PROCESSING SPATIAL RELATIONS: THE ROLE OF INSTRUCTIONS ON THE PRIMING OF EGOCENTRIC AND ALLOCENTRIC SPATIAL REPRESENTATIONS

by

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ABSTRACT

Humans process their visual environment using two distinct frames of reference. An egocentric frame of reference is defined in terms of the spatial relation between the observer and an object. This is contrasted to an allocentric frame of reference, which is defined in terms of the spatial relations between different objects and is independent of the observer. Maljkovic & Nakayama (1996) and Ball et al. (2009; 2010) present contrasting views on the significance of each form of processing during visual search tasks. The current study seeks to better understand this incongruity in terms of the task instructions. A visual search task was used to demonstrate priming under four conditions (egocentric, allocentric, combined, control) using two different instructions (absolute and relative). Across both instruction conditions, individuals responded faster to the combined priming condition. In the absolute instruction condition, individuals demonstrated larger facilitation effects in the egocentric priming condition than the allocentric priming condition, while individuals demonstrated larger facilitation effects in the allocentric condition when in the relative instruction condition. These results were discussed in terms of how individuals allocate attentional resources when processing spatial relations.

DEDICATION

This thesis is dedicated to my friends and family who supported, inspired, and encouraged me during the process of completing my thesis.

LIST OF ABBREVIATIONS AND SYMBOLS

n	Sample size
%	Percent
±	Plus-minus
ms	Milliseconds
df	Degrees of freedom: number of values free to vary after certain restrictions have been placed on the data
F	Fisher's *F* ratio: A ration of two variances
M	Mean: the sum of a set of measurements divided by the number of measurements in the set
p	Probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value
S.D.	Standard deviation
S.E.	Standard error
t	Computed value of *t* test
Std.	Standard
=	Equal to
$<$	Less than
RT	Reaction time
ANOVA	Analysis of variance
MANOVA	Multivariate analysis of variance

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CHAPTER 1

INTRODUCTION

Humans operate in a complex visual environment. Everyday tasks such as navigating and reaching to pick up objects requires an efficient system to represent space that can be used in support of a variety of behaviors. This system must account for the location of objects in space relative to the observer and relative to other objects. Additionally, this system must be flexible enough to update the changing positions objects can take due to their motion and our eye movements, but stable enough to allow individuals to store in memory a complex visual environment independent of the exact position of the observer. This system, therefore, must account for different frames of reference. There are at least two distinct frames of reference that humans can use to represent space, egocentric and allocentric.

An egocentric frame of reference is defined in terms of the spatial relations between the observer and the object, and can be body-centered, head-centered, or retinocentric (Hillis & Caramazza, 1995). Spatial perception relying on egocentric frames of reference, especially retinotopic representations, is advantageous because it provides a nearly constant stream of information about the immediate visual environment and allows individuals to act in space (see Burgess, 2006 for a brief discussion). For example, if one could not represent space retinotopically, reaching for an object would be problematic. However, egocentric representations are also less stable, as they are constantly changing with eye, body, and object motions. Thus, egocentric representations, especially retinotopic representations, are easily disrupted and may benefit from a more stable conjunctive system (Burr & Morrone, 2011).

An allocentric frame of reference is defined in terms of the spatial relations between two different objects. This frame of reference is independent of the observer and plays a complementary role to egocentric representations. More specifically, spatial perception relying on allocentric frames of reference is more stable and may provide a coordinate system for objects and egocentric representations to operate (Melcher & Morrone, 2003). Thus, egocentric and allocentric frames of reference combined to represent the various spatial relations between the observer and objects in space.

Current models of visuomotor control incorporate both egocentric and allocentric frames of reference in parallel, though certain models emphasize the role of egocentric frames of reference. For example, Goodale & Milner (1992) and Wang & Spelke (2002) suggest that visuomotor control may be based primarily on egocentric processing, as individuals must rely on the spatial relationships between the observer and objects to effectively move and act in the environment. Broadly speaking, these theories usually posit systems for egocentric representations, scene recognition, spatial updating of egocentric location directed by self-motion, and some sort of geometric or viewer-dependent layout of the environment (Burgess, 2006). Visuomotor control and spatial navigation, therefore, would consist of constantly updated egocentric representations that utilize a separate geometric representation of the external environment to orient one's position in space. The geometric representation of space would theoretically utilize object-to-object spatial relations. These models are supported by several lines of evidence (see Burgess, 2006 for a brief review), but may be incomplete without including a more systematic role of allocentric processing. For example, viewer-independent cognitive maps have long been theorized to exist in humans (Tolman, 1948; O'Keefe & Nadel, 1978; Montello, 1998) and nonhuman primates (Robertson, Rolls, & Georges-François, 1998) as a means to represent space during navigation. Additionally, behavioral studies have generally supported the view that individuals use both frames of reference in parallel to complete visuospatial tasks (Burgess, Spiers, & Paleologou, 2004; Burgess, 2006). In summary, the evidence suggests that humans use both egocentric and allocentric information to represent space and, consequently, models of visuomotor control should include a role for both.

Despite playing complimentary roles to represent space, there is strong neuroscientific evidence that suggests egocentric and allocentric representations rely on an overlapping but distinct neural networks. Neurological studies on spatial neglect suggest that lesion patients may demonstrate frame of reference specific deficits. For instance, Hillis et al. (2005) found that hemispatial neglect could be associated with egocentric or allocentric frames of reference deficits, and that each form of neglect was associated with distinct cortical regions. Zaehle et al. (2007) used fMRI evidence to demonstrate distinct neural activation associated egocentric and allocentric processing. The authors suggest that egocentric processing is more closely associated with the precuneus, while allocentric processing is more closely associated with the right-sided parietal areas, bilateral ventral visual system, and the hippocampal formation. The primary and secondary visual areas, parietal areas, and left premotor region may play a role in both frames of reference or in spatial representation generally. This evidence corresponds to a distinction between the dorsal and ventral visual processing streams. Egocentric and allocentric representations may be a reflection of these separate pathways (Burgess, 2006).

Behavioral evidence also distinguishes between egocentric and allocentric representations. A visual search task that induces location priming is one method that has been used to dissociate different frames of reference. Priming refers to the facilitative effect seen when a feature, such as the color, size, or location, of the target stimulus is repeated in successive displays (see Kristjánsson, 2006, for a review). Location priming refers more specifically to facilitation that occurs when a target is located at a particular location on consecutive trials (Maljkovic & Nakayama, 1996). These consecutive trials are often referred to as a prime and probe trial, where the prime affects the probe. Priming requires a representation in short term memory (Shore & Klein, 2000), and likely reflects a redirecting of visual attention to recently attended items that is both implicit and short term (Bravo & Nakayama, 1992; Kristjánsson & Campana, 2010). Therefore, demonstrating priming in a visual search task under conditions of egocentric or allocentric specific conditions allows us to determine the spatial representation the individual is relying on to complete the task. For example, if an individual demonstrates a facilitative effect when the allocentric information is repeated while the egocentric information changes from a prime to a probe trial, it can be inferred that the individual must have mentally represented the allocentric information during the prime display. This does not rule out the possibility that both frames of reference were represented. It does suggest, however, that an individual is retaining some allocentric information from the prime trial that is facilitating the response to the probe trial.

Maljkovic & Nakayama (1996) attempted to dissociate the effects of allocentric location priming using a paradigm termed the priming of pop-out effect. In this paradigm, participants were asked to identify an odd colored diamond shaped target stimulus among two distractor stimuli. Each diamond was cut off on either the right or left and participants were asked to respond to the side cut off of the target diamond. Maljkovic & Nakayama compared two priming conditions to corresponding control conditions. In the first priming condition, the display was repeated in the same location across consecutive trials. In the second priming condition, the target-distractors configuration of the display was repeated across trials, except that the display appeared in a different location on the screen. Thus, the first condition allowed individuals to use both egocentric and allocentric information because both were repeated on consecutive trials, while the second condition reflected allocentric processing because the egocentric information was changed (as the configuration had moved but the target-distractors relationship had not changed) from the preceding trial. Because the facilitation effect in the first condition (which included egocentric information) was only slightly stronger than the facilitation effect in the second (which excluded egocentric information), the authors concluded that an object-centered or allocentric component must play a large role in the facilitation effect. However, Maljkovic & Nakayama (1996) did not include an egocentric only priming condition to completely dissociate the different effects.

In order to more fully understand egocentric and allocentric frames of reference, Ball, Smith, Ellison, & Schenk (2009) directly compared an egocentric, allocentric, and combined (egocentric and allocentric) condition to a control condition on a visual search priming task. Ball et al. (2009) used a visual search task that required the participants to determine whether a display containing 12 dashes included a target dash, which was designated by having an opposite orientation as the distractors. In all of the search displays, two of the distractor dashes were placed close together to serve as a landmark. Participants responded to whether the target was present or absent. In the combined condition, the target appeared in the same position relative to the landmark and in the same location within the display as on a preceding trial. In the egocentric condition, the target appeared in the same location within the display, but in a different position relative to the landmark as on a preceding trial. In the allocentric condition, the target appeared in the same position relative to the landmark, but in a different location within the display as on a preceding trial. In the control condition, the target appeared in a different position relative to the landmark and a different location within the display as on a preceding trial.

Ball et al. (2009) found that individuals demonstrated a facilitation effect under all three priming conditions. Furthermore, the facilitation effect was stronger in the egocentric and combined conditions than the allocentric condition. This led the authors to conclude that egocentric processing played a larger role than allocentric processing in the observed location facilitation effect in the combined condition. In a later paper, these findings were replicated and extended to specify the importance of body-centered, as opposed to a retinocentric, frame of reference (Ball, Smith, Ellison, & Schenk, 2010). This finding is directly at odds with Maljkovic & Nakayama (1996) who stressed the relative contribution of allocentric processing.

The differing results of Maljkovic & Nakayama (1996) and Ball et al. (2009; 2010) regarding the relative contribution of egocentric and allocentric processing on the priming of spatial relations may be attributed to several factors. Ball et al. (2009) included an egocentric only priming condition. This allows for an explicit comparison of egocentric and allocentric priming. As stated above, there was a significantly larger facilitation associated with the egocentric condition than the allocentric condition. However, participants responded slower to the first presentation of stimuli (the prime) in the egocentric priming displays than the allocentric displays, but there was no difference in response time to the second presentation of the displays (the probe). A similar pattern of results was obtained in Ball et al. (2010). Therefore, an alternative explanation for the larger facilitation effects in the egocentric condition is that the slower response time to the first presentation of the egocentric display allowed for a larger absolute difference between the response times on consecutive displays, as compared to the allocentric condition. This explanation would raise a possible objection to the conclusion that egocentric processing is primarily responsible for the combined facilitation effect.

There are several other differences between the Maljkovic & Nakayama (1996) and Ball et al. (2009) studies that may have contributed to the inconsistent results. The visual search tasks and responses required of participants may have influenced the respective conclusions. For example, the visual search task used by Maljkovic & Nakayama (1996) required participants to process the entire display to identify the oddly colored stimulus. This may have encouraged participants to process the display using an allocentric frame of reference because the distractor stimuli were a necessary component of the visual search. Conversely, the visual search task used by Ball et al. (2009) did not require participants to process the entire display. More specifically, the distractors were not a necessary component of the search. Further, the number of distractors (twelve compared to two) may have encouraged participants to rely less on an allocentric frame of reference in Ball et al. (2009) because the individuals would not be able to remember the location of all of the distractors. Therefore, the participants may have ignored the information from the distractors, thereby promoting an egocentric frame of reference.

The current study was designed to better understand the effect of goals on the processing of spatial relations. The individual's goal was manipulated by changing the instructions given to participants about how to respond to the display in a visual search task. Instructions have been shown to direct spatial attention in a top-down fashion (Jiang, Swallow, & Sun, 2013). Consequently, changing the instructions on how a participant responds may influence how the participant processes spatial relations. For example, having participants' responses dependent on either the location of a target relative to the observer or to the location of the target relative to distractors may influence the type of processing used during the visual search task. The egocentric information may be more salient in the former case, while the latter case may emphasize the allocentric information. The individual's goal may influence how attentional resources are allocated to represent different frames of reference.

In the current study, the role of instructions on the processing of spatial relations was explicitly examined. Participants were asked to complete a visual search task to assess priming of egocentric, allocentric, and combined (egocentric and allocentric) frames of reference. Two sets of instructions on how to respond were given to participants to promote frame of reference specific processing. More specifically, participants responded either to the absolute location of a target (relative to the observer) or to the position of the target relative to distractors. It was hypothesized that having individuals respond to the absolute location of a target in a display would increase the facilitation effect in an egocentric priming condition. Conversely, it was hypothesized that having individuals respond to the location of a target relative to distractors in a display would increase the facilitation effect in an allocentric priming condition. In other words, the response would influence individuals to rely on a specific frame of reference to represent the display, which would be manifested in the facilitation effect.

CHAPTER 2

METHOD

Design

A 2 X 4 completely within-subject design was employed in the current study. The independent variables were instruction (absolute and relative) and priming (egocentric, allocentric, combined, and control). The dependent variable was the response time (RT; in milliseconds) of correct probe trials of the visual search task.

Participants

Forty-four participants were recruited from the Psychology Subject Pool at The University of Alabama. All participants were students at the university and participated for course credit. Four participants were not included in the analyses because of excessive errors (more than 5% errors on probe trials; n = 3) or incomplete data (n = 1). The final sample was 70% female with a mean age of 19.28 (± 1.61) years.

Visual Search Task

All trials began with a fixation point displayed for 500ms. Participants did not respond to the fixation point. The search array appeared following the fixation point and lasted until the participant made a response. No feedback was given on the response. The search array consisted of four squares placed horizontally on the screen. The position of the squares remained constant throughout the experiment. One square contained a solid red circle that designated the target and two other squares contained a blue circle that served as distractors. Participants were asked to press a computer key that corresponded to the target circle. See Figure 1 for a visual representation of a complete trial with the appropriate response.

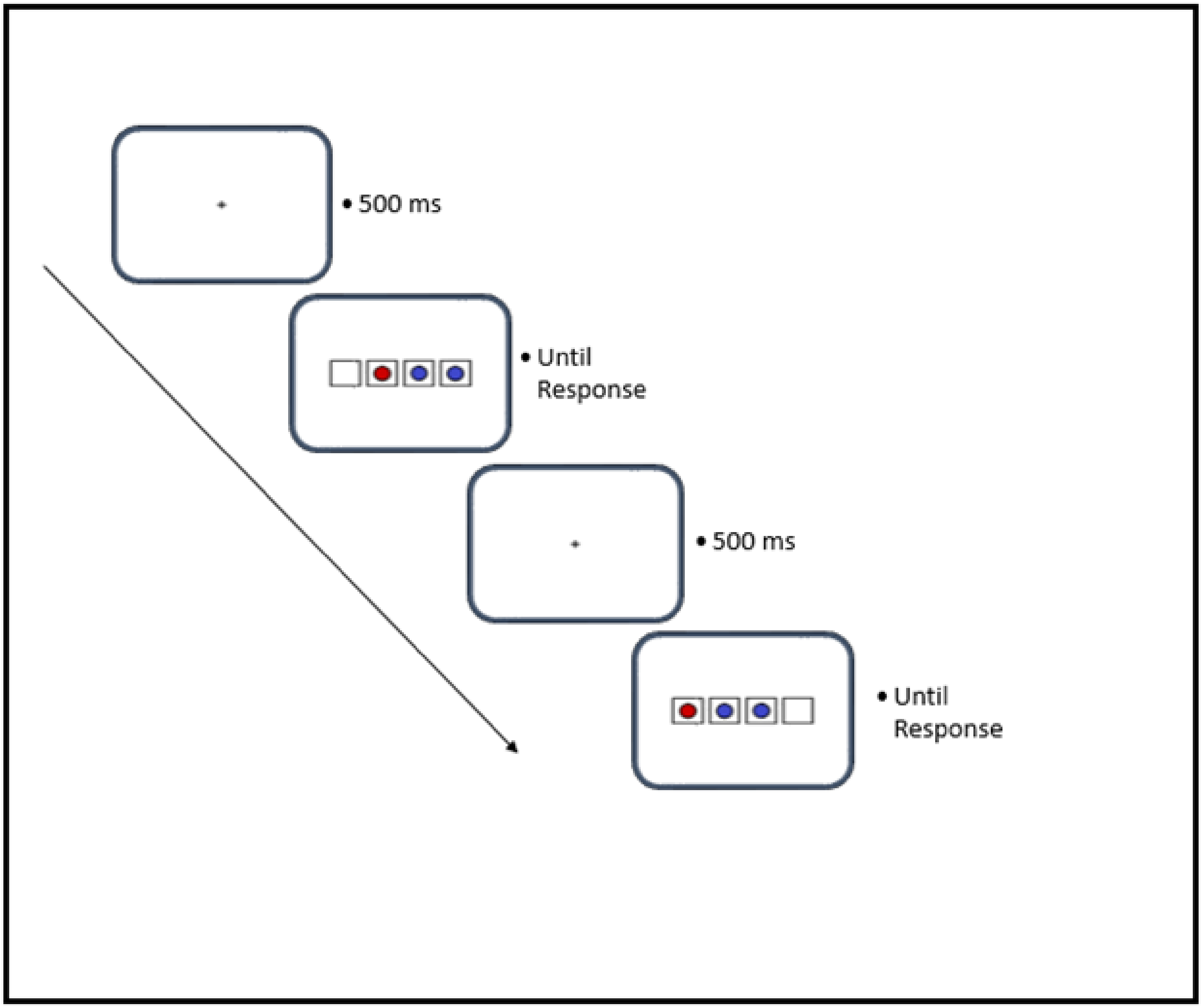

Figure 1. An Example Trial. In the absolute instruction condition, participants responded to a button corresponding to the second square in the prime display and a button corresponding to the first square in the probe display. In the relative instruction condition, participants responded to a button corresponding to the target appearing to the left of both distractors in both the prime and probe displays.

There were four priming conditions. In the combined (egocentric and allocentric) priming condition, the same display was presented in prime and probe. In the egocentric priming condition, the target appeared in the same square in the prime and probe displays but the distractors appear in different squares relative to the target. In the allocentric priming condition, the target and distractors appeared in the same relative location to each other in the prime and probe displays but the entire display shifted to new squares. In the control condition, the target appeared in a previously unoccupied location in the probe display. See Figure 2 for a visual representation of the four priming conditions.

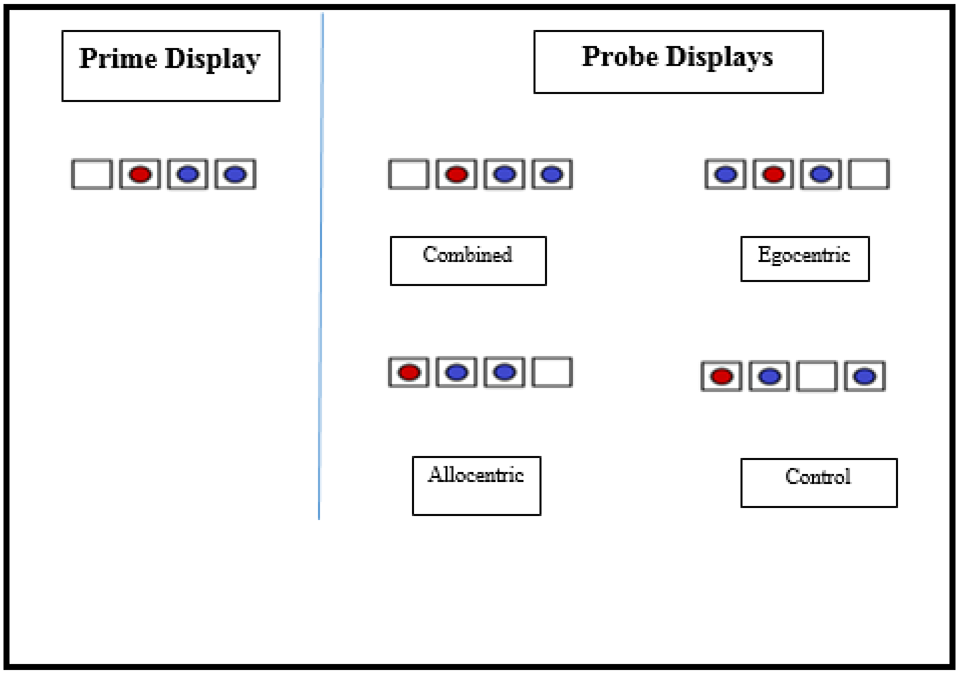

Figure 2. Example probe displays. An example prime display and an example probe display for each of the four priming conditions.

All possible variations of each condition was included in the experiment. This comprised 24 egocentric displays, 2 allocentric displays, 12 combined displays, and 36 control displays. This ensured that the target was located at each of the four possible absolute locations and each of three possible relative locations an equal number of times. This was necessary to avoid any systematic effect associated with the location probability effect in which individuals respond faster to targets when they appear in more often repeated locations (Miller, 1988). Each block contained half of all possible egocentric displays, both allocentric displays repeated six times each, and all possible combined and control displays.

The independent variable instruction dictated how the participants responded to the target. In the absolute instruction condition, participants responded to the square that contained the target. Each square had a designated computer key and participants responded to one of four options. In the relative instruction condition, participants responded to the location of the target relative to the distractors. A designated computer key was pressed when the target appeared to the left of both distractors, between the two distractors, or to the right of both distractors. Participants completed both blocks for the one instruction condition before completing both blocks of the second instruction condition. The order was counterbalanced across participants.

A total of 72 trials were presented in each of four blocks. Each trial consisted of a prime and probe search display. Therefore, the participants responded to 144 displays in each block. Each block contained 12 egocentric, allocentric, and combined trials and 36 control trials. This ensured an equal number of priming and control trials per block. A self-paced break was given after each block.

Procedure

All participants were tested in a single session lasting approximately 15 minutes. Participants were given a brief description of the study and gave assent. After receiving verbal directions, participants read a brief written version of the directions to ensure each participant fully understood the procedure. The experiment began with four practice trials. Next, the first instruction condition began. Participants took a self-paced break after the first block (72 trials; 144 responses; approximately 2.5 minutes) before completing a second block in the same instruction condition. Participants then took another break, were given new instructions, and completed the same procedure for the second instruction condition.

CHAPTER 3

RESULTS

Median RTs were calculated for each participant in each condition. Descriptive statistics for the dependent variable are provided in Table 1. Alpha was set at .05 for all inferential statistics unless stated otherwise. Overall, participants included in the analyses made very few errors when responding to the visual search stimuli (*M* = 5.6, *S.D.* = 3.36; representing less than 2% of total probe displays). Preliminary analyses indicated that presentation order of instruction and sex did not have a significant effect on RTs. Hence, these variables were not considered further.

	Priming Effects							
	Absolute Combined	Absolue Allocentric	Absolute Egocentric	Relative Combined	Relative Allocentric	Relative Egocentric		
Mean	-40.10	-17.66	-32.03	-49.46	-41.62	-2.91		
Std. Deviation	35.93	30.48	29.15	28.33	24.53	24.97		
	Response Times							
	Absolute Combined	Absolue Allocentric	Absolute Egocentric	Absolute Control	Relative Combined	Relative Allocentric	Relative Egocentric	Relative Control
Mean	470.23	492.66	478.30	510.33	494.50	502.34	541.05	543.96
Std. Deviation	48.27	55.49	49.26	58.74	46.37	55.03	61.97	57.19

Table 1. Mean results. Mean and standard deviation for the priming effects and overall response times of each priming condition at each instruction condition.

The main analyses were conducted in two ways. First, the raw RT data was examined to test the effects of the two independent variables and their interaction. Second, facilitation effects were calculated (see below) to compare the effects associated with each condition.

A 2 X 4 repeated measures multivariate analysis of variance (MANOVA) was conducted on the raw RT data to test the effect of the independent variables (instruction and priming) and their interaction. The MANOVA revealed a significant effect of instruction, Wilks' (1, 39) = .564, $p < .001$, partial eta squared = .436, as participants responded significantly faster in the absolute condition (*M* = 487.88, *S.E.* = 7.79) than the relative condition (*M* = 520.46, *S.E.* = 8.30); and a significant effect of Priming, Wilks' (3, 37) .20, $p < .001$, partial eta squared = .79. Participants responded fastest in the combined condition (*M* = 482.36, *S.E.* = 6.90), followed by the allocentric condition (*M* = 497.5, *S.E.* = 497.50), egocentric condition (*M* = 509.67, *S.E.* = 8.01), and control condition (*M* = 527.14, *S.E.* = 8.47). A visual representation of the results can be seen in Figure 3. Follow up tests using a Bonferroni correction indicated that each priming condition was significantly different from the other priming conditions (all p's < .008). Additionally, there was a significant interaction between instruction and priming, Wilks' (3, 37) = .379, $p < .001$, partial eta squared = .62.

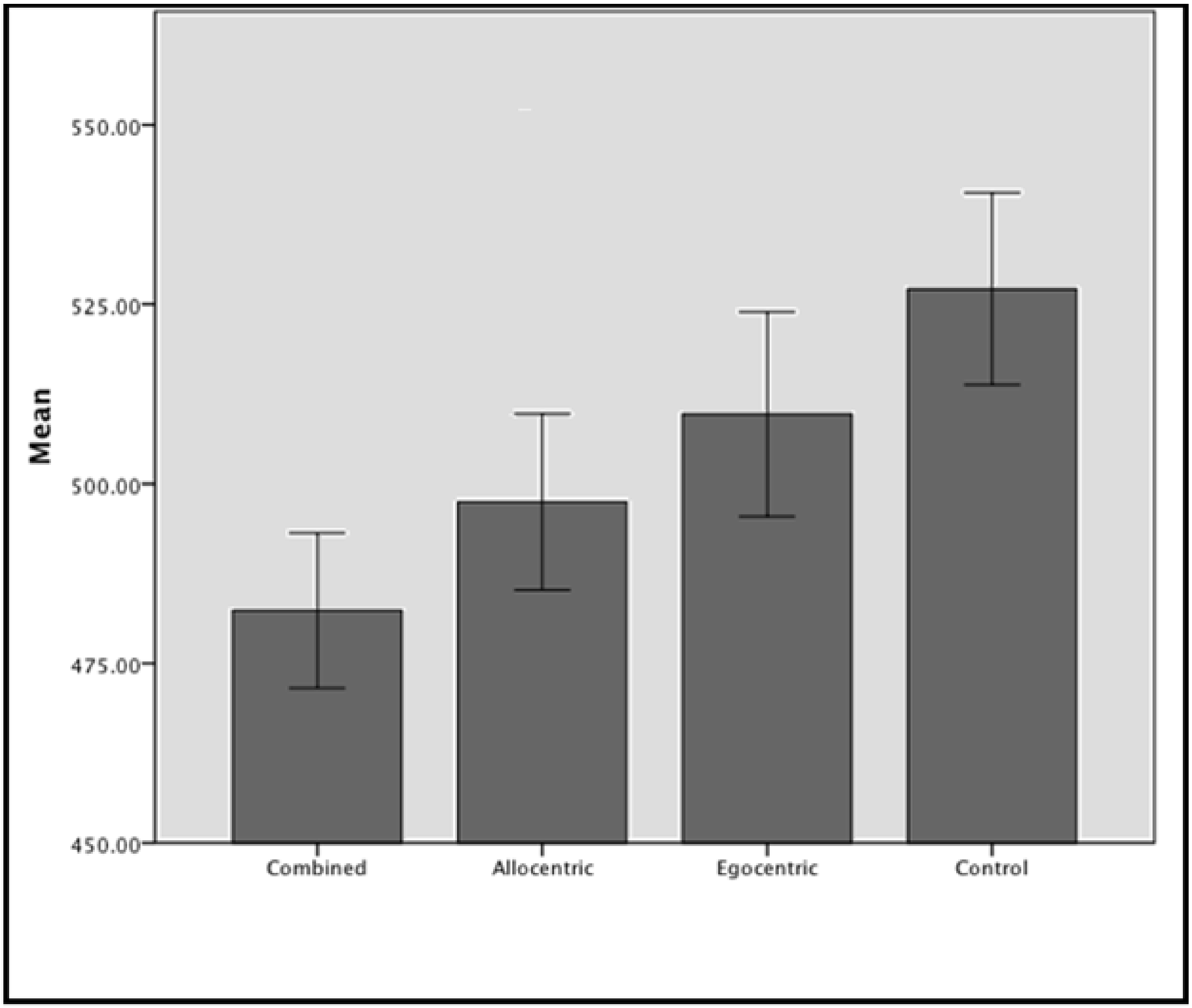

Figure 3. Mean RT for each priming condition. Results after collapsing across instruction conditions. Error bars represent 95% confidence intervals.

Simple effects tests were conducted to follow up on the significant interaction. Resulting p-values were adjusted using the Bonferroni method to control for alpha inflation. In the absolute instruction condition, participants responded significantly faster in the combined, egocentric, and allocentric conditions than in the control condition (all p's $< .004$). Further, participants responded faster in the combined and egocentric conditions than in the allocentric condition, though the difference was only marginally significant for the egocentric condition ($p < .004$ and p = .0042, respectively). In the relative instruction condition, participants responded significantly faster in the combined and allocentric conditions than in the egocentric and combined conditions. The egocentric condition was not significantly faster than the control condition.

For the next set of analyses, facilitation effects were calculated by subtracting the median control RT for each instruction condition from the median RT of each priming condition of the same instruction. For example, the absolute instruction control priming condition minus the absolute instruction combined priming condition equaled the absolute instruction combined priming condition facilitation effect. This created a measure of facilitation; thus, a higher number meant a larger facilitation effect. The facilitation effects were subjected to a 2 X 3 MANOVA to test the effect of the independent variables (instruction and priming) and their interaction. The MANOVA revealed a significant effect of priming, Wilks' (2, 38) = .375, $p < .001$, partial eta squared = .63, as participants demonstrated the largest facilitation effect in the combined condition (*M* = 44.78, *S.E.* = 3.79), followed by the allocentric condition (*M* = 29.64, *S.E.* = 3.31), and the egocentric condition (*M* = 17.47, *S.E.* = 3.41). A visual representation of the results can be seen in Figure 4. Follow up tests using a Bonferroni correction indicated that each facilitation effect was significantly different from the other facilitation effects (all p's < .01) Additionally, there was a significant interaction between instruction and priming, Wilks' (2, 38) = .381, $p < .001$, partial eta squared = .62.

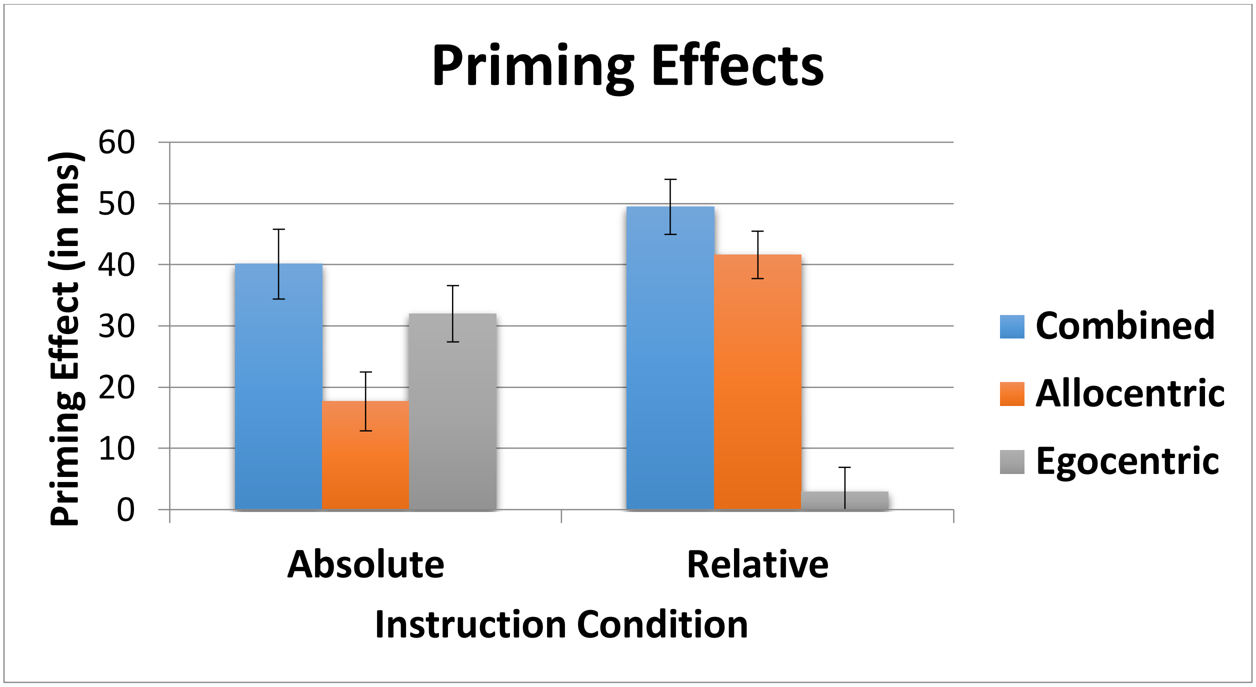

Figure 4. Priming effects for each priming condition. Error bars represent 1 *S.E.* above and below the mean.

Simple effects tests were conducted to follow up on the significant interaction. Resulting p-values were adjusted using the Bonferroni method to control for alpha inflation. In the absolute instruction condition, the combined and egocentric conditions demonstrated significantly larger facilitation effects than the allocentric facilitation effect (both p's $< .008$). There was no significant difference between the combined and egocentric conditions. In the relative instruction condition, the combined and allocentric conditions demonstrated significantly larger facilitation effects than the egocentric condition (both p's $< .008$). There was no significant difference between the combined and allocentric conditions.

To summarize, analyses were conducted using the raw RT data and facilitation effects. The results indicated that participants responded faster in the absolute instruction condition than the relative instruction condition, but that the facilitation effects were not significantly different.

Participants responded faster in the combined priming condition, followed by the allocentric, egocentric, and control priming conditions. The facilitation effects were strongest in the combined priming conditions with both responses. However, the interaction between instruction and priming variables revealed that the facilitation effect for the egocentric condition was larger than the facilitation effect for the allocentric condition in the absolute instruction condition, while the opposite held true in the relative instruction condition.

CHAPTER 4

DISCUSSION

The current experiment was designed to examine the role of goals on the processing of egocentric and allocentric spatial relations. It was hypothesized that having individuals respond to the absolute location of a target would increase the facilitation effect in an egocentric priming condition. It was also hypothesized that having individuals respond to the location of a target relative to distractors will increase the facilitation effect in an allocentric priming condition. Both of these hypotheses were supported.

The pattern of facilitation effects found in the current study is consistent with previous research. More specifically, participants demonstrated the largest facilitation effects in a combined priming condition, where both the egocentric and allocentric information remained consistent across displays. Additionally, the facilitation effects for the separate egocentric and allocentric priming conditions were smaller than the combined facilitation effect. Further, after removing the effects of instructions, both were faster than the control priming condition. Broadly speaking, Ball et al. (2009; 2010) and Maljokovic & Nakayama (1996) found the same pattern of results.

Ball et al. (2009) found that participants responded faster in the egocentric only condition than in the allocentric only condition, while the current study found the reverse. This difference is worth noting; however, the current study found a strong interaction effect when including the effect of instructions. It is possible that the instructions included in the current study had a disproportionate influence on the facilitation effect associated with a given frame of reference. For example, the lack of priming associated with egocentric processing in the relative instruction condition may have disproportionately raised the response time of the egocentric priming condition across the instruction conditions. Thus, the current study does not provide evidence that one frame of reference is more or less responsible for the combined priming in general, but instead points to the important effect that goals have on processing frames of reference.

Importantly, the current study extends the results of previous research by explicitly examining the role of goals on the processing of spatial relations. Individuals demonstrated a larger facilitation effect in the egocentric or allocentric priming conditions depending on the instruction condition. This implies that most of the facilitation effect in the combined priming condition was related to the frame of reference specific information associated with a particular goal. Therefore, the comparative importance or weight given to one particular depends, at least in part, on an individual's goals.

Role of Spatial Attention

The important role of goals in moderating frame of reference specific processing suggests that spatial attention can be directed in a top down manner. This conclusion is not unique, as previous research has demonstrated the effect of attentional processes on spatial attention (e.g., Bravo & Nakayama, 1992); however, the current finding extends previous work by applying it to frame of reference processing. The goal or task may influence how spatial attention is allocated by directing resources to frame of reference specific information. So, a task that requires individuals to locate an object relative to one's self may promote the use of egocentric information. Other variables may have additionally influenced how attention was allocated during the current study. For example, the target was always red in the current experiment, as opposed to paradigms that require participants to detect the odd color stimulus (e.g., Maljkovic & Nakayama, 1996). The consistent feature of the target may promote top down attentional mechanisms, as search can be directed to a single target feature (LaBerge & Brown, 1989). Therefore, it is likely that participants were guided to the target by top down attentional mechanisms as a result of the individual's goal and the nature of the stimuli.

The allocating of resources to more effectively process information from one frame of reference may have the effect of impairing processing of other frames of reference. In the current study, priming was demonstrated in the allocentric priming condition when participants were responding to the absolute position of the target (though the facilitation effect was not as strong as the egocentric facilitation effect). In contrast, priming was not demonstrated in the egocentric priming condition when participants were responding to the relative position of the target. This suggests that the allocation of attentional resources to favor one frame of reference may lead to less efficient processing of the other frame of reference. The neuroanatomical overlap associated with processing different frames of reference, as discussed above, suggest that it is, at least theoretically, possible for one frame of reference to dominate response tendencies, even though both reference codes may develop in parallel.

A related but unlikely possibility is that there is an inhibitory effect associated with relying on one specific frame of reference. This is unlikely as participants consistently had the largest facilitation effects in the combined priming condition. If there was an inhibitory effect, there would have been facilitative and inhibitory components in the combined priming condition, which would likely result in slower, or at least not faster, response times than the single frame of reference condition associated with the one that is most relied upon. The current findings are suggestive, but future research should seek to more explicitly elucidate the consequences of promoting one frame of reference over another.

External Environmental Reference Points

Real world visual scenes contain far more context and complexity than laboratory tasks. This additional information can be used by individuals to represent the spatial relations between objects. For example, contextual cueing paradigms have demonstrated the importance of context during visual search tasks (Chun & Jiang, 1998). In a typical contextual cueing task, the configuration of target and distractors in a display is repeated. Participants tend to implicitly learn the context of the scenes, which is demonstrated by a facilitative effect compared to random displays. These studies show that individuals often process the context of visual scenes and attention can be directed based on this context. Additionally, real world scenes are often very complex and contain much more visual information than individuals can readily attend (Nakayama, 1990; Wolfe, 1999). This suggests that individuals do not rely on all features of an environment when processing spatial information. Learning the spatial relations between the numerous features of environments requires establishing multiple reference frames in parallel. Thus, the process of spatial relations must be understood within the larger context and complexity of the visual scene.

In the current study, there were environmental features of the environment that could have been used as alternative reference points. For example, the object-to-object spatial relations between the computer screen, the boxes containing the stimuli, or other environmental features (e.g., a table in the testing room) may have provided additional information to participants. It must be acknowledged, when discussing egocentric specific processing, that most object-to-object spatial relations remain unchanged on consecutive trials. Rather, only the spatial relation between the target and distractors is changing, while most of the external environmental features remain unchanged throughout the entire experiment.

Ball and colleagues (2009; 2010) made a point to remove much of the external environmental features that may be used as additional reference frames. More specifically, they had participants complete the task in a dark room and projected the stimuli on a blank wall. While this minimizes the potential for other reference points, it may not be necessary. The current study found largely similar results without using the additional precautions. The stimuli used in current study were, arguably, much more salient to participants than other environmental features. The targets and distractors are a necessary component of a goal-related task, whereas other features of the environment are unhelpful for completing the task, as the positions remain constant throughout the durations of the experiment. Therefore, it seems unlikely that participants are using many of these external features when completing the task. Despite the argument that external environmental features likely do not influence the task in a meaningful way, a goal of future research can be to directly compare the two paradigms and try to better understand any possible effect of external reference frames.

Limitations

The current study is not without limitations. Repetition effects occur when participants respond in the same way on consecutive trials, typically resulting in shorter response latencies on subsequent trials (Rabbitt & Vyas, 1974). In the current study, repetition occurs by the very nature of the responses to the priming conditions. The target always appears in the same location across trials in the combined and egocentric priming conditions, but always in a different location in the allocentric and control conditions. So, the correct response to the prime and probe displays was always identical in the combined priming condition, leading to repetition effects.

Further, the participants' response was always repeated in the egocentric condition in the absolute instruction condition, but was always different for the allocentric and combined conditions. In the relative instruction condition, the response was repeated in the combined and allocentric conditions, but only sometimes repeated in the egocentric and control conditions. Therefore, the facilitation effects associated with priming for the combined and egocentric priming conditions may have benefited from an additional facilitation associated with repetition of the correct response. The influence of repetition effects may partially explain the stronger facilitation effect associated with the combined and egocentric priming conditions in the absolute instruction condition, and the combined and allocentric priming conditions in the relative instruction condition.

There are several reasons why repetition effects do not account for the full pattern of results. First, priming was demonstrated in the allocentric condition in the absolute instruction condition, despite requiring a different response on all prime and probe trials. This suggests that the results were not exclusively due to a repetition of response. Second, the results of the current experiment broadly replicate the results of similar studies (e.g., Ball et al., 2009; see above for a more detailed explanation). Therefore, there is reason to believe that the repetition of the response in some trials but not others did not confound the results. However, this should be addressed in future research.

Implications

The current study has several important real-world implications. The current study explicitly examines how individuals process small-scale spaces; however, the results may have implications for large-scale spaces as well. Visual scenes that individuals encounter are often large and involve action through space. For example, individuals must occasionally navigate through unfamiliar large-scale environments. People often learn, either implicitly or explicitly, route and survey knowledge while navigating complex environments (Golledge, 1999; Montello, 1998; Ishikawa & Montello, 2006). Route knowledge refers to the ability to use paths to navigate through an environment, while survey knowledge refers to understanding how routes are integrated in the larger environment (Siegel & White, 1975). Survey knowledge is usually considered to be independent of the observer, which is roughly analogous to allocentric representations. The findings of the current study suggest that individuals may process or learn the environment differently based on particular goals. It may be possible to promote the learning of survey knowledge by having participants focus on the spatial relations between landmarks, as opposed to just focusing on the landmark itself. If empirical evidence supports this conjecture, then it may be possible to create interventions for groups that have demonstrated deficits in survey knowledge, such as young children (Piaget & Inhelder, 1967; Nys, Gyselinck, Orriols, & Hickmann, 2015) and adults with intellectual disability (Mengue-Topio, Courbois, Farran, & Sockeel, 2011; Davis, Merrill, Conners, & Roskos, 2014).

Conclusion

The current study examined the role of instruction on the priming of egocentric and allocentric spatial relations. While participants consistently responded fastest to a combined condition, the results indicated that the relative facilitation effect in egocentric and allocentric specific priming conditions was dependent upon the type of instruction. It is argued that the individual's goals can influence frame of reference specific processing, potentially by means of a top-down attentional mechanism. The current findings have general significance for interpreting and designing future experiments that seek to better dissociate egocentric and allocentric spatial processing. Future research will hopefully extend these findings by identifying other variables that influence spatial processing.

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APPENDIX

Office for Research

Institutional Review Board for the Protection of Human Subjects

THE UNIVERSITY OF ALABAMA

R E S E A R C H

June 22, 2015

Edward Merrill, PhD
Dept. of Psychology
College of Arts & Sciences
Box 870348

Re: IRB Protocol # 12-014-R3 "Processing of Spatial Relations in People with and without Down Syndrome"

Dear Dr. Merrill:

The University of Alabama Non-Medical IRB recently met to consider your renewal application. The IRB voted to approve your protocol for a one year period.

Your application will expire on June 18, 2016. If your research will continue beyond this date, complete the IRB Renewal Application by the 15th of the month prior to project expiration. If you need to modify the study, please submit the Modification of an Approved Protocol Form. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, please complete the IRB Study Closure Form.

Please use reproductions of the IRB approved stamped consent/assent form to provide to your participants.

Should you need to submit any further correspondence regarding this application, please include the above application number.

Good luck with your research.

Sincerely,

Stuart Usdan, PhD
Chair, Non-Medical Institutional Review Board

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IRB Project #: 12-014-R3

UNIVERSITY OF ALABAMA
INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN SUBJECTS
REQUEST FOR APPROVAL OF RESEARCH INVOLVING HUMAN SUBJECTS

I. Identifying information

	Principal Investigator	Second Investigator	Third Investigator
Names:	Edward C. Merrill	Frances Conners	Zachary Himmelberger
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Title of Research Project: Processing of Spatial Relations in People with and without Down syndrome

Date Submitted: 05/15/15
Funding Source: Department funds made available to Edward Merrill for research purposes

☒ Revision ☒ Renewal ☐ Completed
Please attach a renewal application

UA faculty or staff member signature:

II. NOTIFICATION OF IRB ACTION (to be completed by IRB):
Type of Review: __X__ Full board _____ Expedited

IRB Action:
___ Rejected Date:
___ Tabled Pending Revisions Date:
___ Approved Pending Revisions Date:
X Approved-this proposal complies with University and federal regulations for the protection of human subjects.

6/18/2016
(dated)
(dated____________)
(dated____________)
(dated____________)

Approval signature