Paper PO07-2011

The Effects of Previous Trial Validity on the Gaze Cuing Effect: A Meta-Analysis

Deanna Schreiber-Gregory, North Dakota State University, Fargo, ND

Abstract

A meta-analysis was performed to explore whether the validity of the previous trial affects the magnitude of the cuing effect on the current trial in gaze cuing studies. The eight selected studies for the analysis were all performed by one researcher. The hypothesis was that the facilitation for a validly-cued target (compared with an invalidly-cued target) would be greater when the target on the previous trial was validly-cued than when the target on the previous trial was invalidly-cued. The results indicated that previous trial validity does have an effect on the current trial validity and evidence of a cuing effect was well established.

Introduction

Cuing research is essential to determining how individuals shift their spatial attention in response to their environment. Not only are wild animals observed to be highly responsive to sights and sounds, but humans also have a tendency to behave very sensitively to environmental cues. The crunch of leaves or a flash of color may signal the approach of another person so one's attention is naturally shifted to the location of the stimulus source. Also, when in the presence of another human or animal, both humans and animals seem to take advantage of having another pair of eyes and ears and will respond to the perceived attentional shifts of their companion in order to look out for potential sources of danger or reward (Emery, 2000; Friesen & Kingstone, 1998).

Traditional cuing research has most commonly explored exogenous and endogenous orienting, also known as reflexive and volitional orienting respectively. Exogenous orienting is called such because the orienting of an individual's attention is driven by an external stimulus. Researchers studying exogenous orienting typically do so by presenting a sudden-onset stimulus in the periphery of a display before the onset of a target. These peripheral cues have been known to have effects on an observer's attention even though the observer is aware that the cues are not predictive of where the target will appear. In contrast, endogenous orienting is thought to be driven by an observer's goals or expectations, and it is typically studied by using centrally-presented cues (such as arrows) that predict where the target is most likely to appear. This type of orienting is said to be controlled because the observer has time to process the cue and intentionally shift their attention (Johnson & Proctor 2004). Traditional orienting research such as this has fathered the ever-growing study of attention shifts to social stimuli. One such social stimulus is a face with eyes that gaze in the direction of a potential target. The observed gaze direction serves as a social directional cue and even when gaze direction does not predict target location the observer's attention tends to shift reflexively to the gazed-at location (Frischen, Bayliss, & Tipper, 2007).

In a typical gaze cuing study, a stimulus face appears in the center of a computer screen with the eyes looking either to the left or the right, and then a target appears with random probability on either side of the face. The observer is required to respond by locating, identifying, or simply detecting the target and making a speeded manual key-press (e.g., Friesen & Kingstone, 1998; Friesen, Moore, & Kingstone, 2005). The response times of the observers are thus recorded in milliseconds and studied to see if there is a longer latency when the cue stimulus was invalid (the target appeared in the direction opposite to where the face's eyes looked) versus when it was valid (the target appeared at the location to which the eyes looked). The typical finding in these studies is that responses are facilitated for validly-cued targets, indicating that gaze direction caused observers to shift their attention to the gazed-at location (e.g., Friesen & Kingstone, 1998; Friesen, Moore, & Kingstone, 2005; for a recent review, see Frischen, Bayliss, & Tipper, 2007).

As mentioned, gaze cuing studies are normally concerned with whether the validity of a gaze direction cue has an effect on the response time of the observer in a given trial. Previous trial research, on the other hand, is concerned with how response time on a given trial is affected by the nature of the trial that preceded it. For example, if on a given trial the left side is cued and then the target subsequently appears on the left side will the response time of the observer be faster if the following trial is also similarly valid, compared to the response time on a valid trial that was immediately preceded by an invalid trial? Some research has shown that the there is indeed an effect on the observer’s response time for a trial as a function of whether the previous trial was invalid or valid (for a review, see Fecteau & Munoz, 2003). This indicates that the effect of a previous trial's validity carries over to the next trial and thus influences response time on the next trial (Fecteau & Munoz, 2003; Jongen & Smulders, 2006; Mordkoff, Halterman & Chen, 2008). More specifically, this effect is seen if the reaction time of the current trial is faster than that of the previous trial even though they are both valid trials. Another example would be if the current invalid trial's

reaction time was longer given a previous trial that is valid versus one that is invalid. Taking this into consideration, if the previous trial does affect the outcome of a given trial then we can assume that the previous trial left a “residual imprint” in our brains causing us to be influenced by it as we respond to the next trial (Fecteau & Munoz, 2003). Single-cell electrophysiological recording research with monkeys has yielded results that support this hypothesis (Fecteau & Munoz, 2003).

Before this meta-analysis there had not been any research investigating whether there is a previous trial effect with gaze cuing. Since past research on previous trial effects with traditional exogenous and endogenous cues has indicated a marked effect of previous trial validity on a given trial then this is something that should be explored in gaze cuing studies. Gaze cuing studies are put into an interesting position by having the potential to either support or disprove some alternative explanations for previous trial effects observed in traditional cuing studies. This potential arises from the fact that with non-predictive peripheral cues, the cue of a given trial has a 50% chance of appearing at the same location that the most recent stimulus (i.e., the target of the previous trial) appeared. This creates the possibility that the previous trial effects that are observed in peripheral cuing studies may be a perceptual, rather than an attentional, effect. Also, with studies that observe the effects of centrally-placed cues that are predictive (i.e., arrows that indicate where the target is most likely to appear) there is already a bias on behalf of the subjects that encourages them to process the current cue as a valid one. This can have a negative effect on a previous trial analysis because we would have to take into consideration the chance that the cue had of appearing predictive of the target in the first place. This would certainly skew the numbers for our invalid trials because they are the less likely outcome all around. Using this experimental model, subjects may process a valid cue as a reminder that the cue is a reliable predictor of the target location and therefore may become more likely to respond to the cue in the next trial. This presents a further problem in that the violation of this predictability for invalid trials will create an even greater violation of expectancy given the previous trial before it was valid. Nonpredictive centrally-presented gaze cues are able to avoid both of these potential problems because the location of the target is always randomized (which helps prevent the creation of a “mental set” that would normally be presented in a predictive centrally-presented cuing study) and it appears at a location that is remote from the location of the cue; (which prevents the confound of the previous trial’s target and the current trial’s cue appearing at the same physical location). The current meta-analysis on previous trial effects in gaze cuing studies was done to provide concrete evidence that the validity of the previous trial, itself, can have a significant effect on the deployment of spatial attention.

Thus, the main purpose of the present study was to explore whether there is a previous trial effect in gaze cuing studies. Since there are numerous studies demonstrating the attentional effects of gaze cuing (e.g. Friesen & Kingstone, 1998; Friesen & Kingstone, 2003; Friesen, Moore & Kingstone, 2005; see Frischen, Bayliss & Tipper, 2007) and still others demonstrating previous trial effects with nonsocial spatial cues (Dodd & Pratt, 2007; Jongen & Smulders, 2007; Mordkoff, Halterman & Chen, 2008), a study that tests for previous trial effects with gaze cues has the potential to make a valuable contribution to both research areas.

In order to test my hypothesis I performed a meta-analysis on some of the in-house data gathered in Dr. Chris Kelland Friesen's labs over the past decade. My hypothesis was that the previous trial's validity would indeed affect the reaction time of a given trial. The reason for this is that a valid previous trial where the gaze direction and target location are the same might create a “prediction” of validity in the observer's attention but an invalid previous trial where the gaze direction and target location are different would just reinforce the fact that gaze is nonpredictive. I predicted that a previous trial that was valid would either shorten the response time of a current valid trial or lengthen the response time of a current invalid trial, thereby enhancing the gaze cuing effect, and that a previous trial that is invalid would have either the opposite effect or no effect at all.

Methods

Sample of Studies

To conduct the meta-analysis I used the data from several studies conducted under Dr. Friesen in her labs. These studies were chosen based on their similar characteristics and relevance to the topic of previous trial validity. None of the studies was originally conducted for this purpose but all of the raw data were recoded to indicate whether the previous trial for a given trial was valid or invalid.

Characteristics shared by the experimental trials extracted from the selected gaze cuing studies included:

- response times were measured in a speeded manual keypress task and recorded as milliseconds
- cue directions and target locations were left and right only
- the gaze-cue direction was always nonpredictive of the subsequent target location
- all stimuli were presented using a computer monitor in a dimly lit room
- ages of the subjects were mainly at the undergraduate level

- the analysis was conducted using the mean or median response time for each SOA by validity condition for each subject for each experiment

Coded Variables

There were some differences between the studies, and these were recorded and taken into account during our coding process. I had two coders, myself and Dr. Friesen; I also took into account any input provided from Dr. Fu-Chih Cheng as well. The main factors of interest across experiments were previous-trial validity and current-trial validity. Other factors that were coded for are face type (schematic vs. photographic), response task (identification, detection, or localization), emotional expression (present or not), target type (shape, object, or letter) and whether or not there was a gap or overlap between cue onset and target onset. The mean or median (depending on how the data were originally analyzed for each experiment) response time for the validity pairings was the main factor I was concerned with. The continuous variables that were accounted for were SOA (stimulus onset asynchrony, the time interval between the cue onset and the target onset [there were 2 to 4 per study, ranging from 100-1200 ms]) and sample size.

I started the meta-analysis by selecting the appropriate studies and coding any factors that might affect our data and cause the studies to be heterogeneous. Such differences that were taken into consideration are continuous covariates (sample size and SOA) and categorical variables (face type, response task, target type, overlap/gap, and emotional expression). Since I was working with raw data, I made sure to remove any error trials and catch trials. Error trials are those in which the subject responded incorrectly, failed to respond at all, or responded abnormally fast which is indicative of anticipation of the target instead of actually responding to the target itself. Catch trials are those in which a target did not appear. I also excluded the trials immediately following errors and catch trials, as well as the first trial in each block, and for studies that included straight-gaze ("neutral") trials I removed trials immediately following neutral trials. Thus, all current trials in the analysis had been preceded by a trial that was either valid or invalid. I also reanalyzed each experiment so that my residuals could be calculated from a mean or median (for each SOA condition for each individual subject) based on the validity pairings of valid/valid, valid/invalid, invalid/valid, and invalid/invalid for previous-trial validity and current-trial validity respectively. The coded data were then analyzed in SAS under the guidance of Dr. Cheng.

Results

A total of eight experiments were selected for this analysis. Of the eight, three were published articles from academic journals and five were unpublished. There were two assumptions about the organization of data that I took into consideration during the analysis: 1) the gaze cuing effect observed from all studies was consistent, 2) the variation of response time was constant (i.e., the variance of response time is unchanged among all studies). I tested these assumptions by using residuals estimated from ANOVA (Analysis of Variance) models for each study using only previous and current validity as my factors. A residual represents the estimate for the random term which is based on the random error for each study. Taking this into consideration, the residual contains a random variation because all known effects have been removed. After fitting an ANOVA (Analysis of Variance) model to the data I estimated the random error (residual) of each experiment and then combined them to test for homogeneity of constant variance among the studies. Of the eight studies, six residuals were calculated using means and two were calculated using medians. The total residual standard deviation was 49.63526.

To test the assumption that the variance of response time is constant I needed to perform a homogeneity of variance test, Bartlett's test. Bartlett's Test of Homogeneity indicated that the studies were not homogeneous ($\chi 2 = 264.5$ with $p < .0001$). I then used my coded covariates to account for the heterogeneous variances observed among studies. The variables that I chose were face type (2 levels: schematic and photograph), target type (3 levels: letter, shape, and object), response task (3 levels: detection, localization, and identification), whether or not there was emotion (2 levels: no emotion and emotion), and whether the study used only overlap trials or both gap and overlap between cue onset and target onset during analysis (2 levels: overlap and overlap/gap). Continuous covariates were also taken into consideration as sample size and SOA. Also, since Study #1 (Friesen & Kingstone, 1998) used all three levels of response task, I calculated individual residuals and standard deviations for each response task and then combined them to control for the fact that the same subjects were used for every task.

After fitting the coded data using a fixed effects model, I tested for any interaction effects between the studies. Since the assumption of homogeneous gaze cuing effects among the studies still needed to be verified, then I tested the homogeneity using the interaction term. The interaction between SOA and each study was significant (F [6]= 10.68, $p < .0001$). This means that the effect of SOA on reaction times is dependent on the study itself.

Considering these results, I can conclude that the assumption of a constant variability of reaction times among the studies has been violated, thus requiring me to adjust my residuals. To do so, I took the reciprocal of the Mean

Squared Error (MSE) estimated from the ANOVA model of each experiment. The reciprocal of each residual of MSE was used as a weight for each experiment. This weight was incorporated into the Mixed Effects model to account for the heterogeneous variances of reaction time among studies. The overall adjusted residual mean was again equal to zero but with a standard deviation of 1.029569.

Since I found the interaction between SOA and each study to be significant, I used a random effects model to test my assumption of a consistent gaze cuing effect. Using a random effects model I found that the coded factors and covariates all had significant results: sample size (F [1] = 82.92, $p < .0001$), gap/overlap (F [1] = 115.69, $p < .0001$), face type (F [1] = 71.98, $p < .0001$), target type (F [2] = 224.10, $p < .0001$), presence of emotion (F [1] = 199.24, $p < .0001$), and SOA (F [1] = 220.57, $p < .0001$). Also, previous versus current validity still yielded significant results (F [3] = 4.80, $p = .0025$).

I used Tukey's HSD to test how the levels of the factors that I found significant (significant factors are analyzed with the default $\alpha = 0.05$) were different. All of the factors (except gap/overlap) had significantly different levels but target type (M = 492.626 for object, M = 343.002 for shape, and M = 320.460 for letter) and task type (M = 315.079 for detection, M = 344.103 for localization, and M = 386. 176 for identification) had more than two levels with significant differences between each level. The results indicated that average reaction times for letter are significantly shorter than for shape and the average reaction times for object were significantly longer than for both letter and shape. Also, the average reaction times for task type also differed significantly from each other with reaction times decreasing from detection to localization and from localization to identification. Previous versus current validity yielded interesting results with validity parings of valid/invalid (M = 349.353), invalid/invalid (M = 348.696), and invalid/valid (M = 343.086) being not significantly different from each other but with valid/valid (M = 339.721) being significantly different from all of them except invalid/valid. This indicates that there is a significant gaze cuing effect on the current trial when the previous trial was valid and that there is no gaze cuing effect on the current trial when the previous trial was invalid.

Discussion and Future Directions

My hypothesis was that the previous trial's validity would affect the reaction time of a given trial. The reasoning for this was that a valid previous trial where the gaze direction and target location are the same will create a “prediction” of validity in the observer's attention but an invalid previous trial where the gaze direction and target location are different would just reinforce the fact that gaze is nonpredictive. I had predicted that a previous trial that was valid would either shorten the response time of a current valid trial or lengthen the response time of a current invalid trial, thereby enhancing the gaze cuing effect, and that a previous trial that is invalid would either have the opposite effect or no effect at all. My results show that reaction times on current valid trials preceded by a valid trial were not statistically different from reaction times on current valid trials preceded by an invalid trial, and that reaction times were statistically equivalent (and almost numerically equal) for current invalid trials preceded by valid and current invalid trials preceded by invalid trials. However, reaction times for current valid trials preceded by a valid trial were sufficiently short to be significantly different from reaction times for current invalid trials preceded by a valid trial. In other words, there was a significant gaze cuing effect for trials preceded by valid trials. In contrast, there was no significant gaze cuing effect for trials preceded by invalid trials. Thus, my hypothesis that the gaze cuing effect would be greater when the previous trial was valid compared to when the previous trial was invalid was supported.

One interesting result that was made very apparent from the analysis was that the length of SOA had a significant negative correlation with the reaction time of subjects. In other words, when taking SOA as a continuous variable, the longer the SOA was the shorter the reaction times became. Though this is a known effect among studies that use SOA length as a factor, the simple fact that this meta-analysis supports this point could help in the analysis of SOA related factors in the future. Also, sample size was shown to have a significant negative correlation with the average reaction times across studies. In other words, longer reaction times were observed in studies with smaller sample sizes while shorter reaction times were observed in studies with larger sample sizes. This is an interesting fact that could to be due to the nature of the studies themselves.

Another point that can be taken away from this analysis is that differences in target type, response task, face type, and emotion all have a significant effect on the reaction time of the observer. However, the differences between the levels of each factor do prove to be significant. For instance, when comparing target types, a letter target produces significantly faster reaction times than a shape target but an object target produces significantly slower reaction times than a shape target. A possible explanation for this would be that letters naturally grab our attention more than abstract shapes or objects because they hold meaning to us just like a shape might hold more meaning and can be identified more easily than an object. Also, when comparing response tasks, a detection task will produce significantly faster reaction times than localization tasks but identification tasks produce significantly slower reaction times than localization tasks. This is easily explained by the difficulty of the task because detection requires the subject to merely detect the target appearance, localization requires the target's location be correctly pinpointed, and identification

requires the target's identity be correct, each respective task requiring more complex brain function and thus taking more time to complete. As far as face type is concerned, reaction times are significantly shorter for schematic faces than the reaction times for photographic faces. This could possibly be explained by the increased amount of detail found on photographic faces than on schematic. The same explanation could hopefully shed light on why the faces that displayed emotion had significantly slower reaction times than the faces that were neutral. Taking all these factors into consideration, each one did not significantly affect the difference between the studies by themselves but rather their interaction overall was what made the studies different. A possible way to combat this would be to have a wider range of studies that covered some of the combinations of factors that I did not have so that I could explore exactly which combinations produced the fastest reaction times.

My predictions and hypothesis that the previous trial's validity would affect the gaze cuing effect on a given trial had significant support. Contributing factors that this research could boast would be that SOA length and sample size do make a difference and this meta-analysis has provided significant evidence to support that. Also, the various types of targets, faces, tasks, and emotions also have significant effects on the response time outcomes when considering the interactions of each factor.

Future directions for another analysis would be to include a wider variety of studies that cover more combinations of factors so that each factor's effects could be accounted for. Even though each factor individually didn't affect the difference between the studies, the overall interaction between the factors should still be considered if another analysis were to be conducted with the intent of testing the same hypothesis.

References

Dodd, M., & Pratt, J. (2007). The effect of previous trial type on inhibition of return. *Psychological Research*, *71*, 411-417.

Emery, N.J. (2000). The eyes have it: The neuroethology, function and evolution of social gaze. *Neuroscience and Biobehavioral Reviews*, *24*, 581-604.

Fecteau, J., & Munoz, D. (2003). Exploring the consequences of the previous trial. *Neuroscience*, *4*, 1-9.

Friesen, C. K., Moore, C., & Kingstone, A. (2005). Does gaze direction really trigger a reflexive shift of spatial attention? *Brain and Cognition*, *57*, 66-69.

Friesen, C. K., & Kingstone, A. (2003). Covert and overt orienting to gaze direction cues and the effects of fixation offset. *NeuroReport*, *14*, 489-493.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin and Review, 5*, 490-495.

Frischen, A., Bayliss, A., & Tipper, S. (2007). Gaze cuing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin*, *133*, 694-724.

Johnson, A., & Proctor, R. W. (2004). Selective Visual Attention. In Brace-Thompson, J. (Eds.), *Attention: Theory and Practice*. (pp. 57-94). Thousand Oaks, CA: Sage Publications.

Jongen, E. M. M., & Smulders, F. T. Y. (2006). Sequence effects in a spatial cuing task: Endogenous orienting is sensitive to orienting in the preceding trial. *Psychological Research*, *71*, 516-523.

Mordkoff, J. T., Halterman, R., & Chen, P. (2008). Why does the effect of short-SOA exogenous cuing on simple RT depend on the number of display locations? *Psychonomic Bulletin and Review*, *15*, 819-824.

Contact Information

Your Comments and questions are valued and encouraged. Contact the author at:

Deanna N Schreiber-Gregory

North Dakota State University

Phone: 701-799-6905

E-mail: annies94ranger@hotmail.com