

PRIOR PROBABILITIES AND REPRESENTATIONAL MOMENTUM

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Abstract

In previous experiments on representational momentum, participants judged whether a probe presented after a target vanished was at the same location where that target vanished or at a different location. Two experiments manipulated actual or expected prior probability a same response would be correct. In Experiment 1, a same response was correct on 10, 30, 50, 70, or 90% of trials, but participants were not informed of these probabilities. In Experiment 2, a same response was correct on 11% of trials, but participants were instructed a same response would be correct on 10, 30, 50, 70, or 90% of trials. Probabilities of same responses, weighted mean estimates of representational momentum, hit and false alarm rates, and d' and β are reported. Actual or expected prior probability a same response would be correct influenced probability of same responses but did not influence representational momentum.

Memory for the final location of a moving target is often displaced in the direction of target motion, and this is referred to as *representational momentum* (RM; for review, Hubbard, 2005). An observer's expectations regarding target behavior (e.g., Johnston & Jones, 2006) and interactions of the target with nontarget stimuli (e.g., Hubbard et al., 2001) influence such displacement; however, whether an observer's expectations regarding how memory for the target would be measured influences such displacement has not been examined. The experiments reported here examined (a) effects on RM of actual or expected prior probability that a subsequent probe would appear at the final location of the target or at a different location and (b) a new application of ideas from signal detection theory to psychometric functions related to RM.

A common methodology within the RM literature is to present a probe after the target vanished, and participants judge whether the probe is at the same location where the target vanished or at a different location. Studies typically have not informed participants about nor manipulated prior probability a *same* response would be correct, and whether differences in prior probability or mismatches between actual and expected prior probabilities influence RM is not known. In one suggestive study, Ruppel et al. (2009) presented feedback regarding participants' judgments of probes over a large number of trials, and this feedback provided indirect information regarding prior probabilities. Feedback influenced the likelihood of a *same* response (i.e., the height of the distribution of the probability of *same* responses as a function of probe position) but did not influence estimates of RM (i.e., the shape of the distribution of the probability of *same* responses as a function of probe position).

Examination of effects of actual or expected prior probability a *same* response would be correct in displacement is analogous to examination of effects of prior probability a signal would be present in signal detection (i.e., varying prior probability a *same* response would be correct is analogous to varying prior probability a signal would be present in signal detection). A *same* response to a probe at the final target location is a "hit," a *same* response to a probe not at the final target location is a "false alarm," a *different* response to a probe at the final

target location is a “miss,” and a *different* response to a probe not at the final target location is a “correct rejection.” Varying prior probability a probe would be at the final target location (i.e., a signal was present) is analogous to varying a payoff matrix in signal detection, and this suggests signal detection theory can be applied to consideration of prior probability in RM.

Experiment 1

Participants viewed leftward or rightward target motion. After the target vanished, a probe appeared, and participants judged whether the probe was at the same location where the target vanished or at a different location. Prior probabilities varied across participants, and different groups of participants received trials in which a *same* response would be correct on 10, 30, 50, 70, or 90% of trials. Participants were not informed of these probabilities.

Method

Participants. Participants were 101 undergraduates who received partial course credit and were naive to the hypothesis. Each participant was assigned to either the 10% probability group ($N = 20$), 30% probability group ($N = 20$), 50% probability group ($N = 21$), 70% probability group ($N = 20$), or 90% probability group ($N = 20$).

Apparatus. Stimuli were displayed upon and the data collected by an Apple iMac desktop computer equipped with a 15-inch color monitor.

Stimuli. The target and probe were black squares 20 pixels (0.83 degrees) in width and presented on a white background. On each trial, there were five successive presentations, referred to as *inducing stimuli*, of the target that implied rightward or leftward motion. Each inducing stimulus was presented for 250 milliseconds, and the interstimulus interval between successive inducing stimuli was 250 milliseconds. For rightward motion, the first inducing stimulus appeared midway between the left side and center of the display, and each successive inducing stimulus was 40 pixels (1.66 degrees) right of the previous inducing stimulus; for leftward motion, the first inducing stimulus appeared midway between the right side and center of the display, and each successive inducing stimulus was 40 pixels left of the previous inducing stimulus. Vertical coordinates of inducing stimuli were along the vertical axis of the display.

The probe was at the same vertical coordinates as the target and one of nine horizontal positions relative to the final target location: -12, -9, -6, -3, 0, +3, +6, +9, or +12 pixels. Probe positions denoted by a minus sign indicated probes shifted backward (i.e., in the direction opposite to target motion) from the final target location, and probe positions denoted by a plus sign indicated probes shifted forward (i.e., in the direction of target motion) from the final target location; the zero probe position was the same as the final target location. Probe positions denoted by a minus sign or a plus sign were *different probes*, and the zero probe position was the *same probe*. Each of the eight different probes for each direction was presented on 9, 7, 5, 3, or 1 trial(s) in the 10, 30, 50, 70, and 90% probabilities groups, respectively. Each of the same probes for each direction was presented on 8, 24, 40, 56, and 72 trials in the 10, 30, 50, 70, and 90% probability groups, respectively. Each participant received 160 trials in a different random order.

Procedure. Participants were given a practice session consisting of 10 practice trials randomly drawn from experimental trials for their probability group. Participants pressed a designated key to begin each trial. The inducing stimuli appeared, and 250 milliseconds after the final inducing stimulus vanished, the probe appeared. Participants pressed a key marked *S* or a key marked *D* to indicate if the location of the probe was the same as or different from the final target location. Participants then initiated the next trial.

Results

Same/Different Judgments. Probabilities of a *same* response are shown in Figure 1. Participants' responses were not influenced by Probability, $F(4,96) = 1.59, p = .18$, but Probability interacted with Probe, $F(32,768) = 1.46, p < .05$; probability of a *same* response for probe positions more distant from the final target location increased when actual prior probability increased. Participants were more likely to respond *same* to probes closer to the final target location, $F(8,32) = 125.78, p < .0001$.

Weighted Means. Estimates of RM were determined by calculating a weighted mean (WM; sum of the products of the proportion of *same* responses and distance of the probe from the final location of the moving target, in pixels, divided by the sum of the proportions of *same* responses) for each participant for each condition. The sign of a WM indicated the direction of displacement (i.e., a minus sign indicated displacement in the direction opposite to target motion, a plus sign indicated displacement in the direction of target motion), and the absolute value of a WM indicated the magnitude of displacement (i.e., a larger absolute value indicated larger displacement). A WM larger than zero indicated RM occurred.

WMs were not influenced by Probability, $F(4,96) = 0.13, p > .96$. WMs for the 10% ($M = 1.54$), $t(19) = 6.33, p < .0001$, 30% ($M = 1.61$), $t(19) = 4.38, p < .0003$, 50% ($M = 1.86$), $t(20) = 6.67, p < .0001$, 70% ($M = 1.59$), $t(19) = 3.92, p < .0009$, and 90% ($M = 1.64$), $t(19) = 3.57, p < .002$, groups were larger than zero. Robust RM occurred regardless of actual prior probability, but the magnitude of RM was not influenced by actual prior probability.

Hits and False Alarms. Probabilities of hits and false alarms are shown in Figure 1. Probability was not significant, $F(4,96) = 1.31, p = .27$, and least mean square comparisons revealed the average of hit rate and false alarm rates for the 10% ($M = .56$), 30% ($M = .50$), 50% ($M = .52$), 70% ($M = .47$), and 90% ($M = .53$) groups did not differ. Performance was significant, $F(3,12) = 235.74, p < .0001$, and least mean square comparisons of hits ($M = .80$), FA-behind ($M = .30$), FA-beyond ($M = .53$), and FA-total ($M = .42$) revealed all pairwise comparisons were highly significant¹. Performance interacted with Probability, $F(12, 288) = 1.94, p < .03$; hit rate did not systematically vary with increases in actual prior probability, but false alarm rates decreased between 10-70% and increased between 70-90%.

d' and β . Values of d' and β based on hit rate and FA-total were calculated. Probability influenced d' , $F(4,96) = 2.86, p < .03$. Least mean square comparisons revealed d'

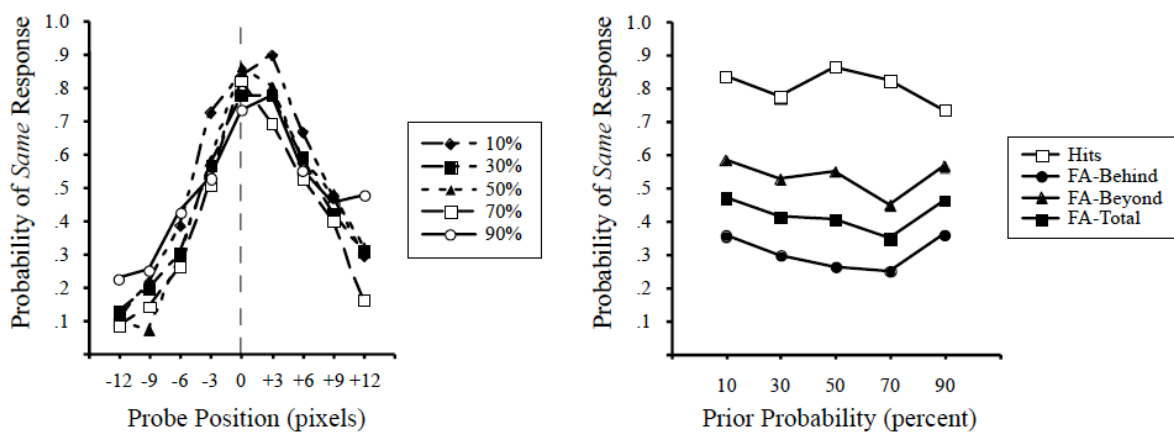


Figure 1. Probability of a *same* response in different probability groups as a function of probe position (left panel) and probability of a *same* response in hits and false alarms as a function of prior probability (right panel) in Experiment 1.

was smaller for the 90% group ($M = 0.80$) than for the 10% ($M = 1.32$), 30% ($M = 1.17$), 50% ($M = 1.45$), or 70% ($M = 1.52$) groups. Probability influenced β , $F(4,96) = 3.11$, $p < .02$. Least mean square comparisons revealed β for the 10% ($M = .52$), 30% ($M = .65$), 50% ($M = .66$), and 70% ($M = .67$) groups were less than β for the 90% ($M = .92$) group.

Discussion

Participants exhibited robust RM regardless of actual prior probability, and RM was not influenced by actual prior probability. Changes in prior probability did not change the overall probability that participants would generate a *same* response, but increases in prior probability increased the probability that participants would generate a *same* response to probe positions more distant from the final target location. Decreases in probability of a *same* response with decreases in prior probability for the majority of probe positions, coupled with the lack of an effect of prior probability on RM, is consistent with Ruppel et al. (2009).

Lowest d' and highest β occurred in the 90% group, and neither d' nor β differed across other groups. Decrease in d' for the 90% group suggests participants in the 90% group were less sensitive to differences between same probes and different probes. This might occur if there was insufficient exposure to or practice with different probes. Increase in β for the 90% group is puzzling, as increased likelihood of a signal being present would be expected to decrease β . It might be those participants adopted an even higher criterion in an attempt to compensate for what they considered as too many *same* responses.

Experiment 2

Experiment 2 varied expected prior probability a *same* response would be correct on a given trial by varying instructions given to participants. All participants received trials in which a *same* response would be correct on 1/9 of the trials, but instructions given to different groups of participants specified a *same* response would be correct on 10, 30, 50, 70, or 90% of trials.

Method

Participants. Participants were 101 undergraduates from the same participant pool as in Experiment 1, and none had participated in Experiment 1. Each participant was assigned to either the 10% probability group ($N = 20$), 30% probability group ($N = 20$), 50% probability group ($N = 21$), 70% probability group ($N = 20$), or 90% probability group ($N = 20$).

Apparatus. The apparatus was the same as in Experiment 1.

Stimuli. The targets and probes were the same as in Experiment 1, with the following exceptions: Each probe position was equally likely across experimental trials (i.e., presented on 1/9 of the trials). Each participant received 162 trials (2 directions x 9 probes x 9 replications) in a different random order.

Procedure. The procedure was the same as in Experiment 1, with the following exceptions: All participants received the same set of probes in which each probe position was equally likely across experimental trials. Participants in the 10, 30, 50, 70, and 90% probability groups were instructed prior to the beginning of the trials that a response of *same* would be correct on 10, 30, 50, 70, or 90% of the trials, respectively.

Results

Same/Different Judgments. Probabilities of a *same* response are shown in Figure 2. Participants' responses were influenced by Probability, $F(4,96) = 4.93$, $p < .0012$. Probability

of a *same* response increased when expected prior probability increased, and least mean square comparisons revealed a *same* response was less likely in the 10% ($M = 0.44$) group than in the 50% ($M = 0.55$), 70% ($M = 0.62$), and 90% ($M = 0.60$) groups and less likely in the 30% ($M = 0.49$) group than in the 70% and 90% groups. Probe influenced probability of a *same* response, $F(8,32) = 212.92$, $p < .0001$, with participants more likely to respond *same* to probes closer to the final target location.

Weighted Means. WMs were calculated as in Experiment 1 and were not influenced by Probability, $F(4,96) = 0.40$, $p > .98$. WMs for the 10% ($M = 1.65$), $t(19) = 5.54$, $p < .0001$, 30% ($M = 1.56$), $t(19) = 7.08$, $p < .0001$, 50% ($M = 1.69$), $t(20) = 4.76$, $p < .0001$, 70% ($M = 1.67$), $t(19) = 6.49$, $p < .0001$, and 90% ($M = 1.56$), $t(19) = 4.47$, $p < .0003$, groups were larger than zero. Robust RM occurred regardless of expected prior probability, but the magnitude of RM was not influenced by expected prior probability.

Hits and False Alarms. Probabilities of hits and false alarms are shown in Figure 2. Probability was significant, $F(4,96) = 5.27$, $p < .0007$, and least mean square comparisons revealed the average of hit rate and false alarm rates for the 10% ($M = .49$) group was less than for the 50% ($M = .59$), 70% ($M = .67$), and 90% ($M = .53$) groups, the 30% ($M = .56$) group was less than the 70% and 90% groups, and the 50% group was marginally less than the 70% group. Performance was significant, $F(3,12) = 251.37$, $p < .0001$, and least squares comparisons of hits ($M = .86$), FA-behind ($M = .38$), FA-beyond ($M = .62$), and FA-total ($M = .50$) revealed all pairwise comparisons were significant. Hit rate and false alarm rates increased with increases in expected prior probability.

d' and β . Values of d' and β based on hit rate and FA-total were calculated. Probability did not influence d' , $F(4,96) = 0.61$, $p < .65$, and no comparisons of the 10% ($M = 1.17$), 30% ($M = 1.49$), 50% ($M = 1.07$), 70% ($M = 1.38$), or 90% ($M = 1.26$) groups were significant. Probability influenced β , $F(4,96) = 3.16$, $p < .02$. Least mean square comparisons revealed β for the 10% ($M = .65$) group was larger than β for the 70% ($M = .25$) and 90% ($M = .42$) groups, that β for the 50% ($M = .50$) group was larger than β for the 70% group, and that β for the 30% ($M = .44$) group did not differ from β in other groups.

Discussion

Participants exhibited robust RM regardless of expected prior probability, and RM was not influenced by expected prior probability. Increases in expected prior probability led to

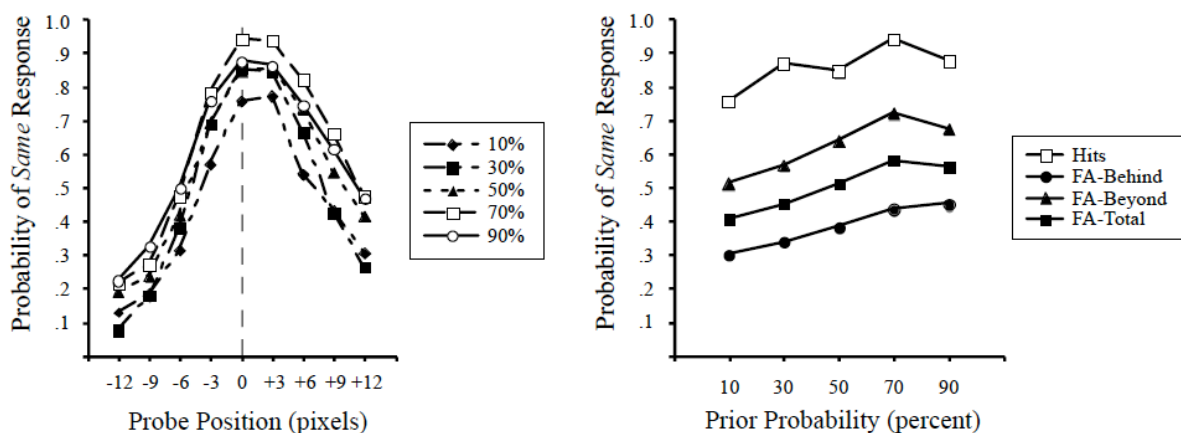


Figure 2. Probability of a *same* response in different probability groups as a function of probe position (left panel) and probability of a *same* response in hits and false alarms as a function of prior probability (right panel) in Experiment 2.

increases in the probability of a *same* response, hit rate, and false alarm rates, and also led to decreases in β . These patterns are consistent with Ruppel et al. (2009). Expectations regarding prior probability did not influence d' . This is consistent with the possibility the decrease in d' in the 90% probability group in Experiment 1 was due to a decrease in sensitivity related to insufficient exposure to or practice with different probes.

General Discussion

Increases in actual or expected prior probability that a *same* response to a probe would be correct increased the probability of a *same* response (i.e., influenced the height of the distribution of *same* responses as a function of probe position) for probes more distant from the final target location in Experiment 1 and for all probes in Experiment 2, but increases in actual or expected prior probability did not influence RM (i.e., did not influence the shape of the distribution of *same* responses). Increases in actual prior probability did not result in systematic changes in hit rate or false alarm rates, but increases in expected prior probability resulted in systematic increases in hit rate and false alarm rates, as well as decreases in β . Given the lack of an effect of prior probabilities in Experiments 1 and 2 on RM, investigators can have greater confidence in use of probe methodology in studies of RM.

Insensitivity of RM to prior probability might seem inconsistent with previous findings that displacement is influenced by expectations (for review, Hubbard, 2005). However, information regarding the probe was not a cause or a consequence of the target or of target motion, and so might be less likely to influence the representation of the target. Even though prior probability can influence the probability of a *same* response on a given trial, prior probability presumably does not influence representation of the target per se. Such a notion is consistent with findings that attempts to eliminate RM by providing feedback (Ruppel et al., 2009) or explicit instruction (Courtney & Hubbard, 2008) have not been successful.

References

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¹Levels of performance were not independent (FA-total = FA-behind + FA-beyond), and this violates assumptions of ANOVA. However, performance is significant even with the most conservative error correction, and it is useful to note FA-behind is smaller than FA-beyond.