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BRIEF REPORT

# Does Constraining Field of View Prevent Extraction of Geometric Cues for Humans During Virtual-Environment Reorientation?

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Environment size has been shown to influence the reliance on local and global geometric cues during reorientation. Unless changes in environment size are produced by manipulating length and width proportionally, changes in environment size are confounded by the amount of the environment that is visible from a single vantage point. Yet, the influence of the amount of the environment that is visible from any single vantage point on the use of local and global geometric cues remains unknown. We manipulated the amount of an environment that was visually available to participants by manipulating field of view (FOV) in a virtual environment orientation task. Two groups of participants were trained in a trapezoid-shaped enclosure to find a location that was uniquely specified by both local and global geometric cues. One group (FOV 50°) had visually less of the environment available to them from any one perspective compared to another group (FOV 100°). Following training, we presented both groups with a control test along with three novel-shaped environments. Testing assessed the use of global geometry in isolation, in alignment with local geometry, or in conflict with local geometry. Results (confirmed by a follow-up experiment) indicated that constraining FOV prevented extraction of geometric properties and relationships of space and resulted in an inability to use either global or local geometric cues for reorientation.

*Keywords:* virtual environment, orientation, global geometry, local geometry, field of view



Information about current position within a surrounding environment is fundamental to successful navigation. It provides critical information about current location in space and permits the planning and comparison of potential routes of travel. This ability to determine current position is predicated on an ability to determine which direction is which—an ability to orient with respect to the environment.

One way to investigate this orientation process has involved placing disoriented participants into a rectangular enclosure. Having previously been trained to locate a target object situated in a particular corner marked with a unique feature, participants are then required to locate the target object in the absence of the unique feature. Participants not only search at the corner in which the target object had been previously located but also at its rotationally equivalent corner (the 180° equivalent). The proportion of searches at these two locations are not only equivalent but are also at above-chance levels (for a review, see Cheng & Newcombe, 2005). Such equivalent, above-chance searching at these two locations has been interpreted as evidence for the encoding of the geometric properties of the overall shape of the enclosure (see Cheng, 2005). This rotational error suggests that during initial learning, information regarding the shape of the enclosure was encoded. In the absence of the disambiguating feature, confusion occurred regarding the "correct" location because the trained and rotationally equivalent locations were identical with respect to the geometry of the enclosure.

In the almost 30 years since the discovery of the rotational error phenomenon (see Cheng, 1986; Gallistel, 1990), this reorientation paradigm has revealed environmental cues responsible for successful orientation (e.g., Bodily, Eastman, & Sturz, 2011; see also Cheng, 2005; Ratliff & Newcombe, 2008; Sovrano & Vallortigara, 2006), and evidence suggests that nongeometric cues, such as beacons and landmarks, and geometric cues, such as corner angles and enclosure axes (e.g., the principal axis of space—which runs through the centroid and approximate length of the enclosure), are used for successful reorientation (see Lee, Sovrano, & Spelke, 2012; Lubyk, Dupuis, Gutiérrez & Spetch, 2012; Kelly & Bischof, 2008; Sturz, Gurley, & Bodily, 2011; Sutton, Twyman, Joanisse, & Newcombe, 2012). Recent research has shown that changes in enclosure size from training to testing influence the relative contribution of feature and geometric cues to the reorientation process (Ratliff & Newcombe, 2008; Sovrano, Bisazza, & Vallortigara, 2005; Sovrano, Bisazza, & Vallortigara, 2007; Vallortigara, Fer-

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uglio, & Sovrano, 2005). Feature cues appear to exert a greater influence in larger enclosures whereas geometric cues appear to exert a greater influence in smaller enclosures (see, Miller, 2009). More recent research suggests that reliance on local (e.g., wall lengths, corner angles) and global (e.g., principal axis of the enclosure) geometric cues is also influenced by enclosure size, such that local geometric cues exert a greater influence in larger enclosures and a lesser influence in smaller enclosures (Sturz, Forloines, & Bodily, 2012).

Of note, enclosure size has been manipulated in a variety of ways within the reorientation paradigm. Although some experiments have changed length and width of the enclosure by a fixed proportion (e.g., Sturz & Kelly, 2009), others have changed length and width of the enclosure disproportionally (e.g., Learmonth, Newcombe, Sheridan, & Jones, 2008). Assuming an arbitrary and fixed field of view (FOV; i.e., the amount of the visible world seen at any given time) at the centroid of an enclosure, the amount (i.e., percent) of the enclosure visible from this location remains the same across proportional manipulations of enclosure size, but changes across disproportional manipulations of enclosure size. As a result, enclosure-size manipulations involving disproportional changes in the enclosure's length and width appear to be confounded with the amount of the environment that is visible at any moment (see also Sturz & Bodily, 2011a, 2011b, 2012).

One intriguing possible explanation for the reported influence of enclosure size on the use of local and global geometric cues relates to this discrepancy in the amount of the enclosure that is visibly available across disproportionate enclosure-size manipulations. Specifically, global geometric cues may exert more influence in a disproportionately manipulated small enclosure, relative to a large enclosure, because adjacent corners of a small enclosure may be viewed simultaneously, thereby allowing the overall shape of a small enclosure to be relatively easier to apprehend compared to a large enclosure (see Sovrano & Vallortigara, 2006). In other words, the amount of the enclosure that is visible at any moment may influence the relative reliance on global versus local geometric cues during reorientation.

To address this question, we explicitly manipulated FOV to determine whether the amount of the environment that was visually available influences reliance on global and local geometric cues for reorientation. We trained two groups of participants to complete a dynamic three-dimensional (3-D) virtual orientation task. The groups differed only with respect to the amount of the virtual environment that was visually available, with one group (FOV 50°) having less of the environment visibly available to them at any moment compared to another group (FOV 100°; see Figure 1). We trained both groups to approach a beacon which always appeared in the same corner of a trapezoid-shaped enclosure. This enclosure shape was selected because an isosceles trapezoid is rotationally asymmetric, that is, opposite wall lengths and corner angles (local geometric cues) are not equal. In addition, the principal axes (global geometric cues) of an isosceles trapezoid bisect opposite sides (not opposite corners), similar to a rectangle. Therefore, the beacon location was uniquely specified by both local and global geometric cues. Following training, we tested both groups in the absence of the training beacon in a trapezoid- (i.e., control), a rectangle-, and two parallelogram-shaped (mirror transformed) enclosures (see Figure 1). The trapezoid test enclosure allowed us to assess whether participants primarily used the local or global geometric cues in the absence of the training beacon. The rectangle enclosure allowed us to assess the use of global geometry in the absence of trained local geometric cues (i.e., obtuse corner angle). Finally, the parallelograms allowed us to assess the use of local and global geometric cues when aligned (i.e., the parallelogram 1 enclosure) or in conflict (i.e., the parallelogram 2 enclosure). Such a training and testing regimen allowed us to control for orientation by alternative environmental cues (Dawson, Kelly, Spetch, & Dupuis, 2010; Miller & Shettleworth, 2007; for a review, see Cheng, 2008) and assess the extent to which FOV influenced the use of local and global geometric cues for reorientation.

If constraining FOV enhances the use of local geometric cues, perhaps because of a reduced ability to extract global geometric properties and relationships of space, then the constrained FOV group (i.e., FOV 50°) should allocate relatively more responses than the large FOV group (i.e., FOV 100°) to locations specified by trained corner angles during testing. Reciprocally, if increasing FOV enhances the use global geometric cues, perhaps due to an enhanced ability to extract the global geometric properties and relationships of space, then the large FOV group (i.e., FOV 100°) should allocate relatively more responses than the constrained FOV group (i.e., FOV 50°) to locations specified by the trained side of the principal axis of space during testing. Alternatively, constraining FOV may diminish the ability to extract any geometric properties or relationships of space (i.e., both local and global geometric cues), in which case the constrained FOV group should be unable to use either the corner angles or the principal axis of space during testing and should allocate responses equivalently to each corner of the test enclosures. In summary, our design allowed us to determine the extent to which FOV influenced the use of local and global geometric cues.

In addition to the measures of response location, we also analyzed response latencies during testing to assist in illuminating the role of FOV on the use of local and global geometric cues. Similar to the predictions of response locations discussed above, if constraining FOV enhances the use local geometric cues, then the constrained FOV group (i.e., FOV 50°) should have shorter response latencies in the presence of the trained corner angles (i.e., parallelogram 1) and longer response latencies in the absence of trained corner angles (i.e., rectangle) relative to the large FOV group (i.e., FOV 100°). Reciprocally, if increasing FOV enhances the use global geometric cues, then the large FOV group (i.e., FOV 100°) should have shorter response latencies in the rectangle and equivalent response latencies in the other enclosure types compared to the constrained FOV group (i.e., FOV 50°). Alternatively, if constraining FOV diminishes the ability to extract geometric properties and relationships of space, then the constrained FOV group (i.e., FOV 50°) should have longer response latencies across all testing enclosure types compared to the large FOV group (i.e., FOV 100°).

## Experiment 1

### Methods

**Participants.** Forty-eight undergraduate students (24 men and 24 women) served as participants. Participants received extra class credit or participated as part of a course requirement.

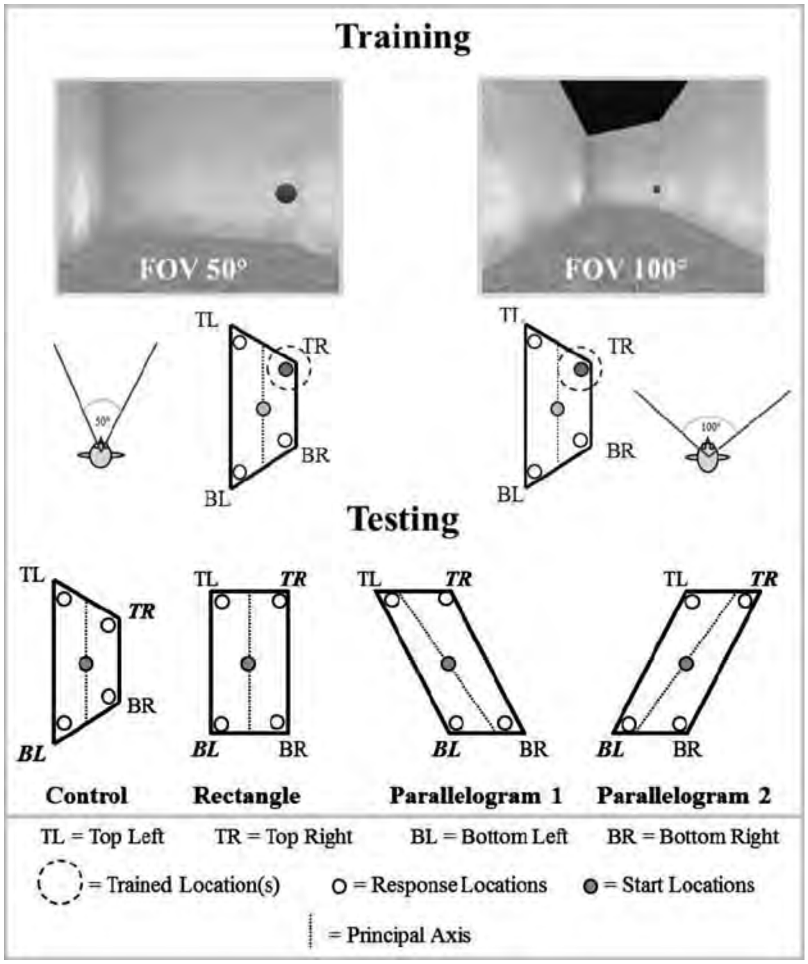


*Figure 1.* First-person perspective images of the training trials along with the schematics of training and testing trials for each group. Please note that images depict a view from the back wall of the enclosure. For illustrative purposes, the gray circles mark the position where participants entered the virtual enclosures for all training and testing trials, unfilled circles indicate invisible response locations, dotted lines represent the principal axis of space. Bold, italicized locations (TR = top right and BL = bottom left) in control, rectangle, parallelogram 1, and parallelogram 2 testing enclosures reflect locations specified by the trained side of the principal axis.



**Apparatus.** An interactive, dynamic 3-D virtual environment was constructed and rendered using Valve Hammer Editor and run on the Half-Life Team Fortress Classic platform. A personal computer, 22-inch flat-screen liquid crystal display monitor, gamepad joystick, and speakers served as the interface with the virtual environment. The monitor (1680 × 1050 pixels) provided a first-person perspective of the virtual environment. The FOV was manipulated via the software settings, which allowed direct manipulation of the horizontal FOV and then automatically adjusted the vertical FOV to fill the screen. The resulting Horizontal × Vertical FOV settings were 50° × 32° for the FOV 50° group and 100° × 74° for the FOV 100° group. Participants navigated within the environment via the joystick on the gamepad. Speakers emitted auditory feedback. Experimental events were controlled and recorded using Half-Life Dedicated Server on an identical personal computer.

**Stimuli.** Dimensions are Long Wall(s) × Short Walls × Height and measured in virtual units (vu = ~2.54 cm). Five virtual enclosures were created (see Figure 1): trapezoid (550 × 275 × 260 vu), control trapezoid (550 × 275 × 260 vu), rectangle (550 × 275 × 260 vu), parallelogram 1 (550 × 275 × 260 vu), and parallelogram 2 (550 × 275 × 260 vu). Corner angles for the trapezoid-shaped enclosures were 60° for both acute angles and 120° for both obtuse angles. Corner angles in the parallelograms were also 60° for both acute angles and 120° for both obtuse angles. All angles were 90° in the rectangle. Please note that all short walls shown in Figure 1 were identical in length. Each enclosure contained four response locations (48 × 48 vu), but response locations were invisible to participants. On training trials (see below), a single blue sphere (48 × 48 × 48 vu) was located at the correct location (i.e., top right in Figure 1). All surfaces were white in color with the exceptions of the floors (gray tile) and the ceilings (black).

**Procedure.** Participants were informed to find the location that transported them to the next virtual room and to move via the joystick on the gamepad: ↑ (forward), ↓ (backward), ← (rotated view left), and → (rotated view right). Participants selected a location by walking into it (i.e., a response was defined as coming into contact with one of the four invisible response locations). Selection of the rewarded location resulted in auditory feedback (bell sound) and a 7-s intertrial interval (intertrial interval [ITI]) in which the monitor went black and participants progressed to the next trial. Selection of a nonrewarded location resulted in different auditory feedback (buzz sound) and required participants to continue searching.

**Training.** Training consisted of 12 trials. Participants were randomly assigned to one of two groups: FOV 50° or FOV 100°. Gender and number of participants were balanced across groups. For both groups, the rewarded location was indicated by a blue sphere and was always located in the top-right corner (see Figure 1). Participants started each trial at the centroid of the trapezoid enclosure (marked with a gray circle in Figure 1) facing in a randomly selected orientation which ranged from 0° to 270° in increments of 90°. Only the rewarded location was marked with the blue sphere; the remaining locations were unmarked.

**Testing.** Testing consisted of 60 trials composed of 12 five-trial blocks. Each trial block was composed of four training trials and one test trial. The order of the training and test trials was randomized within each block. For each test trial, one of four enclosures was presented: control trapezoid, rectangle, parallelogram 1, parallelogram 2 (see Figure 1). Each enclosure was presented once without replacement until all four had been presented. Each enclosure was presented three times (total of 12 test trials). Participants made one response during test trials which resulted in no auditory feedback followed by the 7-s ITI and progression to the next trial. As during training, participants started each trial at the centroid of the enclosure (marked with gray circles in Figure 1) facing in a randomly selected orientation which ranged from 0° to 270° in increments of 90°. All response locations were unmarked during test trials (i.e., the blue sphere was absent).

## Results

**Training.** All participants rapidly learned to respond to the rewarded location (i.e., blue sphere). Such learning was at an equivalent rate and to an equivalent level of terminal accuracy for both groups—mean proportion of correct first choices: FOV 50° Block 1 ($M$ = .81; $SEM$ = .05), Block 2 ($M$ = .89; $SEM$ = .04), Block 3 ($M$ = .92; $SEM$ = .04), Block 4 ($M$ = 1.0; $SEM$ = 0.0); FOV 100° Block 1 ($M$ = .83; $SEM$ = .05), Block 2 ($M$ = .92; $SEM$ = .04), Block 3 ($M$ = 1.0; $SEM$ = 0.0), Block 4 ($M$ = .97; $SEM$ = .03). These results were confirmed by a three-way mixed analysis of variance (ANOVA) on the mean proportion of correct first responses with Group (FOV 50°, FOV 100°), Gender (Male, Female) and Block (1–4) as factors that revealed only a main effect of Block, $F(3, 132) = 11.19$, $p < .001$. None of the other main effects or interactions were significant, $F$s $< 1.87$, $p$s $> .13$. Post hoc tests on the Block factor revealed that each block was significantly different from all other blocks ($p$s $< .05$)—Block 1 ($M$ = .82, $SEM$ = .03), Block 2 ($M$ = .90, $SEM$ = .03), Block 3 ($M$ = .96, $SEM$ = .02), Block 4 ($M$ = .99, $SEM$ = .01)—with the exception that Block 3 was not significantly different from Block 4 ($p$ = .2). In addition, all blocks were significantly greater than chance (0.25), $t$s(47) $> 24.93$, $p$s $< .001$.

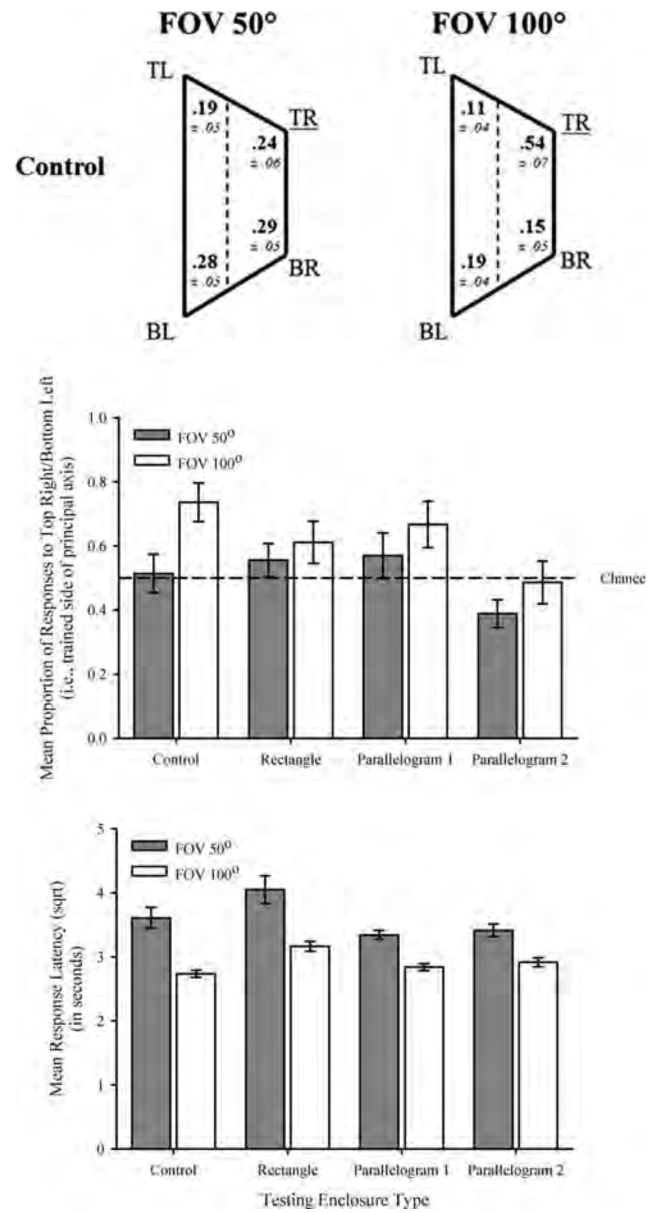


*Figure 2.* Top panel: Mean proportion of responses to each location (bold) and standard errors of the means (italic) in the control enclosure by group. The top-right (TR) location is underlined to designate it as the trained location. Dashed lines represent the principal axis of space. Middle panel: Mean proportion of responses to locations specified by the trained side of the principal axis (i.e., TR and bottom-left locations) plotted by enclosure type for each group. Dashed line represents chance performance. Bottom panel: Mean transformed (square-root) response latencies (in seconds) plotted by enclosure type for each group. Error bars represent standard errors of the means.

**Testing: Response location.** Figure 2 (top panel) shows the mean proportion of responses to each location in the control enclosure for the FOV 50° and FOV 100° groups. As shown, participants in the FOV 50° group did not allocate responses to the rewarded location (i.e., the location where the blue sphere would have been) at a level that was significantly different from chance (i.e., 0.25), one-sample *t* test, $t(23) = -0.24$, $p = .81$, whereas participants in the FOV 100° group allocated responses to the rewarded location at a level that was significantly above chance, $t(23) = 4.42$, $p < .001$.

Figure 2 (middle panel) shows the mean proportion of responses to the top-right and bottom-left locations (i.e., locations specified by the trained sides of the principal axis) plotted by enclosure type for each group. Response allocation to these locations was selected for analysis because, in the absence of the blue sphere, the proportion of responses to these locations is representative of the use of global geometric cues across all test enclosures. A three-way mixed ANOVA on mean proportion of responses to the top-right and bottom-left locations (i.e., locations specified by the trained sides of the principal axis) with Group (FOV 50°, FOV 100°), Gender (Male, Female), and Enclosure Type (Control, Rectangle, Parallelogram 1, Parallelogram 2) as factors revealed a main effect of Group, $F(1, 44) = 5.56$, $p < .05$, and a main effect of Enclosure Type, $F(3, 132) = 4.36$, $p < .01$. No other main effects or interactions were significant, $F$s $< 1.6$, $p$s $> .19$. Overall, the FOV 100° group ($M = 0.63$; $SEM = 0.04$) allocated a greater mean proportion of responses to the top-right and bottom-left locations than the FOV 50° group ($M = 0.51$; $SEM = 0.03$). Moreover, this overall mean proportion of responses was significantly greater than chance (0.50) for the FOV 100° group, $t(23) = 3.14$, $p < .001$, but not for the FOV 50° group, $t(23) = 0.24$, $p = .81$. Post hoc tests on the enclosure type factor revealed that parallelogram 2 was significantly lower than each of the other test enclosures ($p$s $< .05$), but that none of the other test enclosures differed from each other ($p$s $> .46$).

**Testing: Response latency.** To further illuminate the role of FOV on the use of local and global geometric cues, we analyzed response latency (i.e., the time between the start of a trial and response completion) on test trials. As with most latency data, response latencies were positively skewed (skewness: $M = 2.06$; $SEM = 0.52$). As a result, we subjected all response latencies to a square-root transformation (see, Sheskin, 2004). Figure 2 (bottom panel) shows the mean transformed response latencies by enclosure type for the FOV 50° and FOV 100° groups. A three-way mixed ANOVA on mean transformed response latencies with Group (FOV 50°, FOV 100°), Gender (Male, Female), and Enclosure Type (Control, Rectangle, Parallelogram 1, Parallelogram 2) as factors revealed a main effect of Group, $F(1, 44) = 40.22$, $p < .001$, and a main effect of Enclosure Type, $F(3, 132) = 12.22$, $p < .001$. None of the other main effects or interactions were significant, $F$s $< 3.6$, $p > .06$. Overall, participants in the FOV 100° group ($M = 2.91$; $SEM = 0.05$) took significantly less time to make a response than participants in the FOV 50° group ($M = 3.60$; $SEM = 0.10$). Post hoc tests on the Enclosure type factor revealed that the mean response latency in the rectangle was significantly longer than all other enclosure types ($p$s $< .01$), but mean latencies for the other enclosure types did not significantly differ from each other ($p$s $> .08$).

## Discussion

Results from training indicated that participants in both groups learned to respond to the correct location at an equivalent rate and to an equivalent terminal level of accuracy. During testing, participants trained with a larger FOV (i.e., FOV 100°) were able to use geometric cues whereas participants trained with a constrained FOV (i.e., FOV 50°) were unable to use geometric cues. Moreover, participants with a constrained FOV (i.e., FOV 50°) took significantly longer to select a location across all enclosure types compared to participants with a larger FOV (i.e., FOV 100°). We interpret these results as suggesting that constraining FOV prevented the extraction of geometric properties and relationships of space (i.e., both the corner angles and the principal axis). As a result, participants in the FOV 50° group were unable to use either the corner angles or the principal axis of space for reorientation.

These results suggest that constraining FOV diminished the ability to extract any geometric properties and relationships of space, and this resulted in an inability to use either corner angles or the principal axis of space for reorientation by participants in the FOV 50° group. Despite these results, it could be argued that the blue sphere competed with learning about geometric cues to a greater extent for participants in the FOV 50° group compared to the FOV 100° group. In short, it is possible that group differences obtained during Testing may have resulted from differential cue competition. Such differential cue competition would undermine an explanation based upon an inability to extract geometric properties of space with a constrained FOV.

# Experiment 2

As mentioned above, it could be argued that differential cue-competition was responsible for the obtained differences during testing between the groups instead of an inability to extract geometric properties and relationships of space for participants in the FOV 50° group. To shed light on this possibility, we conducted a follow-up experiment in which we repeated the design of Experiment 1 with new participants, but we removed the blue sphere from the correct location during Training such that only the global and local geometric cues could be utilized to respond to the correct location. If the blue sphere competed with learning about geometric cues to a greater extent for participants in the FOV 50° group compared to the FOV 100° group, then removal of the blue sphere should result in the absence of group differences because the blue sphere would no longer be able to differentially compete with geometric cues. Interestingly, however, if constraining FOV prevented the extraction of geometric properties and relationships of space for participants in the FOV 50°, then they should be unable to acquire the task in the absence of the blue sphere because they should be unable to use the global and local geometric cues to determine the correct location.

## Method

**Participants.** Forty undergraduate students (20 males and 20 females) different from those who participated in Experiment 1 served as participants. Participants received extra class credit or participated as part of a course requirement.

**Apparatus & Stimuli, and Procedure.** The apparatus, stimuli, and procedure were identical to Experiment 1 with the exception that the single blue sphere was absent from the correct location for the duration of training. As a result, participants needed to rely exclusively on geometric cues to determine the correct location. As with Experiment 1, participants were randomly assigned to one of two groups: FOV 50° or FOV 100°. Gender and number of participants were balanced across groups.

## Results and Discussion

Acquisition in the absence of the blue sphere was more difficult than in its presence. Overall, only 14 out of 40 (35%) participants made two correct first choices in the last three trials of acquisition (i.e., reached a criterion of above chance levels by the end of training—these last three trials would be analogous to Block 4 of Experiment 1). Given that the FOV 50° group did not acquire the task (see below), between group comparisons during testing were not meaningful. As a result, we only analyzed training data.

We first compared the number of participants to reach the acquisition criterion across groups. In the FOV 100° group, 11 of 20 (i.e., 55%) participants reached criterion, whereas in the FOV 50° group, only three of 20 (i.e., 15%) of participants reached criterion. Importantly, these proportions were significantly different from each other, binomial test, $z = 2.92$, $p < .01$. In addition, we compared the mean proportion of correct first choices in the last three training trials across groups. The mean proportion of correct first responses for the FOV 100° ($M = .58$; $SEM = 0.1$) and FOV 50° ($M = .30$; $SEM = 0.06$) groups were significantly different from each other, independent-samples $t$ test, $t(38) = 2.4$, $p < .05$. Importantly, these mean proportion of correct first choices for the last three trials of training were significantly above chance (0.25) for the FOV 100° group, one-sample $t$ test $t(19) = 3.26$, $p < .01$, but not significantly different from chance for the FOV 50° group, $t(19) = 0.85$, $p > .4$.

Results from Experiment 2 suggest that in the absence of the blue sphere, participants in FOV 100° were able to acquire the task (i.e., use global and local geometric cues to determine the correct location) whereas participants in FOV 50° were unable to acquire the task. These results provide converging evidence that constraining FOV results in an inability to extract geometric properties and relationships of space.

## General Discussion

Results from both experiments suggested that constraining FOV prohibited participants in the FOV 50° group from extracting geometric properties and relationships of space. Collectively, we suggest that our results argue for a role of FOV in the reorientation process. Importantly, we suggest that such a role for FOV is independent of environment size. In short, we suggest that FOV and environment size exert independent influences on reorientation with a critical caveat that FOV cannot be ruled out as influential in the orientation process for environments that are changed disproportionally in size.

It is worth noting that manipulating FOV on a monitor can result in the environment becoming distorted (i.e., causing objects to be minified or magnified to fit onto the monitor), and this distortion has been shown to produce changes in distance judgments (see Kuhl, Thompson, & Creem-Regher, 2009; Zhang, Nordman, Walker, & Kuhl, 2012). Although it remains unclear to what extent any potential distortions in distance perceptions may have occurred in the present task, travel times were identical across FOV manipulation and wall lengths would have maintained the same relative metrics regardless of underestimations or overestimations (i.e., scaled up or down to the same extent within each FOV). Given that reorientation has been shown to be based upon relative metrics for humans (see Sturz & Kelly, 2009), any potential differences in distance perceptions should exert little influence with respect to the current reorientation task.

It is also worth noting that view-based matching models of orientation and navigation involve the consideration of the participants' perspective (e.g., see Cheng, 2012; see also, Pecchia & Vallortigara, 2010; Wystrach & Graham, 2012); however, we are explicitly referring to its influence on the extraction of geometric cues as opposed to the matching of stored views to current perception (see also, Sturz & Bodily, 2011b). As a result, our obtained results suggest a role for FOV in the reorientation process; however, we acknowledge that the current training conditions did not require exploration of the entire space. To the extent that exploration of the entire space is critical in this process remains an open question, but present results have implications for experiments investigating the relative use of feature and geometric cues (especially those involving manipulations of enclosure size) and for experiments investigating the ability of participants to extract geometric relationships of space (e.g., Lee et al., 2012). Our results suggest that the amount of the environment visible at a given moment influences the extent to which geometric relationships of space can be extracted from the environment. This suggests that the influence of FOV should be incorporated into existing theoretical models of orientation (e.g., Miller & Shettleworth, 2007; Ratliff & Newcombe, 2008).

Perhaps most importantly, our results appear to broach a seemingly larger, and potentially more fundamental, issue in spatial cognition regarding objective definitions of space versus subjective perceptions of space. In short, our results suggest that differences in the amount of an environment viewed at one time can produce differences in the extent to which geometric relationships of space may be extracted. Such an issue regarding spatial perception would appear to be fundamental to delineating the nature and content of any resulting representation of space (see Sturz & Bodily, 2011b, 2012). Although the extent to which global- and local-based orientation strategies are able to speak to the nature and content of spatial representations remains unclear, it appears that the amount of the environment viewable at a time influences spatial behavior. Future research could continue to explore the extent to which visual access to an environment influences the relative use of global and local geometric cues and the extent to which such visual access influences the nature and content of spatial representations.

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