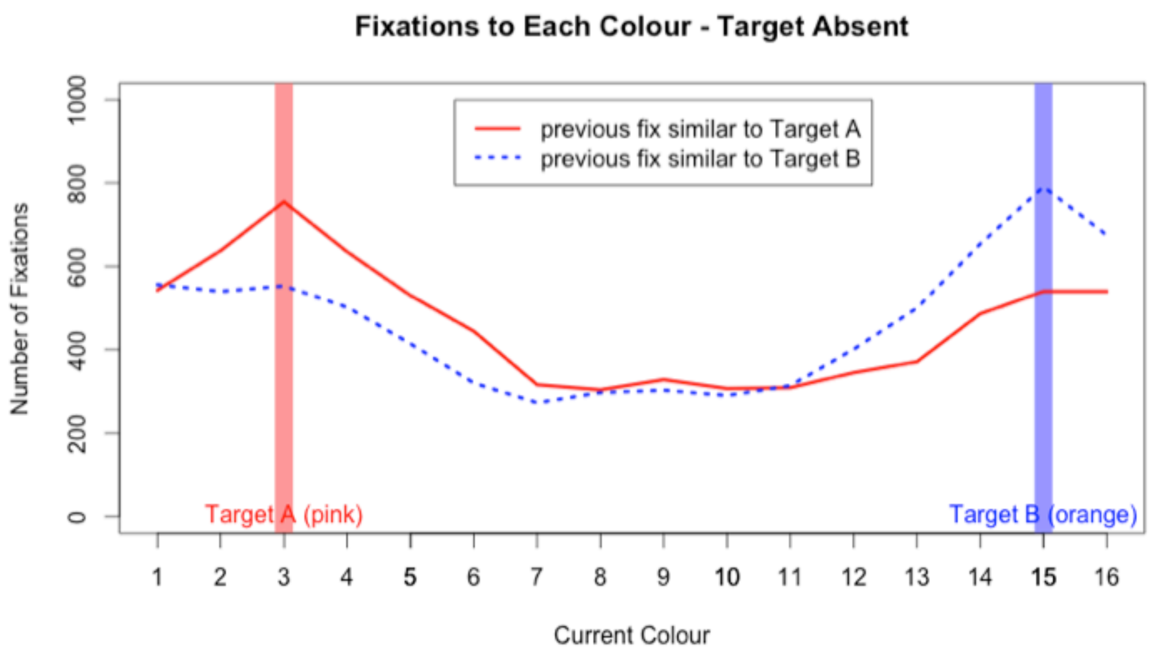

Fixations to Each Colour - Target Absent
previous fix similar to Target A
previous fix similar to Target B
Number of Fixations
0
200
400
600
800
1000
Target A (pink)
Target B (orange)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Current Colour

Figure 5

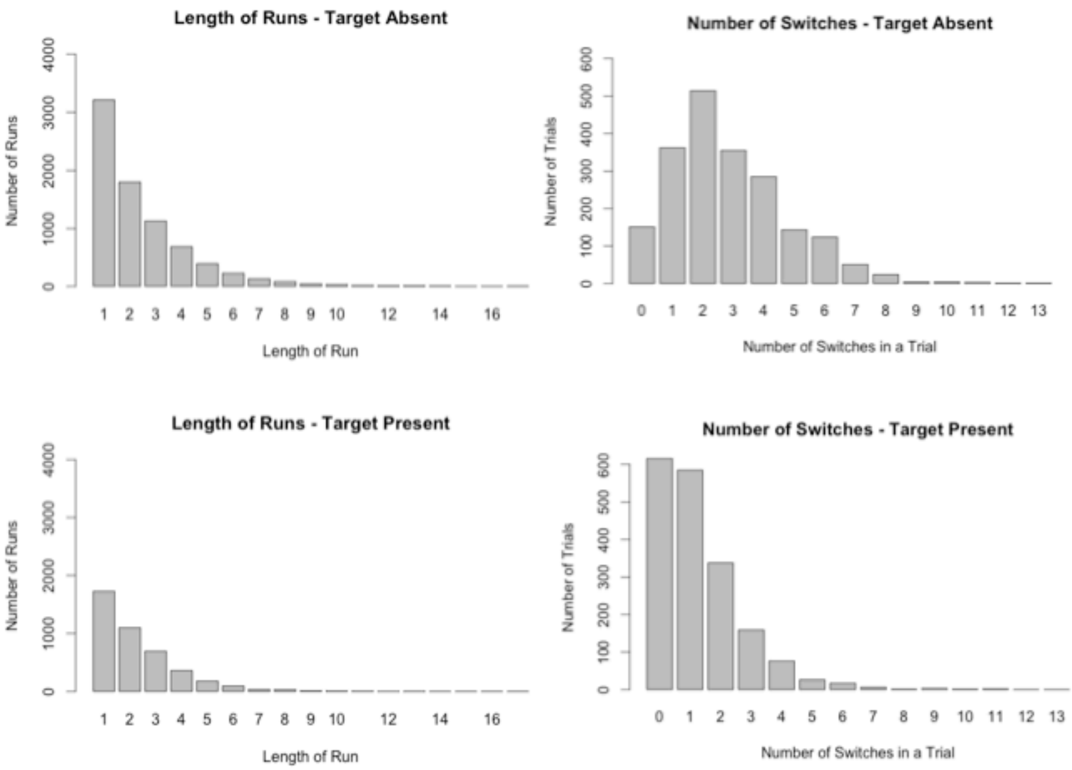

Length of Runs - Target Absent
Number of Runs
Length of Run
Number of Switches - Target Absent
Number of Trials
Number of Switches in a Trial
Length of Runs - Target Present
Number of Runs
Length of Run
Number of Switches - Target Present
Number of Trials
Number of Switches in a Trial

Figure 6

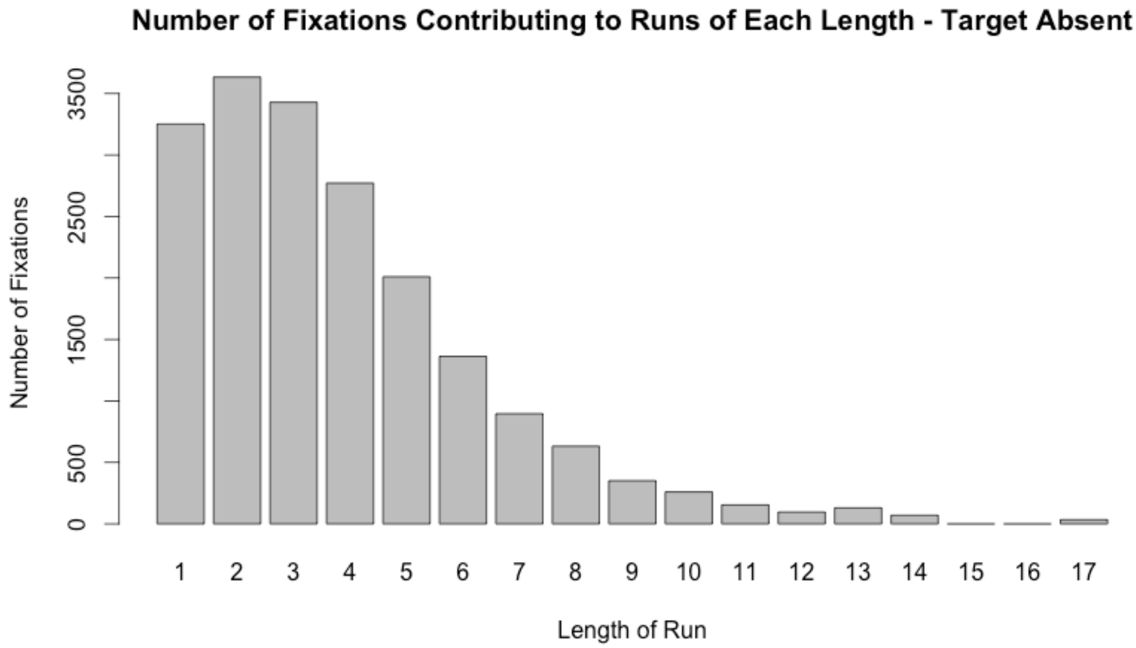

Number of Fixations Contributing to Runs of Each Length - Target Absent
Number of Fixations
0
500
1500
2500
3500
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Length of Run

Figure 7