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Children's Use of Slope to Guide Navigation: Sex Differences Relate to Spontaneous Slope Perception

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Recent findings show that human adults can use slope to guide spatial search, although men significantly outperform women. To examine the sex difference more closely, we tested school-age children in a similar paradigm. Over four trials, children ($n = 110$) were disoriented and asked to locate a hidden target when the floor of a square enclosure was flat (control condition), sloped (slope condition), or sloped with a "ball drop demonstration," intended to make the slope more salient (ball drop condition). In the presence of the slope cue, children performed above chance, although boys significantly outperformed girls. Boys were also more likely to notice the slope, and spontaneous slope perception was key to using the slope cue.

Keywords: gradient cues; navigation; reorientation; sex; slope

1. INTRODUCTION

Gradient cues, such as scent (Wallraff, 2004), sound (King & Parsons, 1999), and luminance (Petie, Garm, & Nilsson, 2011), provide useful information to guide navigation. At a gradient's source, the intensity of the stimulus is greatest, and decreases logarithmically as the source becomes more distal (e.g., illumination dims as you move away from the light bulb). Intensity as a function of source proximity provides two useful types of information: direction and distance. Direction is deduced through changes in intensity. Increasing

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intensity denotes movement towards the source, while decreasing intensity denotes movement away from the source (Jacobs & Schenk, 2003). The intensity's rate of change provides distance information. Because the rate of change is nonlinear, distance relative to the source can be deduced via changes in intensity over time. Relative to the source, rapid versus gradual changes in intensity would indicate near and far locations, respectively.

An important, yet relatively under-studied gradient cue is terrain slope. Slope is a unique gradient in two ways. First, slope is a multimodal cue, and can be perceived by the kinesthetic (angle of the joints/muscular exertion), vestibular (sense of balance), and/or visual (angles formed when a sloped terrain intersects a vertical plane) sensory systems (Nardi, Newcombe, & Shipley, 2011, 2013). Second, because the intensity of the slope stimulus (i.e., steepness) does not consistently vary as a function of source proximity in the natural environment (e.g., a sloped terrain can be steepest at its base, midpoint, and/or apex), slope typically provides only direction information, deduced from changes in elevation relative to a horizontal surface (e.g., uphill versus downhill). There are no implications for distance.

For many animal species, slope is a salient directional cue and successfully guides navigation (e.g., rats: Miniaci, Scotto, & Bures, 1999; pigeons: Nardi, Nitsch, & Bingman, 2010). Sometimes slope is weighted over other spatial cues. For example, in an indoor environment, pigeons reorient primarily by the sloped floor, even when equally valid spatial cues (Nardi & Bingman, 2009) and more reliable spatial cues (Nardi et al., 2010) are available. For humans, it appears that slope can also be used to reorient, although adults' performance varies by sex in certain environments.

In real-world paradigms, when slope perception is multimodal, there is a consistent male advantage. In a series of studies, human adults were disoriented and asked to locate a target, hidden in one of four corners, in a completely featureless, but sloped square enclosure. Although adults performed above chance, males significantly outperformed females – by 1.4 *SD*s (Nardi et al., 2011), an effect size exceeding those detected in tests of mental rotation (Voyer, Voyer, & Bryden, 1995). Males were also significantly more confident in their target choice (Nardi et al., 2013). When the slope cue was made explicitly salient via a ball rolling downhill (i.e., "ball drop demonstration"), and participants were encouraged to use the slope, although performance improved overall, men still outperformed women (Nardi et al., 2011).

Virtual environments (VE) that provide visual information only – i.e., participants are seated, eliminating slope's kinesthetic and vestibular information – have yielded mixed results on sex differences. Chai and Jacobs (2009) detected a significant male advantage for target estimations encoded in a sloped VE. When spatial cues of equivalent validity were added to the sloped VE, removal of the slope cue significantly hindered performance for males only, suggesting that slope may be differentially weighted by sex (Chai & Jacobs, 2010). However, other VE studies found no significant effect of sex in slope performance. For example, both males and females more accurately recalled a spatial layout when located on a sloped versus flat surface (Kelly, 2011). Furthermore, after exploring a sloped environment, males and females performed equally well on judgements of relative direction (JRD) tasks and sketch maps (Restat, Steck, Mochnatzki, & Mallot, 2004; Weisberg & Newcombe, 2013).[1]

1.1. Current Study

Taken together, research suggests that slope-guided navigation appears more difficult for women, at least in the real, multimodal world. But when does the sex difference first appear? For that matter, can children use slope at all? To answer these questions, we tested 8- to 10-year-old children in a reorientation paradigm similar to that used with adults (e.g., Nardi et al., 2011). Children were tested in a square, featureless environment and randomly assigned to one of three conditions: control (no slope); slope (5-degree slope); and ball drop (identical to slope condition, with the addition of a "ball drop demonstration," intended to draw attention to the sloped floor.) In each condition, children were disoriented and asked to locate a hidden target over four trials.

We chose 8–10-year-old children for two reasons. First, we wanted to examine slope performance in a prepubescent population to minimize any possible effects of pubertal onset and maturation (for a review of the effects of puberty on spatial ability, see Newcombe & Dubas, 1992). Second, we wanted to examine slope use at an age before females consistently wear heeled footwear. Although Nardi et al. (2013) detected no correlation between reported mean heel height and female adults' performance, it's possible that frequent heel use could desensitize the kinesthetic and vestibular sensory systems over time, hindering slope perception even when wearing flat footwear.

1.2. Study Goals

This study had three goals. First, we wanted to determine whether children could use slope above chance. To date, it is unclear whether children can use slope – or any gradient – as a directional cue to guide navigation. Previous studies show that humans' ability to reorient develops quite early. By 18–24 months, toddlers can successfully locate a hidden object in an enclosed space using a variety of spatial cues (e.g., geometric layout: Hermer & Spelke, 1994,

1. In the Restat et al. (2004) study, it's important to note that participants explored the sloped environment while simultaneously pedaling on a stationary bicycle. Resistance was relative to the slope's incline, providing *some* kinesthetic information in terms of muscular exertion, but excluding information provided by the angle of the joints.

1996; nongeometric scalar dimensions: Huttenlocher & Lourenco, 2007; Lourenco, Addy, & Huttenlocher, 2009) and can flexibly integrate multiple cues (e.g., geometric layout + colored wall: Learmonth, Newcombe, & Huttenlocher, 2001). Although toddlers' ability to use some spatial cues varies by room size — such that 18–24-month-olds can navigate using geometric and nongeometric scalar cues in small and large enclosures, respectively — this effect is largely eliminated by 6 years of age (for a full review, see Cheng & Newcombe, 2005; Newcombe & Ratliff, 2007). But given the difficulty many adult women, and even some adult men, had with using slope, we wondered whether 8–10-year-olds would be able to use slope significantly above chance (25%).

Second, we wanted to examine sex differences in children. Sex differences in school-age children have been previously reported for spatial tasks such as the rod-and-frame (Block & Block, 1982; Maccoby & Jacklin, 1974) and water-level tasks (Thomas & Jamison, 1975), two spatial measures associated with the ability to perceive space using a vertical-horizontal spatial frame, parallel or perpendicular to the force of gravity, respectively (Sholl & Liben, 1995). In previous work with adults, performance on the water-level task significantly correlated with a variety of measures in the slope task, such as percentage of correct trials (Nardi et al., 2011: Exp. 1 & 2), reliance on the slope cue in conflict trials (Nardi et al., 2013), and use of the slope in single-cue trials (Nardi et al., 2013) - although sometimes, when the effect of sex is controlled, this correlation is not significant (e.g., Nardi et al., 2011: Exp. 1 & 3). Thus, it seemed possible that there would be a prepubertal sex difference in the use of slope for reorientation as well.

Third, we wanted to examine the effect of spontaneous slope perception on performance, and whether such perception significantly differed by sex. In previous studies with adults (Nardi et al., 2011, 2013), assessment of slope perception was prompted with explicit questions (e.g., "Is the floor slanted?"), whereas in the current study, slope perception was assessed using open-ended questions (e.g., "Is there anything unusual about this room?"). Thus, we wanted to examine – for the first time – whether spontaneous slope perception mediates the effect of sex in children (if significant), even when the slope is made explicitly salient, as in the ball drop condition.

2. METHOD

2.1. Participants

One hundred and ten 8- to 10-year-old children participated in this study (Mage = 108.60 months, SD = 10.80; range: 96.10–131.50). Split by sex, the sample was composed of 54 boys ($M_{\text{age}} = 107.70$ months, $SD = 10.20$; range = 96.10–131.40) and 56 girls ($M_{\text{age}} = 109.50$ months, $SD = 11.40$; range = 96.40–131.50). Children were predominantly Caucasian, came from a mid-high SES suburban area, and were recruited from a database compiled from mailing lists, flyers, craigslist, and Facebook. At the end of the experiment, children received a small toy and certificate for their participation.

2.2. Materials

The experimental enclosure was identical to that used by Nardi et al. (2011, 2013). It was a square enclosure measuring 244 cm (length) × 244 cm (width) × 203 cm (height), placed in a small building (755 cm long × 528 cm wide × 250 cm high). Suspended from the enclosure's PVC-pipe frame, four white sheets and one brown sheet formed the walls and ceiling, respectively. The floor, covered in grey carpet, was composed of a 12-cm-thick wooden platform, measuring 244 cm × 244 cm. Using a wooden lever, the enclosure could be adjusted to one of two positions, either parallel to the ground (flat) or tilted — with one end resting on wooden blocks, forming a 5-degree sloped floor.

In each of the room's four corners, an over-turned red bowl (16 cm in diameter, 8 cm deep) was located in front of a 25-W lamp (11 cm long × 11 cm wide × 18 cm high). During testing, a plastic pink pig (6 cm long × 4 cm wide × 4 cm high) was hidden beneath one of the red bowls. A black swivel chair (base: 56 cm in diameter; total height: 110 cm) was placed in the center of the room, with a brown sheet loosely covering its base (see Figure 1).

2.3. Procedure

Children were tested in a square, featureless environment and randomly assigned to one of three conditions: control (no slope); slope (5° sloped floor); or ball drop (5° sloped floor, "ball drop demonstration"). Within each condition, distribution by sex and age was as follows: control (15 boys/girls; $M_{age} = 107.60$ months, $SD = 9.60$); slope (20 boys/girls; $M_{age} = 109.90$ months, $SD = 11.60$); ball drop (19 boys/21girls; $M_{age} = 108.10$ months, $SD = 11.00$). Each condition consisted of one practice trial and four test trials. Target location for the test trials was random without replacement (i.e., no corner constituted the correct target location more than once); target location for the practice trial matched that of test trial four.

2.3.1. Control Condition

While being led into the experimental enclosure, each child wore a blindfold and entered from the side that could be raised, independent of condition. The child remained seated on the swivel chair (with the blindfold on) while the experimenter closed and ruffled the curtains at the front of the enclosure. "Ruffling the curtains" at the point of entrance ensured that all curtain walls were visually indiscriminate – that is, all curtains were randomly wrinkled. The child was then gently spun two to three times in both directions. Following

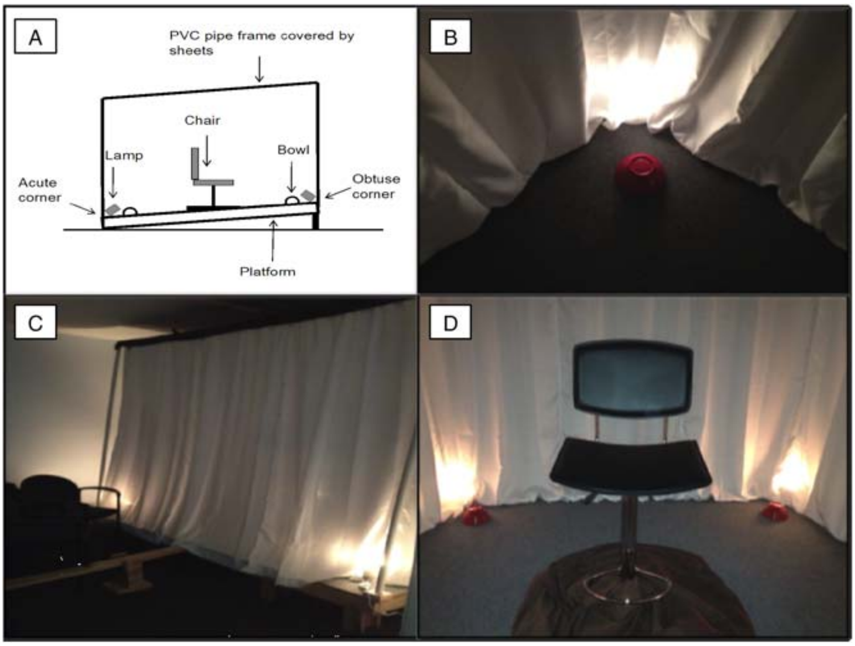

Figure 1: Four views of the experimental enclosure. (a) External side view of the apparatus when tilted, as implemented in the slope and ball drop conditions. (b) Internal corner view depicting a potential target location. (c) External front view. (d) Internal center view depicting the swivel chair used for disorientation. View (a) adapted from "The World is not Flat: Can People Reorient Using Slope?" by D. Nardi, N. S. Newcombe, and T. F. Shipley, 2011, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37*, p. 356.

disorientation, the child removed the blindfold and explored the enclosure. At this time, the experimenter asked, "Tell me what you notice about this room. Is there anything unusual?" No responses in the control condition indicated the presence of polarizing feature cues.

At this time, the practice trial began. While standing, the child watched the experimenter hide the pig under one of the four bowls. Next, the child returned to the swivel chair, put on the blindfold, and was again disoriented. The direction the child faced prior to, and immediately following disorientation never matched, and varied pseudo-randomly. Following disorientation, the child remained seated with the blindfold on while the experimenter draped the curtains *in front of* the lights. It is important to note that the position of the curtains in relation to the lights differed during target encoding and retrieval; if the curtains were behind the lights during encoding, they were positioned in front of the lights during retrieval. This ensured that no polarizing cues (e.g., a wrinkle in the curtain) could be used to reorient.

The child was then instructed to remove the blindfold and stand up. Location of target identification was recorded (e.g., corner 1, 2, 3, or 4) when the child overturned, pointed to, or verbally indicated a bowl as the hiding location. If incorrect, the child was permitted to continue searching until the correct location was identified. The procedure for the four test trials was identical to that of the practice trial.

2.3.2. Slope Condition

The slope procedure was identical to the control procedure, except for three points. First, the floor of the experimental enclosure was tilted at a 5-degree angle. Second, a wedge was placed under the chair, such that the chair's base was flat (180°). Third, following exploration, spontaneous slope perception was assessed when the experimenter asked, "Is there anything unusual about this room?" Positive slope perception was recorded if the sloped floor was verbally acknowledged via such words as "slanted, tilted, uneven, uphill, downhill, etc."

2.3.3. Ball Drop Condition

The ball drop procedure was identical to the slope procedure, except for two points. First, this condition included a "ball drop demonstration." After slope perception was recorded, the experimenter held up a small ball and stated, "Watch what happens when the ball is placed on the floor." The experimenter then released the ball at the upper end of the enclosure, and the child watched as the ball rolled downhill. Second, the ball drop condition assessed children's ability to identify the direction of the slope gradient. Following the "ball drop demonstration," the experimenter asked the child to stand in the center of the enclosure and point uphill. Response time was recorded for this task.

3. RESULTS

3.1. Correct Performance

For each child, performance was calculated as the proportion of successful retrievals (correct first choice) over four test trials. Initial analyses compared mean performance in each condition to chance (.25). As expected, performance was at chance in the control condition ($M = .22$, $SD = .19$), $t_{(29)} = 0.94, p = .35$. Performance in both the slope ($M = .44$, $SD = .33$), $t_{(39)} = 3.61$, $p = .001$, and ball drop conditions ($M = .54$, $SD = .33$), $t_{(39)} = 5.46$, $p < .001$, was significantly greater than chance.

In the subsequent analyses, age was included as a covariate in all ANCOVAs. A one-way ANCOVA confirmed the significant effect of condition, $F_{(2,106)} = 9.96$, $p < .001$, $\omega_p^2 = .14$ (nonsignificant main effect of age, $F_{(1,106)} = 3.32$, $p = .07$, $\omega_p^2 = .02$). Assuming heterogenous variances, Bonferroni-corrected contrasts ($\alpha = .0166$) showed that children in the slope, $t_{(64.82)} = 3.51$, $p = .001$, $d = .82$, and ball drop conditions, $t_{(64.54)} = 5.06$,

$p < .001$, $d = 1.19$, significantly outperformed those in the control; performance did not significantly differ between the slope and ball drop conditions, $t_{(77.99)} = 1.35$, $p = .18$, $d = .30$. Because these results confirmed that disorientation was successful and that aside from the sloped floor, the enclosure lacked additional spatial cues, the control condition was dropped from further analyses.

3.1.1. Slope and Ball Drop Conditions

A 2 (sex) × 2 (condition) ANCOVA yielded only a significant main effect of sex, $F_{(1,75)} = 6.55$, $p = .01$, $\omega_p^2 = .07$. Overall, boys ($M = .58$, $SD = .34$) significantly outperformed girls ($M = .40$, $SD = .31$). The main effects of age, $F_{(1,75)} = 2.93$, $p = .09$, $\omega_p^2 = .02$, condition, $F_{(1,75)} = 2.51$, $p = .12$, $\omega_p^2 = .02$, and the sex*-condition interaction, $F_{(1,75)} = 0.19$, $p = .66$, $\omega_p^2 = .01$, were not significant, suggesting that the ball drop demonstration did not improve performance for either sex (see Figure 2). However, after watching the ball drop demonstration, *all* children correctly pointed uphill. Furthermore, a one-way ANCOVA yielded no significant effects of age, $F_{(1,37)} = 0.50$, $p = .48$, $\omega_p^2 = .01$, or sex, $F_{(1,37)} = 0.99$, $p = .33$, $\omega_p^2 = .00$, on mean response time.

3.1.2. Spontaneous Slope Perception

A one-way chi-square showed that boys ($n = 21/39$; 54%) were more likely than girls ($n = 13/41$; 32%) to notice the slope unprompted, $\chi^2(1) = 4.01$, $p < .05$, Cramér's $V = .22$. To examine if slope perception mediated the main effect of sex, we added this factor to the previous ANCOVA. In a 2 (sex) × 2 (condition)

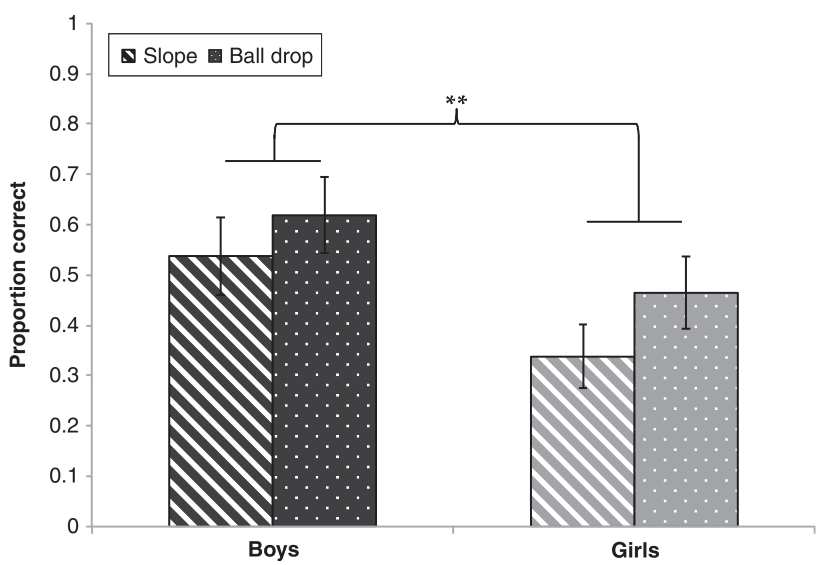

Figure 2: Performance (± SEM) by sex and experimental condition. **$p = .01$.

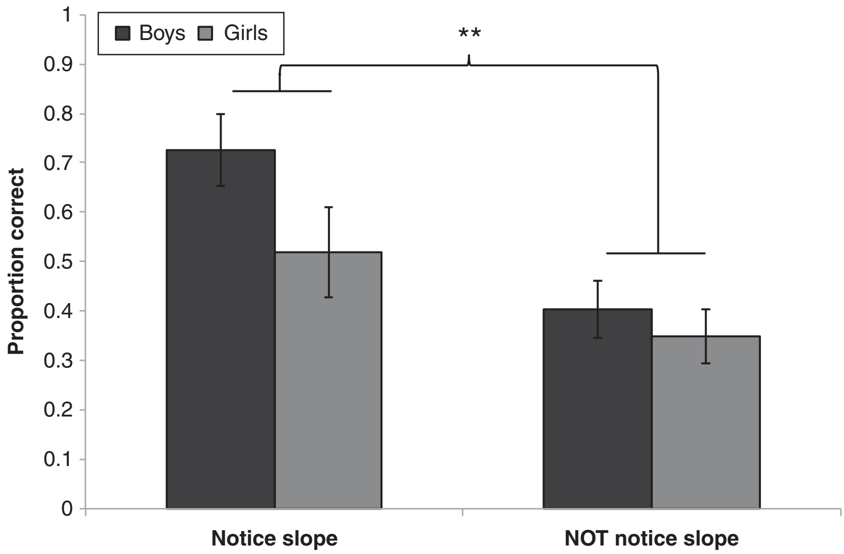

Figure 3: Performance (± SEM) by sex and slope perception collapsed across experimental conditions. $^{**}p < .01$.

× 2 (slope perception) ANCOVA, only slope perception significantly predicted performance, $F_{(1,71)} = 10.25$, $p = .002$, $\omega_p^2 = .10$. Children were significantly more likely to find the target if they noticed the slope ($M = .65$, $SD = .34$), than if they did not notice the slope ($M = .37$, $SD = .27$) (see Figure 3). The main effects of age, $F_{(1,71)} = 1.73$, $p = .19$, $\omega_p^2 = .01$, sex, $F_{(1,71)} = 4.05$, $p = .05$, $\omega_p^2 = .04$, condition, $F_{(1,71)} = 2.09$, $p = .15$, $\omega_p^2 = .01$, and all interactions (sex*condition, $F_{(1,71)} = 0.06$, $p = .81$, $\omega_p^2 = .01$; sex*perception, $F_{(1,71)} = 1.46$, $p = .23$, $\omega_p^2 = .01$; condition*perception, $F_{(1,71)} = 0.07$, $p = .79$, $\omega_p^2 = .01$; sex*condition*perception, $F_{(1,71)} = 0.11$, $p = .74$, $\omega_p^2 = .01$) were not significant.

The marginal effect of sex ($p = .05$) warranted further examination. Hierarchical multiple regression analyses were used to contrast the predictive power of sex versus slope perception. Entered first, sex accounted for 7% of

Table 1: Hierarchical regression analysis evaluating the predictive power of sex and slope perception.

DV	Condition	Factor	*R*	R^2	ΔR^2	ΔF	*Sig.*	*df*	β	*Sig.*
Score	Slope & Ball Drop									
		1. Sex	.26	.07	.07	5.84	**.02***	1,78	−.26	**.02***
		2. Recog.	.45	.20	.13	12.89	**.001*****	1,77	.38	**.001*****
Score	Slope & Ball Drop									
		1. Recog.	.42	.17	.17	16.21	**.000*****	1,78	.42	**.000*****
		2. Sex	.45	.20	.03	2.97	.09	1,77	−.18	.09

Note. Betas reported are those at which the variable was entered into the equation.
$^{*}p < .05$, $^{***}p \leq .001$.

variance (adjusted $R^2 = .06$), which significantly differed from zero, $F_{(1,78)} = 5.84$, $p = .02$. Entered next, slope perception accounted for an additional 13% of variance, a significant increase from that predicted by sex alone, $F_{(1,77)} = 12.89$, $p = .001$. However, when slope perception was entered first, the sex-added variance (3%) was nonsignificant, $F_{(1,77)} = 2.97$, $p = .09$ (see Table 1).

3.2. Errors

Errors were categorized by their location relative to the target. Orthogonal errors were incorrect with respect to the target's left/right location, but correct with respect to the slope; vertical and diagonal errors were both slope discordant errors, and were vertically and diagonally aligned with the target, respectively (see Figure 4). For children not at ceiling, we calculated the proportion of orthogonal errors (e.g., number of orthogonal errors/total number of errors) to examine if children who noticed the slope were more likely to accurately encode the slope, but erred in the target's left/right location.

This prediction was correct — when children noticed the slope, they made more orthogonal errors ($M = .51, SD = .38$) than those who did not notice the slope ($M = .28$, $SD = .29$), $t_{(61)} = 2.71$, $p = .01$, $d = .70$. The proportion of orthogonal errors significantly differed from chance (e.g., the proportion that would be expected if children guessed randomly $= .33$) only for those who noticed the slope, $t_{(19)} = 2.12, p < .05$, suggesting that when children did not notice the slope, they did not attempt to use the slope, even erroneously ($t_{(42)} = 1.25, p = .22$).

4. DISCUSSION

Results show that school-age children are able to use slope to reorient, as children's performance was significantly above chance in the presence of the

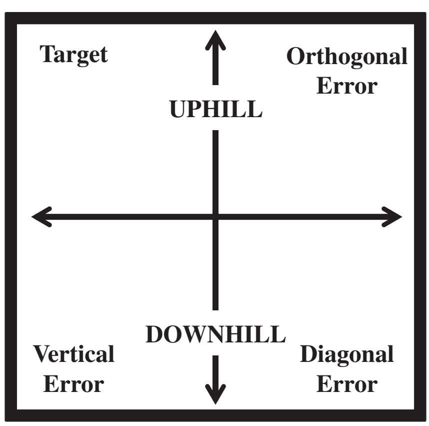

Figure 4: Errors categorized according to their location relative to the target.

slope cue. In addition, boys significantly outperformed girls, suggesting that the male advantage previously detected with adults (Nardi et al., 2011, 2013) is not linked to pubertal factors, nor frequency of heel use. Spontaneous slope perception also showed a sex difference that appeared to underlie the male advantage in slope performance, as boys were significantly more likely to notice the slope unprompted. Apparently, slope perception must be self-generated, because making the slope explicit and salient in the ball drop condition did not improve performance.

Why did only 43% of children notice the slope unprompted? And of those, why were 62% boys? Positive slope perception may be linked to cue salience. Cue salience is defined by the frequency of cue exposure and reliability over time (Cheng, Huttenlocher, & Newcombe, 2013). Cue salience is thus subjective, and varies as a function of previous experience (see rearing effects Brown, Spetch, & Hurd, 2007; Twyman, Newcombe, & Gould, 2012). When multiple cues are available, each cue will be flexibly weighted, and perceived, encoded, and relied upon accordingly (Ratliff & Newcombe, 2008). In the context of the current study, previous experience with sloped terrains might hone the ability to perceive slope at varying degrees.

Speculatively, one possibility is that experiential factors may impact children's experience with sloped terrains. Type of play (e.g., Miller, 1987) and activity level (e.g., Else-Quest, Hyde, Goldsmith, & Van Hulle, 2006) both differ by sex. For example, boys are given a wider variety of toys, ranging from blocks to cars to sports equipment, while girls are given toys largely related to domestic activities, such as dollhouses and mock cooking ware (Baenninger & Newcombe, 1989; Bradbard, 1985). Masculine toys elicit movement, and often incorporate sloped terrains (e.g., sports are played on nonuniform fields, toy cars come with multilevel ramps, etc.). Even in the absence of masculine toys, males are generally more active than females (Eaton & Enns, 1986; Else-Quest et al., 2006), and the majority of males' activity occurs outdoors (Harper & Sanders, 1975; Eaton & Enns, 1986; Cherney & London, 2006).

Of course, prenatal hormone exposure may also lead to greater experience with sloped terrains (Collaer & Hines, 1995; Newcombe, 2007). For example, exposure to androgens is linked to open-field exploration (rats: Stewart & Cygan, 1980), rough-and-tumble play (rats: Meaney, 1988; monkeys: Ward & Stehm, 1991), and greater interest in masculine toys (females with congenital adrenal hyperplasia: Dittman et al., 1990). Whether a factor of experience, biology, or both, greater experience with sloped terrains may hone the kinesthetic, vestibular, and visual sensory systems' ability to perceive slope at various degrees (Liss, 1983).

Over time, however caused, divergent experience might differentially impact slope perception. For example, high and low experience with sloped terrains may yield multiple (e.g., a category for 5-degree slopes, 10-degree slopes, etc.) and limited slope categories (e.g., one category for all sloped terrains), respectively. Multiple categories facilitate the detection of small variations among similar stimuli (e.g., x-rays: Sowden, Davies, & Roling, 2000; gender: Biederman & Shiffrar, 1987; phonemes: Liberman, Harris, Hoffman, & Griffith, 1957), i.e., categorical perception supports perceptual discrimination (Goldstone, 1998; Goldstone & Hendrickson, 2010). If minimal exposure with sloped terrains limits the number of categories within the slope domain, slope perception might be impeded, especially when the incline is relatively slight. Perhaps girls were less likely to differentiate a 5-degree incline from a flat surface because their sensory systems were less attuned to this small differentiation in terrain.

Interestingly, when the slope was made explicitly salient by the ball drop demonstration, children who did not notice the slope still did not use the slope, perhaps because they had little experience in doing so. Because the slope lacked reliability as a spatial cue, it may have appeared irrelevant to the task at hand. In previous work with adults, it is worth noting that a ball drop demonstration – very similar to the one used in the current study - did significantly improve performance (e.g., Nardi et al., 2011: Exp. 1 & 2). Because adults' experience with sloped terrains exceeds that of children, adults perhaps were more likely to perceive the slope cue as highly reliable, and thus rank the slope above other erroneous spatial cues. But when experience is limited, drawing attention to the slope cue — or any spatial cue previously undetected — may be insufficient to induce use, as salience does not automatically increase perceived reliability.

4.1. Future Directions

This study leaves several questions unanswered. One question is whether slope is easier to perceive and use in more naturalistic settings, which might be true for at least two reasons. First, the slope in the current study was homogenous. However, sloped terrains in the real world are *rarely* homogenous, requiring the kinesthetic and vestibular sensory systems to constantly recalibrate the degree of the slope gradient. Compared to a heterogenous slope, a homogenous slope reduces the sensory systems' need to recalibrate, perhaps making spontaneous slope perception less probable. Second, the interior of the enclosure may have provided relatively poor visual information regarding the slope cue (i.e., the acute and obtuse angles formed when the lower and upper ends of a sloped surface intersect a vertical plane, respectively). Because the enclosure's walls were composed of curtains, and the curtains' excess material rested on the sloped floor, the angles of intersection were visually imprecise (see Figure 1B).

Another unanswered question is whether experience really affects slope perception, as we have speculated. Does the type and frequency of children's play activities actually correlate with slope perception? Furthermore, why did the ball drop demonstration have no effect on children's performance? How much experience with such events would be required for children to use slope and hone slope perception? These questions may be practically important. A meta-analysis by Uttal et al. (2013) has demonstrated significant training effects on spatial tasks in general, including the water-level and rod-and-frame tasks, and hence optimism about training the use of slope in navigation is warranted.

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