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Sex differences in direction giving: Are boys better than girls?

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Previous research has extensively documented sex differences favoring boys in various domains of spatial cognition. However, relatively little research has examined sex differences in children's direction giving. The current study aimed to bridge this gap. A total of 143 children aged 3 to 10 years were asked to describe and recall routes from survey perspectives (via maps) and route perspectives (via videos). Significant sex effects (favoring boys) in direction-giving accuracy were found in describing route trials. However, boys and girls did not differ in the frequency of utterances encoding landmarks and direction of turns, suggesting that the quality rather than the quantity of words played a more important role in explaining sex differences. In addition, there was no sex difference in the route recall task. Although accuracy was overall higher in the map condition than in the video condition, it did not moderate sex differences. Overall, our study showed a robust sex difference in direction giving, which has important theoretical implications for understanding the development of human sex differences and critical clinical implications for designing training programs to improve children's spatial cognition.

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Introduction

Sex may be the most prominent and often studied factor associated with individual differences in spatial cognition (Coluccia & Louse, 2004; Lawton, 2010). Many researchers exploring spatial cognition (Boone et al., 2019; Hegarty et al., 2023; Newcombe et al., 2013) have called for a greater understanding of the nature of individual differences given that they present "one of the most vital lines" (Vasilyeva & Lourenco, 2010). However, one understudied topic, especially with respect to possible sex differences, is children's direction giving in spatial navigation.

Navigation technology, including the Global Positioning System (GPS), has made great strides during recent years. However, young children might not use navigation aids such as GPS because they do not have access to them, they do not know how to use them, and GPS does not cover all types of environments (e.g., indoor). Therefore, giving and following directions is still a critical aspect of daily life for many children. For example, young children are often given directions at home or school (e.g., a teacher asking an elementary school student to deliver something to the main office). Older children may need to give or follow directions when navigating around their neighborhoods and campgrounds. There are also cognitive and social benefits to understanding and giving directions. For instance, it could foster children's independence (Yang et al., 2011) and spatial awareness (He & Hegarty, 2020) and could facilitate cognitive development in other aspects (e.g., memory, attention, reasoning). Lastly, to produce/comprehend directions, one must construct spatial representations of the environment and map language to these representations. Thus, by examining direction giving in children, the nature of the underlying spatial representations and their development can be better understood (Jackendoff, 1987).

As we review below, the method in which girls and boys map language to spatial representations when navigating may differ; such a finding would have significant implications for understanding individual differences in navigation in children and may also help to close the gender gap, especially in STEM (science, technology, engineering, and mathematics)-related disciplines (e.g., encouraging more females to pursue the career of airplane pilots, a field that has been dominated by males and requires high wayfinding-related skills). Thus, the main aim of the current study was to systematically examine sex differences in direction giving among children aged 3 to 10 years—a broad age range in which research (see below) has explored direction giving in children, yet in which few studies have tested for sex differences systematically.

The development of direction giving

Spatial navigation, often referred to as "wayfinding" in the literature, is a complex spatial skill commonly defined as the ability to identify one's current location and successfully navigate to an unseen location in the environment (Montello, 2005). In humans, language often is used to aid spatial navigation through direction giving. More specifically, route directions are a series of verbal instructions explaining the environment that aid wayfinding (e.g., "Turn left at the corner of the coffee shop"; Lovelace et al., 1999). The ability to provide directions has been shown to improve with age during early childhood and early adolescence (Blades, 1992; Nys et al., 2015, 2018; Spencer & Darvizeh, 1983). For instance, Blades (1992) asked participants to provide route directions based on a map. Young children aged 6 to 8 years were less accurate than 10- to 12-year-olds, who in turn were worse than adults. In fact, none of the 6-year-olds could provide complete accurate descriptions of any turn along the routes. The cognitive mechanisms for the increased competency in direction giving may be related to how children use landmark and direction words in their route directions. When providing directions, young children were more likely to include landmarks, yet their use of direction terms (e.g., left, right) was somewhat vague (Austin & Sweller, 2017, 2018; Blades, 1992; Lloyd, 1991). Blades (1992) found that 6-year-olds focused more on describing landmarks and used vague directions such as "over there" and "that way." Landmarks represented 57% of the utterances for 6-year-olds, whereas they accounted for only 20% of adults' utterances. Older children started to use "left" and "right" and even cardinal directions in addition to landmarks. Adults were able to give more comprehensive route directions, including road sequence, type of junction, and turn required at junctions among other information (e.g., turn left at the next junction). Similar results were found with younger children aged 3 to 5 years in recalling directions from a video of a speaker (Austin & Sweller, 2017, 2018; Spencer & Darvizeh,1983) and with 7- to 10-year-olds in reading routes from a map (Lloyd, 1991).

The preference for landmark words during early childhood is consistent with behavioral studies of wayfinding. Children aged 6 to 8 years made fewer wayfinding errors when the landmarks were present than when they were absent (Lingwood et al., 2015b). Verbally emphasizing landmarks could further improve children's accuracy in spatial navigation (Farran et al., 2010; Lingwood et al., 2015a). In contrast, using direction terms, particularly left and right, goes through a more protracted development. Although 7-year-olds are able to correctly use left and right to refer to their bodies, it is not until after 8 or 9 years of age that children start to correctly use left and right when perspective taking is needed such as using these terms referring to people who are facing them (Rigal, 1994, 1996; Shusterman & Li, 2016). Even some 10- and 11-year-olds struggle to apply left and right terms when multiple levels of perspective taking are involved such as deciding whether A is to the left/right of B when A and B are facing toward the participant (Rigal, 1996). Given these findings, we hypothesized that boys and girls under 10 years of age will encode landmarks when giving directions, and the use of left and right may be less frequent. The current study's design aimed to encourage children to use direction words but also included landmark encoding. By measuring both direction and landmark terms, the current study will help to better understand whether changing certain environmental factors could encourage children's use of direction words and hence direction-giving accuracies and qualities.

Sex differences in children's direction giving

The discussion above explained how direction giving in spatial navigation changes over development. In addition to differences across age, studies also suggest differences in direction giving between the sexes, although the majority of these studies have focused on adults. Adult women use more landmarks in their direction giving than men, whereas men refer to cardinal directions more frequently than women (Lawton, 2001; Miller & Santoni, 1986; Montello et al., 1999). Men's stronger preference for cardinal directions, and hence better allocentric spatial representations, may help to explain why men are typically better than women at survey-based assessment of wayfinding knowledge (e.g., Castelli et al., 2008; Chen et al., 2009).

However, the evidence for sex differences in children's direction giving is less clear because few studies have systematically examined this issue (e.g., Blades, 1992; Nys et al., 2015). Whereas some studies have not found significant sex differences (3- to 5-year-olds: Austin & Sweller, 2017, 2018), two studies (Choi & Silverman, 2003; Schmitz, 1997) have reported sex differences. More specifically, Choi and Silverman (2003) asked children aged 9 to 13 years to give route directions from a map. They found significant sex differences such that the preference for landmark terms over distance terms was stronger in girls than in boys for 12- and 13-year-olds, but not for 9- to 11-year-olds. Furthermore, Schmitz (1997) had 7- to 10-year-olds explore a real-life maze of two constructed "floors" within a single room. The analysis of children's written description of the maze showed no difference in the total elements (i.e., landmarks + directions). However, boys preferred directions more than girls, and girls preferred landmarks more than boys.

Why did some studies find sex differences, whereas others did not? Two possibilities are (a) the extent of memory involved in the tasks and (b) the differences in the learning perspectives presented. Choi and Silverman (2003) asked children to *recall* route directions from memory (also see Austin & Sweller, 2017, 2018; Nys et al., 2015; Schmitz, 1997). In contrast, Blades (1992) asked children to *describe* route directions while viewing a map. Extensive research has documented that memory is not an accurate representation of lived experience (e.g., Hardt et al., 2013; Oberauer, 2019). Thus, how children give directions may differ depending on whether they are trying to describe them at the moment or recall them from memory; whereas the former shows an "online" active processing of the spatial information, the latter reflects an "offline" effortful retrieval of the spatial information. Perhaps any sex differences present in young children could be attenuated when memory is involved. The current study included children giving directions both immediately and after a delay, and thus it can shed light on this issue.

The second possible explanation for the contrasting findings in the literature pertains to learning perspectives. The existing studies differed in the perspectives in which the environments were presented. Focusing on the studies of Choi and Silverman (2003) and Schmitz (1997), both of which documented sex differences in direction giving but at different ages, Choi and Silverman (2003) presented maps to children (see also Blades, 1992). However, according to Schmitz (1997), children directly experienced the route by physically walking through it (see also Austin & Sweller, 2018, and Nys et al., 2015). Using maps versus direct experience has significant implications for understanding spatial cognition. A map typically presents a "survey" perspective of an environment, which shows all the information simultaneously and depicts a birds-eye view, an allocentric survey perspective. In contrast, directly experiencing the environment shows a "route" perspective of an environment, which shows all the information sequentially over time and involves a first-person egocentric perspective. Research on adults supports the idea that learning perspectives affect the characteristics of mental representations of space (e.g., Shelton & McNamara, 2004; Van der Kuil et al., 2021; Zhang et al., 2014). More specifically, studies of college students showed no sex differences in navigation time when learning through a route perspective (i.e., guided sign) but showed significant sex differences favoring males when learning from a survey perspective (i.e., "you are here" map) (Chen et al., 2009). Therefore, it is possible that learning perspectives may moderate sex differences in children's direction giving, such that sex differences may be more prominent in the survey (i.e., map) condition than in the route (i.e., directly experiencing) condition. The current study included children giving directions from both a route and survey perspective and thus can shed light on this issue as well.

The current study

Given these mixed findings on sex differences in direction giving and the importance of considering the effects of immediate description versus delayed recall, as well as spatial learning perspectives, the current study systematically measured how boys and girls aged 3 to 10 years describe or recall directions across two perspectives: survey and route. If sex differences in direction giving are not limited to the conditions in Schmitz (1997) and Choi and Silverman (2003), then boys should outperform girls in both immediate description and delayed recall and in both route and survey perspectives. However, if sex differences in direction giving are contingent on the implication (or the absence) of memory and learning perspectives, then sex differences may be found only in some conditions but not others.

Most previous studies on children's direction giving have focused on slightly older children such as those aged 6 to 10 years (e.g., Blades, 1992; Schmitz, 1997). However, Austin and Sweller (2017) presented 3- to 5-year-olds videos of a person verbally providing route directions and then asked the children to verbally recall the route. Results found that the 3- to 5-year-olds could correctly recall more than 25% of landmark-based location information (e.g., trees, bird) and about 10% of direction-based movement information (e.g., go under, go past, go around). Although Austin and Sweller's (2017) study differed from previous studies of children's direction giving in many ways (e.g., presenting a video of a narrator rather than a map), it showed the potential of studying preschoolers. Therefore, bridging the literature, the current study included children aged 3 to 10 years. This wide age range would afford the possibility to examine age-related differences in direction giving.

Method

Participants

Power Analysis using G*Power 3.1.9.7 showed that a minimum of 128 participants were needed to detect the main effects and interaction effects in our $2 \times 2 \times 2$ within-participants analysis of variance (ANOVA; more details described below) and mixed analysis of covariance (ANCOVA) designs with a medium effect size (f = .25), alpha of .05, and power of .80.[1] We recruited and tested 143 children aged 3 to 10 years. Two participants had missing or incomplete data. The final sample of 141 included 78 boys and 63 girls (M_{age} = 7.25 years, SD = 2.05). See Table 1 for age and gender breakdowns. Among them, 3 children's native language was not English (i.e., Spanish) but had been introduced to English at around 1 year of age (currently 4, 7, and 9 years of age). In addition, 22 children spoke another language other than English (e.g., Hindi, Chinese, Spanish), and 22 children were not White (i.e., 4 Hispanic, 13 Asian, and 5 African American). Finally, only 3 parents reported having only a high school diploma or lower (46 had some college, and 92 had a college degree or higher). They were recruited through schools, professional organizations, and online networks (i.e., Children Helping Science). Parental consent and child assent were obtained before the start of the study. After completing the study, parents received a $10 Amazon gift card. The study was approved by and conducted in accordance with the university institutional review board.

Materials

There were four environments: Environments 1/2 and Environments 3/4 were roughly mirror images of each other (see Fig. 1). Each environment could be shown on a map (survey perspective) or in a video (route perspective). Maps 1 to 4 and Videos 1 to 4 corresponded to Environments 1 to 4. Each environment consisted of five decision-making points with three choices each (right, left, or straight). Each environment consisted of 10 landmarks: 5 at decision points and 5 at non-decision points. The landmarks were age appropriate (i.e., mango, teddy bear, tomato, monkey, penguin, bell pepper, bunny, and a bowl of cherries). All environments were built in the software Unity 3D. The map condition captured the layout from a bird's-eye view. A red dot marked the start of the maze, and a yellow star marked the end. For the video condition, we recorded an avatar navigating the correct path from a first-person view lasting 1.3 to 2.1 min. At each decision point, the avatar would look left and right and then walk down the correct path.

Procedure

The study was conducted online over Zoom, which lasted approximately half an hour. The session was recorded. Parents were asked to refrain from answering for their children. Breaks were provided to avoid fatigue when necessary.

Practice task

All children were presented with a short practice video showing geometric shapes (Heider & Simmel, 1944). They were asked to describe their movements and actions during this 1.33-min video. This task helped children to become acquainted with describing dynamic videos.

Main task

Before starting the main task, all children were shown all 10 landmarks and asked to identify each landmark. The RA corrected children if they mislabeled a landmark. This happened often, with the RA usually needing to correct at least one object (e.g., tomato) for each participant during the practice phase. However, afterward no children showed any trouble in identifying the objects throughout the testing phase.

The main task included two conditions: map and video. Within each condition, there were two trials. Each child participant was randomly assigned to one of four testing orders: A (Map 1 → Map 3 → Video 1 → Video 3), B (Video 1 → Video 3 → Map 1 → Map 3), C (Map 4 → Map 2 → Videos 4 → Video 2), or D (Video 4 → Video 2 → Map 4 → Map 2). See Fig. 2 for a flowchart for Testing Order A.

[1] Note that although power analyses were conducted for ANOVAs, we ultimately decided to analyze the data using linear mixed-effects models. Linear mixed-effects models are more powerful than ANOVAs thereby alleviating concern about the current study being underpowered (Brysbaert & Stevens, 2018; Stevens & Brysbaert, 2023).

Table 1
Mean age (and standard deviation) and gender in each year of age

	3.0–3.99 years	4.0–4.99 years	5.00–5.99 years	6.0–6.99 years	7.0–7.99 years	8.0–8.99 years	9.0–9.99 years	10.0–11.0 years
n	7	20	17	17	25	20	19	16
Age mean (*SD*)	3.64 (0.31)	4.49 (0.34)	5.59 (0.34)	6.49 (0.25)	7.54 (0.27)	8.44 (0.30)	9.37 (0.25)	10.40 (0.24)
Number of males	2	12	8	12	15	9	10	10

Each trial consisted of three phases. In free description (Phase 1), children were asked to describe what they saw while watching the video/map. This was done to familiarize the children with the environment. In route description (Phase 2), children were asked to give directions to a friend who could not see. More specifically, before showing the map/video, children were shown an image of "Mr. Birdie" (a blue cartoon bird), who first appeared without a blindfold and then with a blindfold on. Children were told that Mr. Birdie could not see and that they needed to assist Mr. Birdie in finding the location of his friend, "Mr. Star". Children were also told that they could use objects in the environment and directions to tell him "which way to go" (see Appendix A for the script). Then children were presented with the video/map and asked to give directions while watching the video/map. In route recall (Phase 3), the stimuli (i.e., map/video) were removed from the screen (which then showed only the desktop wallpaper), and children were asked to recall the directions from their memory.

Results

Original data and analysis scripts/outputs can be found on the Open Science Framework (https://osf.io/h7pdm/?view_only=5dd1b9a2747640c3956144ae1b22b4e3).

Data coding and analysis plan

Four trained RAs transcribed and coded participants' utterances using the ELAN annotation software (Version 4.0; The Language Archive, 2020). We scored direction-giving accuracies for the last two phases of each trial (i.e., route description and route recall). We did not code the free description phase because children were asked to describe what they saw, not to give directions. The terms in the coding scheme are similar to those used in previous research (e.g., Blades, 1992; Choi & Silverman, 2003). We coded all the direction and landmark terms that could effectively disambiguate a route. Notably, the direction terms include both relative terms (e.g., left, right) and cardinal terms (e.g., south, east, west, north). Although other terms such as the position of objects (e.g., the bear is on the left) were spatial in nature, they could not serve as effective directions and hence were not included. Because not all Zoom videos showed children's hands (only faces at times), gestures were not coded (see "Future directions and limitations" section in Discussion).

Two trained RAs rated accuracies for each route/condition and each participant. Each route (e.g., map_trial 1_description) contained five decision-making points. For example, at the first decision-making point in Map 1 of Trial 1, a monkey (landmark) was located at the decision point, and turning left was needed. In order for children to receive 1 point (i.e., accurate response), they would need to specify the correct direction using (a) an action word plus an accurate landmark (e.g., "turn monkey"), (b) a correct direction word (e.g., "left"), (c) an action word plus a direction word (e.g., "go left"), or (d) any other elaborate correct combination (e.g., "turn left at the monkey"). If children used (a) an action word alone (e.g., "turn/go"), (b) a landmark alone (e.g., "monkey"), or (c) vague words (e.g., "this way"), they would receive a 0 points for that decision point. For each route, the total points across the 5 decision points were added and then divided by 5 to obtain the accuracy score, which ranged from 0 to 1.

To ensure accurate inter-rater reliability, we employed a double-coding scheme where each accuracy data point was rated by two well-trained undergraduate RAs. Most commonly, score

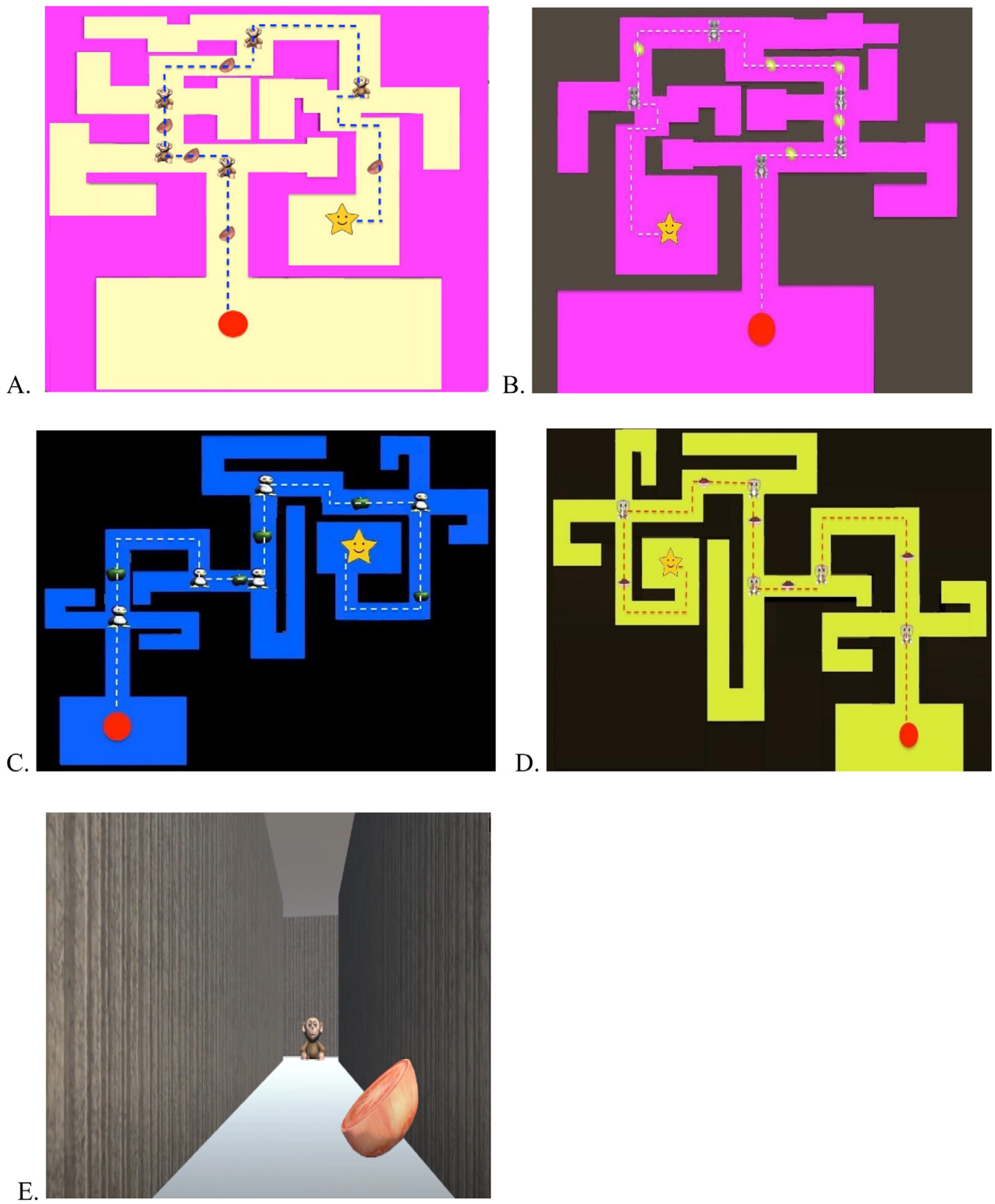

Fig. 1. Experimental materials. (A–D) Maps 1 to 4. The dotted line shows the path. The red dot is the starting point, and the star is the end point. (E) Screenshot of Video 1.

discrepancies between RAs occurred in the video conditions where there were differences in the timing of the directions (i.e., before, during, or after a visible turn) uttered by the child. However, any rating discrepancies were resolved through discussions between the two RAs or were elevated to be discussed between the two RAs and the first author. Before solving any discrepancy, the inter-rater agreement exceeded 75% for all accuracy scores. All the discrepancies were resolved.

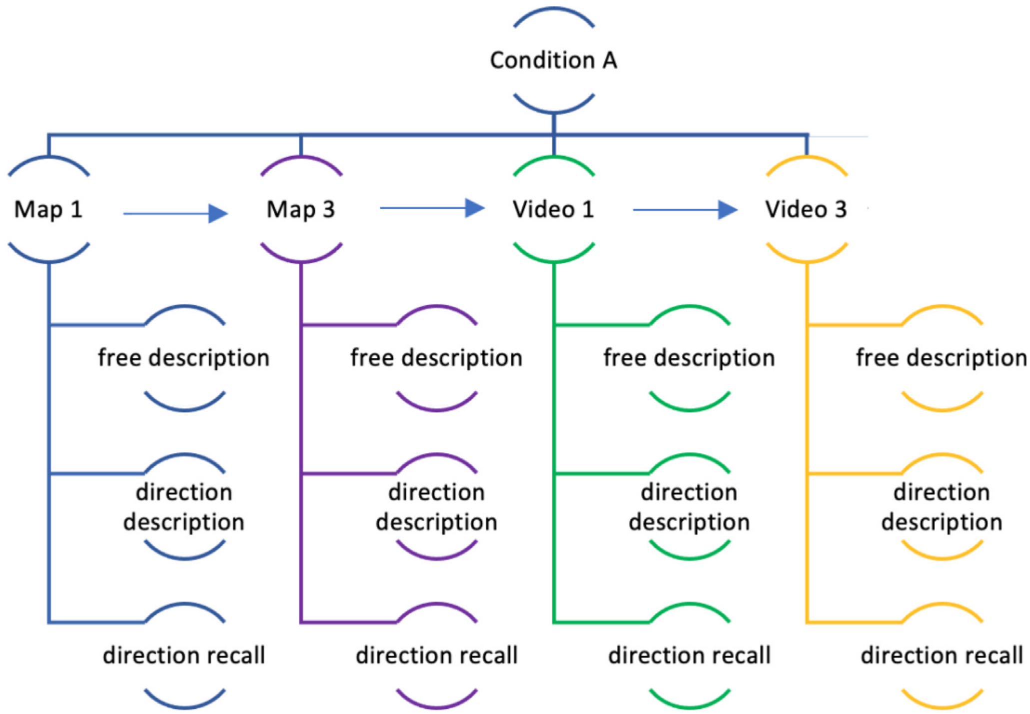

Fig. 2. Flowchart for Testing Order A. The experiment proceeded from left to right. The same color set was completed (i.e., vertically) before proceeding to the next color set (i.e., horizontally).

In addition to accuracy, for each condition we also coded (a) the cumulative number of direction terms (e.g., left, right, up) regardless of its accuracy, (b) the cumulative number of object/landmark-based nouns (e.g., cherries, bunny) regardless its accuracy, and (c) total words. See Appendix B for the specific words being coded.

Study design

The dependent variables (DVs) were accuracy, landmark words, direction words, and total words. There were two between-participants factors: age and sex. There were three within-participants factors: perspective (map vs. video), task phase (route description vs. route recall), and trial number (1 vs. 2). Note that two within-participants factors, task phase and trial number, were key components of the experimental design. Hence, we included them in the following analyses. Furthermore, if we found converging evidence across different task phases and trial numbers, it may provide stronger support for sex differences or the lack of, direction giving. Below, we organized our analyses into main analyses focusing on sex differences and exploratory analyses focusing on spatial perspectives. See Table 2 for descriptives.

Linear mixed-effects modeling

We used the GAMLJ3 module in Jamovi 2.4.11, which is a free and open-source graphical user interface (GUI) for the R programming language. We ran three linear mixed-effects models on accuracy, landmark, and direction words, respectively (the analysis for total words is in Appendix C). The fixed effects were intercepts, sex, perspective, task phase, trial, and age. Whereas sex, perspective, task phase, and trial were entered as categorical variables, age was entered as a continuous variable. Random intercepts were included for participants to account for participant-level variations. The model

Table 2
Means (and standard deviations) of accuracy, direction, and landmark words in each trial by sex

	Description		Recall	
	Boys	Girls	Boys	Girls
Accuracy				
Video_trial1	0.40 (0.34)	0.28 (0.26)	0.11 (0.14)	0.07 (0.15)
Video_trial2	0.40 (0.37)	0.31 (0.33)	0.09 (0.15)	0.06 (0.11)
Map_trial1	0.56 (0.40)	0.39 (0.36)	0.18 (0.21)	0.18 (0.20)
Map_trial2	0.56 (0.38)	0.49 (0.42)	0.21 (0.24)	0.17 (0.17)
Direction words				
Video_trial1	11.72 (7.33)	12.46 (9.49)	3.29 (4.17)	3.86 (6.51)
Video_trial2	14.83 (11.87)	12.57 (8.07)	4.54 (5.33)	5.92 (8.15)
Map_trial1	13.62 (7.80)	15.14 (9.99)	6.06 (5.95)	6.40 (8.69)
Map_trial2	12.00 (10.16)	14.43 (8.31)	6.17 (6.45)	7.00 (7.73)
Landmark words				
Video_trial1	5.59 (7.27)	5.83 (7.41)	1.15 (2.17)	0.94 (2.14)
Video_trial2	5.15 (7.51)	7.30 (8.69)	1.51 (3.63)	0.87 (2.09)
Map_trial1	5.77 (8.40)	6.29 (8.06)	0.87 (3.84)	0.78 (2.50)
Map_trial2	6.18 (7.13)	7.37 (7.73)	1.00 (2.68)	1.14 (2.60)

included all possible interaction terms between the categorical variables (i.e., excluding age). We used the REML estimation method. Visual inspection of the residual histogram did not reveal significant deviations from normality. See Tables 3 and 4 for the results of the fixed and random effects, respectively. As shown in Table 3, there were significant effects for sex (favoring boys over girls), task phase (favoring description over recall), perspective (favoring maps over videos), and age (favoring older children over younger children). The only significant interaction was the one between sex and task phase. See Fig. 3. Post hoc tests using Bonferroni correction showed that although boys outperformed girls in the description condition (MD = .098, SE = .0298), t(237) = 11.746, p < .001, the two groups did not differ from each other in the recall condition (MD = .020, SE = .029), t(237) = 0.677, p = 1.0.

We ran the same model with direction words as a DV. See Tables 5 and 4 for the fixed and random effects, respectively. As shown in Table 5, there were significant effects for task phase (favoring description over recall), perspective (favoring maps over videos), and age (favoring older children over younger children). The main effect of sex was not significant. The only significant interaction was the one between perspective and trial. Post hoc tests showed a significant increase in the use of direction terms from Trial 1 to Trial 2 in the video condition (MD = 1.654, SE = .579), t(966) = 2.858, p = .026, but not in the map condition (MD = 0.455, SE = 0.579), t(966) = 0.786, p = 1.0.

We ran the same analyses with landmarks as a DV. See Tables 6 and 4 for the fixed and random effects, respectively. As shown in Table 6, there were significant effects for task phase (favoring description over recall). The main effect of sex was not significant. The only significant interaction was the one between sex and task phase. However, post hoc tests showed no difference between boys and girls in either the description condition (MD = −1.058 [favoring females], SE = 0.649), t(227) = −1.632, p = .625, or the recall condition (MD = 0.202 [favoring males], SE = 0.649), t(227) = 0.311, p = 1.0.

Additional analyses

Nonlinear effects of age

In all the analyses above, we examined only the linear effects of age. It is possible that there might be a curvilinear relationship between age and the outcome variables. Therefore, we reran the above analyses including age^2 (age^2) as an additional fixed effect. The effects of age^2 were not significant, F(1, 136) = 0.67, p = .415 for accuracy, F(1, 136) = 2.44, p = .121 for direction terms, and F(1, 136) = 2.20, p = .140 for landmark terms. Therefore, a simple linear relationship might be more appropriate for describing the relationship between age and the outcome variables.

Table 3
Parameter estimates (fixed effects) for accuracy

Effect	Estimate	*SE*	*df*	*t*	*p*
(Intercept)	0.28	0.01	137	21.7	<.001
Sex (female or male)	−0.06	0.03	137	−2.28	**.024**
Perspective (map or video)	0.13	0.01	966	8.79	**<.001**
Trial (1 or 2)	0.01	0.01	966	0.99	.325
Task phase (recall or description)	−0.29	0.01	966	−19.73	**<.001**
Age	0.04	0.01	137	5.74	**<.001**
Sex * Perspective	0.00	0.03	966	0.08	.934
Sex * Trial	0.03	0.03	966	0.99	.325
Perspective * Trial	0.03	0.03	966	1.03	.305
Sex * Task Phase	0.08	0.03	966	2.64	**.008**
Perspective * Task Phase	−0.05	0.03	966	−1.70	.089
Trial * Task Phase	−0.03	0.03	966	−1.17	.241
Sex * Perspective * Trial	0.00	0.06	966	0.07	.945
Sex * Perspective * Task Phase	0.02	0.06	966	0.39	.698
Sex * Trial * Task Phase	−0.08	0.06	966	−1.35	.178
perspective * trial * Task phase	−0.01	0.06	966	−0.12	.902
Sex * Perspective * Trial * Task Phase	−0.13	0.12	966	−1.08	.280

Note. p < .05 are in bold.

Table 4
Random components for accuracy, direction words, and landmark words

	Group	Name	Variance	*SD*	ICC
Accuracy	Participant	(Intercept)	0.0156	0.125	.206
	Residual		0.0599	0.245	
Direction	Participant	(Intercept)	18.00	4.24	.280
	Residual		46.30	6.80	
Landmark	Participant	(Intercept)	7.86	2.80	.229
	Residual		26.53	5.15	

Note. ICC, intraclass correlation coefficient.

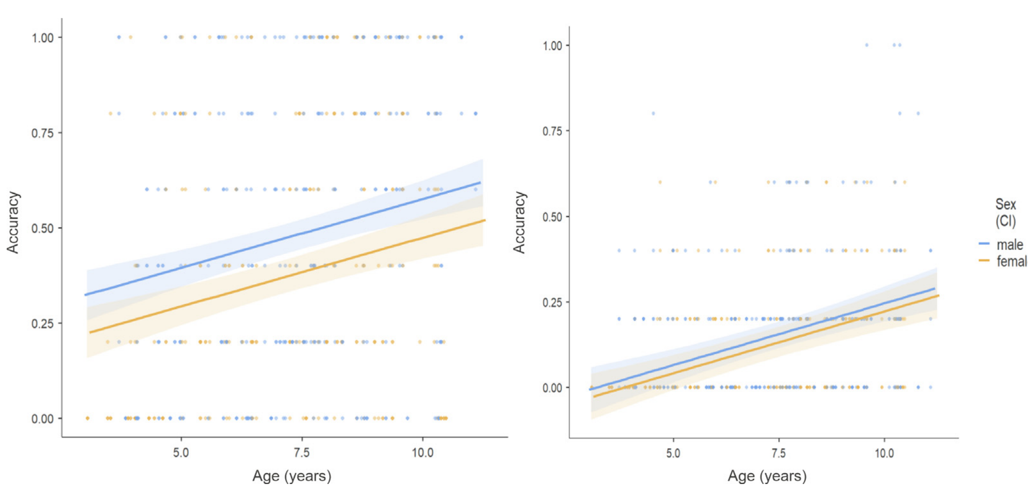

Fig. 3. Regression lines of accuracy as a function of age in boys and girls. The left plot is for the description condition, and the right plot is for the recall condition. Observed scores are provided, and 95% confidence intervals (CIs) around the regression lines are shown.

Table 5
Fixed-effects parameter estimates for direction words

Effect	Estimate	*SE*	*df*	*t*	*p*
(Intercept)	9.45	0.42	137	22.78	<.001
Sex (female or male)	0.92	0.83	137	1.11	.269
Perspective (map or video)	1.45	0.41	966	3.55	**<.001**
Trial (1 or 2)	0.60	0.41	966	1.47	.143
Task phase (recall or description)	−7.98	0.41	966	−19.48	**<.001**
Age	0.44	0.20	137	2.17	**.032**
Sex * Perspective	1.17	0.82	966	1.43	.153
Sex * Trial	−0.22	0.82	966	−0.27	.785
Perspective * Trial	−2.11	0.82	966	−2.58	**.010**
Sex * Task Phase	0.10	0.82	966	0.13	.901
Perspective * Task Phase	1.14	0.82	966	1.39	.166
Trial * Task Phase	0.83	0.82	966	1.01	.312
Sex * Perspective * Trial	1.65	1.64	966	1.01	.313
Sex * Perspective * Task Phase	−3.06	1.64	966	−1.87	.062
Sex * Trial * Task Phase	1.81	1.64	966	1.11	.269
perspective * Trial * Task Phase	1.59	1.64	966	0.97	.331
Sex * Perspective * Trial * Task Phase	−3.99	3.28	966	−1.22	.223

Note. $p < .05$ are in bold.

Table 6
Fixed-effects parameter estimates for landmark words

Effect	Estimate	*SE*	*df*	*t*	*p*
(Intercept)	3.62	0.28	137	12.74	<.001
Sex (female or male)	0.43	0.57	137	0.75	.453
Perspective (map or video)	0.14	0.31	966	0.44	.661
Trial (1 or 2)	0.42	0.31	966	1.34	.179
Task phase (recall or description)	−5.17	0.31	966	−16.68	**<.001**
Age	−0.06	0.14	137	−0.45	.650
Sex * Perspective	0.07	0.62	966	0.11	.914
Sex * Trial	0.60	0.62	966	0.97	.331
Perspective * Trial	0.22	0.62	966	0.35	.725
Sex * Task Phase	−1.26	0.62	966	−2.03	**.042**
Perspective * Task Phase	−0.61	0.62	966	−0.99	.323
Trial * Task Phase	−0.44	0.62	966	−0.70	.482
Sex * Perspective * Trial	−0.18	1.24	966	−0.14	.885
Sex * Perspective * Task Phase	0.77	1.24	966	0.63	.532
Sex * Trial * Task Phase	−1.39	1.24	966	−1.12	.264
Perspective * Trial * Task Phase	−0.23	1.24	966	−0.19	.852
Sex * Perspective * Trial * Task Phase	1.69	2.48	966	0.68	.496

Note. $p < .05$ are in bold.

Older versus younger children

Our study included a relatively wide age range spanning from 3 to 10 years. It is important to take a closer look at the performance of children younger than 5 years old, who might be more limited at performing the task.[2] Therefore, 3- and 4-year-olds were combined into one group named the younger children group, and the rest of the children were combined into the older children group. Descriptive analyses showed that mean accuracies were .168 (SD = .268) for younger children and .309 (SD = .335) for older children. Although relatively low, younger children's performance was generally consistent with results found in Austin and Sweller (2017). We also plotted accuracy as a function of age for younger children. See Fig. 4. Although young children performed relatively poorly as a group, a small proportion of children performed relatively well, even scoring 100% accuracy in certain trials.

[2] We thank an anonymous reviewer for this suggestion.

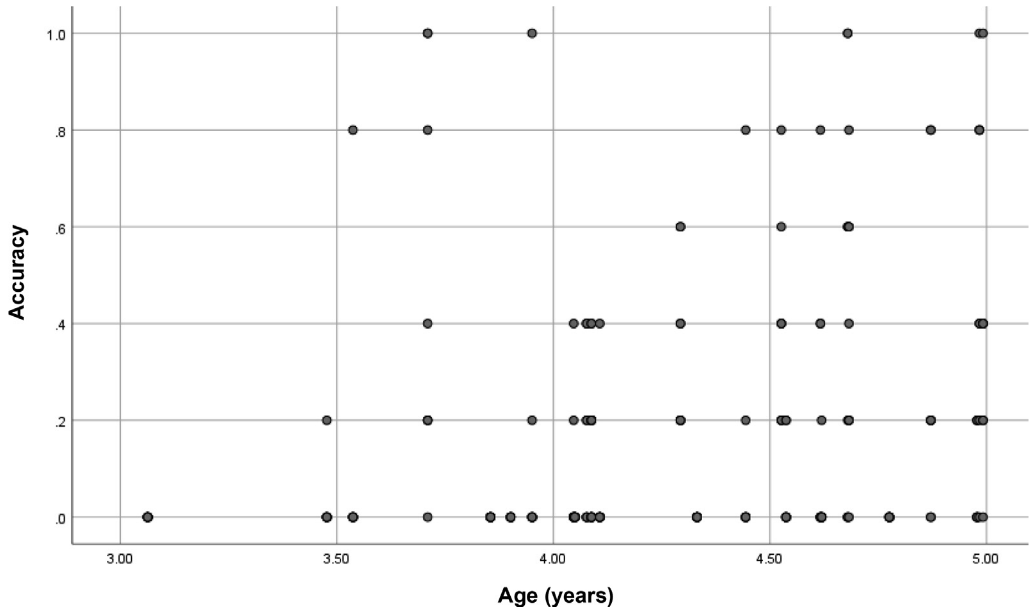

Fig. 4. Scatterplots of accuracy over age for the younger children.

Hence, this showed individual differences during early childhood. Lastly, we conducted two linear mixed-effects model analyses of accuracy for younger and older children, respectively, similar to the one for the entire sample shown above. Generally speaking, the pattern of results found for the entire sample was also found for the younger and older children subgroups. However, although sex differences remained marginally significant for older children, they were no longer significant for younger children. Therefore, sex differences may be relatively late-emerging. It is also possible that the overall low performance in young children may have masked sex differences. See Appendix D for detailed results.

Discussion

The current study systematically examined sex differences in direction giving for children aged 3 to 10 years using two types of spatial perspectives: survey (via maps) and route (via videos). Our results found robust sex differences favoring boys in nearly all accuracy measures in the route description phase. However, no sex difference was found in the route recall phase or the frequency of landmark and direction words. Furthermore, our results found overall better accuracy in maps than in videos and found more utterances of direction words in maps than in videos. Lastly, children were more accurate and mentioned more landmark and direction words in the description phase than in the recall phase. Our study has important theoretical and practical implications.

Insights into human sex differences

Sex differences are among the most studied but also debated individual difference factors associated with human cognition. However, few previous studies (e.g., Blades, 1992; Nys et al., 2015) have systematically examined sex differences in children's direction giving, one key expression of wayfinding and spatial knowledge. The only two studies that found sex differences in children (Choi & Silverman, 2003; Schmitz, 1997) had different conclusions regarding whether sex differences were present in children under 10 years of age, focused exclusively on verbal utterances but not accuracy, and presented the environments via different perspectives. Therefore, our study filled a critical knowledge gap in the research regarding sex differences in children's direction giving by (a) focusing on children aged 3 to 10 years, (b) examining both direction-giving accuracy and verbal utterances, and (c) using two spatial perspectives to present environments while (d) employing an adequate sample size. Our study helps us to understand the emergence, development, and contributing factors of human sex differences in spatial cognition.

Our study is consistent with the meta-analysis conducted by Nazareth et al. (2019) on sex differences in wayfinding by showing that boys were also more accurate in describing the routes than girls. Why were boys more accurate at describing the routes than girls? It is possible that boys may be more likely to correctly use direction words than girls. Although correctly labeling landmark words could also result in correct responses, landmarks were mentioned less often than direction words (as shown in Table 2). We were not able to replicate the findings of previous literature suggesting that landmarks represent the majority of utterances compared with directions (Blades, 1992). This may be due to our task design, where we used two sets of identical objects in each environment to encourage the use of direction words. From a developmental perspective, boys may be allowed to go out alone (e.g., to their friends' houses, to travel on buses) more often than girls (Brown et al., 2008). As a result, boys may have more experience in independent traveling, wayfinding, and hence direction giving. Other factors such as biological factors (e.g., Grimshaw et al., 1995; Johnson et al., 2002) and social–cultural factors (e.g., Tarampi et al., 2016; Yang & Merrill, 2017) may have also contributed to the sex differences in children aged 3 to 10 years.

We found no sex differences in children's frequency of utterances encoding landmark and direction words. We propose that it is not the mere presence of language (e.g., number of utterances) but rather the quality of how language is used (i.e., accuracy) that facilitates spatial cognition as in direction giving. Our study was consistent with Choi and Silverman (2003), who found no sex differences in the preference for landmarks over spatial words for children under 11 years of age. However, our study contrasted with Schmitz (1997), who found boys favoring direction words and girls favoring landmark words in verbal descriptions of the environment. In Schmitz (1997), children were free to explore the environment and girls explored the environment more slowly and more anxiously. However, in our task, boys and girls received the same experience of the environment via maps and prerecorded videos. Therefore, when anxiety- and experience-related confounds were minimized, sex differences in the strategic preferences of landmark and direction words may have also been minimized.

It is also important to note that sex differences were absent in the recall phase. Furthermore, accuracy and the utterances of landmark and direction words were lower in the recall phase than in the description phase. In many situations in real life, we give directions from memory alone without the support of a map. The memory decay from description to recall is consistent with previous literature on memory (Oberauer, 2019; Perez et al., 2022). Furthermore, consistent with our finding in the recall phase, prior research also has demonstrated no sex differences in recalling a map—a finding the authors interpreted as suggesting no general memory differences between the groups (Astur et al., 2016). The increased task and memory demands in the recall phase reduced task performance in both boys and girls, which in turn might have masked sex differences. It is also possible that boys and girls have similar gist memories of the environment, as shown in the recall phase. However, boys were better than girls at using language during the online active processing stage, as in the description phase, to express that knowledge. Taken together, our study shows the nuance and importance of considering experimental conditions when examining sex differences.

The role of spatial perspectives

Another major contribution of the current study was to use both survey (via maps) and route (via video) perspectives when investigating children's direction giving. Although both methods have been used independently in many previous studies (e.g., Austin & Sweller, 2017, 2018; Blades, 1992; Choi & Silverman, 2003; Schmitz, 1997), they were rarely used in the same study of children. Some adult studies have examined the effects of route and survey perspectives simultaneously (e.g., Brunyé & Taylor, 2008; Lee & Tversky, 2001; Meneghetti et al., 2011; Taylor & Tversky, 1992). However, these adult studies focused on receiving rather than giving route directions; they typically characterized route directions as route versus survey (e.g., by using words of left/right vs. north/south/east/west) rather than examining the effects of *presenting* route- and survey-based environments on producing route directions. Overall, the effects of spatial perspectives have been less frequently investigated concerning direction giving and even less with children. Hence, our study filled an important knowledge gap and found that children were more accurate and used more direction words in the survey perspective (via maps) than in the route perspective (via videos).

So, why did children give more accurate route directions in maps than in videos? We propose that this was due to the salience of direction information. Route directions were typically given in first-person route perspectives (e.g., turn left at the store) (Padgitt & Hund, 2012). In maps, children needed to engage in perspective taking (Yang et al., 2020) to imagine how they would turn if they followed the path. In the direct experience of videos, the turns along the route were made automatically by the avatar. Therefore, the mental effort of mentally transforming spatial perspectives may have interfered with the correct mapping of direction word to spatial representation, thereby yielding an inaccurate direction word. Future research can test this hypothesis by increasing the salience of direction information (e.g., special visual or sound effects) when children directly experience the environments via videos.

Practical implications

Our study has practical implications on how to improve children's direction giving. For instance, to enhance children's direction giving, it may be more useful to teach children to use maps than to be exposed to a route. Furthermore, to close the sex gap in direction giving, educators and parents may pay more attention to (a) how accurately children use direction words, including distinguishing different words (e.g., left, right) (Rigal, 1994, 1996); (b) whether children correctly identify useful landmarks (Farran et al., 2010; Lingwood et al., 2015a); and (c) how children combine direction words and landmark words. Finally, our study also has implications for broader domains of spatial cognition. More specifically, route directions facilitate understanding and communicating about important environmental knowledge. Helping children give accurate route directions may facilitate children's behavioral performance in spatial navigation. This is because it may help children to (a) learn what information is important for successful wayfinding and (b) organize their visual graphic knowledge into information bits that could be verbally coded, stored, and retrieved. Therefore, through effective use of route directions, children may also become more competent at wayfinding, which usually goes through an extended period of development (Yang & Merrill, 2022).

Future directions and limitations

As noted in the Introduction, direction giving is arguably highly pertinent in young children's lives given that advanced direction-giving technology (e.g., GPS) might not be as available to children as it is to adults. Yet, one interesting question for future research is whether and how the observed sex differences in the current study may be affected by the use of GPS as children get older. For example, does the male advantage for route directions decrease as children start using GPS that provide directions for them? Another future direction is to examine the role of video game experience in children's direction giving. The existing research has shown that video game experience has rather limited effects on wayfinding-related large-scale spatial cognition (Jansen-Osmann & Fuchs, 2006; Rodriguez-Andres et al., 2018). However, future studies may examine whether this conclusion also applies to direction giving and whether children could learn direction giving when the corresponding training/education program is delivered via video games. Lastly, the current study included children of a relatively wide age range of 3 to 10 years. Some young children struggled with the task. Future studies may consider direction-giving tasks of different difficulty levels to accommodate some of the younger children. There may be developmental spurts and plateaus in children's direction giving that could occur after certain language milestones and developmental markers.

The current study has several limitations that also can be addressed in future research. First, we were not able to code hand gestures, and our analysis was limited to verbal utterances alone. Interestingly, Austin and Sweller (2018) found that when asked to give directions, gestures accompanied about 30% of verbal phrases for both 3- to 5-year-olds and adults. Therefore, it is unclear whether children can effectively compensate for their limited expressive language through gestures when providing route directions. Nevertheless, future studies should further explore whether there were sex differences in children's nonverbal communications about route directions using gestures and the relationship between gestures and verbal direction giving. Second, the current study did not directly examine individual differences in language abilities. However, we had all children practice describing events verbally prior to the direction-giving tasks. All children were typically developing, and no children were reported to have any intellectual/developmental disabilities. Nevertheless, future research may administer language measures such as the Peabody Picture Vocabulary Test-Fourth Edition (PPVT-IV; Dunn & Dunn, 2007) given that their inclusion may help to further determine the role of general language abilities in direction giving.

Conclusions

Route directions help one to communicate knowledge about the spatial environment to others and construct spatial representations of the environment. Our study found that boys aged 3 to 10 years were more accurate in describing routes than girls. Furthermore, route directions were more accurate in the survey perspective of maps relative to the route perspective of first-person videos. We encourage future research to continue exploring individual differences associated with spatial cognition, including direction giving, which has important practical and educational implications for success in spatial abilities and STEM-related disciplines.

CRediT authorship contribution statement

Nardin Yacoub: Data curation, Formal analysis, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Laura Lakusta:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. **Yingying Yang:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Data availability

Data are shared in OSF. Links are provided in the MS.

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Appendix A. Sample scripts

A. Main task: Map condition

1. Free description (Phase 1, with map):
   R: "Can you describe to me what you see here?"
2. Route description (Phase 2, with map): Present the child with a picture of Mr. Birdie and explain the following story:
   R: "Mr. Birdie is inside this map. He is trying to meet his friend Mr. Star, but Mr. Birdie is blind. Can you talk to Mr. Birdie and tell him how to get to his friend, Mr. Star, at the end? Mr. Birdie has a blindfold on, and he cannot see the map that you see, so he needs you to help him. Can you use as many words as you can to tell Mr. Birdie how to go through the maze to reach Mr. Star at the end? This line is the path.

You're going to be moving along this path with Mr. Birdie. You can use the objects to help you, and you can tell him which direction to turn. Remember, he can't see! Can you tell Mr. Birdie which way to go? Start at the red dot.

3. Route recall (Phase 3, no map): Remove all stimuli from the screen, and ask the child the following question:
   R: "Okay now the map is gone, but Mr. Birdie forgot the way. Can you use your memory to take Mr. Birdie from the red dot to the star? Can you tell him which way to go?

B. Main task: Video condition

1. Free description (Phase 1, shows the video):
   R: "Now I am going to show you a room. Can you tell me what you see in this room?"
2. Route description (Phase 2, shows the video): Present the child with a picture of Mr. Birdie and explain the following story:
   R: "Now you are walking through the maze, next to Mr. Birdie. Mr. Birdie still has a blindfold on, and he cannot see the path that you see, so you're the only one who can help him. Can you use as many words as you can to tell Mr. Birdie how to go through the maze to reach Mr. Star at the end? You can use the objects to help you, and you can tell him which direction to turn. Remember, he can't see! Can you tell Mr. Birdie which way to go?
3. Route recall (Phase 3, no video): Remove all stimuli from the screen, and ask the child the following question:
   R: "Okay now the map is gone, but Mr. Birdie forgot the way. Do you remember the directions? Try to use your memory to take Mr. Birdie from the beginning to the star. Can you tell him which way to go?

Note. Verbal instructions from the researcher (R) are italicized and included in quotation marks.

Appendix B

Direction words:

Left	Right	North	South	East	West	Straight	Forward	This way
That way	Up	Down						

Landmark words:

Ball	Bowl/Food bowl	Brick wall	Maze	Door	House	Rectangle	Star	
Wall	Circle	Red circle/ Red dot	Square	Triangle	Bunny	Cherry	Lemon	Mango
Teddy bear	Monkey	Peach	Tomato	Penguin	Pepper	Pickles		

Appendix C

We ran the same linear mixed-effects model with total words as a DV. Results are shown in Tables C1 and C2 below. The main effects of trial (favoring the second trial) and task phase (favoring description over recall) were significant. The only significant interaction was the one between the perspective and task phase. Post hoc tests showed no difference between the video and map conditions in either the description condition ($MD = -9.59$ [favoring maps], $SE = 5.41$), $t(966) = 1.77$, $p = .459$, or the recall condition ($MD = 11.75$ [favoring videos], $SE = 5.41$), $t(966) = 2.17$, $p = .18$.

Table C1
Parameter estimates (fixed coefficients) with total words as DV

Name	Estimate	*SE*	*df*	*t*	*p*
(Intercept)	64.86	2.12	137	30.53	<.001
Sex (female or male)	1.56	4.26	137	0.37	.715
Perspective (map or video)	−1.08	3.82	966	−0.28	.777
Trial (1 or 2)	13.38	3.82	966	3.50	**<.001**
Task phase (recall or description)	−76.60	3.82	966	−20.04	**<.001**
Age	0.28	1.03	137	0.27	.791
Sex * Perspective	4.37	7.65	966	0.57	.568
Sex * Trial	12.44	7.65	966	1.63	.104
Perspective * Trial	−7.88	7.65	966	−1.03	.303
Sex * Task Phase	−6.73	7.65	966	−0.88	.379
Perspective * Task Phase	−21.34	7.65	966	−2.79	**.005**
Trial * Task Phase	−2.55	7.65	966	−0.33	.738
Sex * Perspective * Trial	6.63	15.29	966	0.43	.664
Sex * Perspective * Task Phase	2.32	15.29	966	0.15	.880
Sex * Trial * Task Phase	−12.89	15.29	966	−0.84	.399
Perspective * Trial * Task Phase	−8.42	15.29	966	−0.55	.582
Sex * Perspective * Trial * Task Phase	−12.91	30.58	966	−0.42	.673

Note. $p < .05$ are in bold.

Table C2
Random effects with total words as DV

Group	Name	Variance	*SD*	ICC
Participant	(Intercept)	119	10.9	.0286
Residual		4039	63.6	

Note. ICC, intraclass correlation coefficient.

When we reran the model also including age^2 as an additional fixed effect, the effect of age^2 was not significant, $F(1, 136) = 1.68$, $p = .197$.

Appendix D

See Tables D1 and D2.

Table D1
Parameter estimates (fixed effects) for accuracy for younger children

Effect	Estimate	*SE*	*df*	*t*	*p*
Sex (female or male)	−0.04	0.07	24	−0.61	.547
Perspective (map or video)	0.09	0.03	175	3.18	**.002**
Trial (1 or 2)	0.02	0.03	175	0.64	.523
Task phase (recall or description)	−0.16	0.03	175	−5.88	**<.001**
Age	0.13	0.07	24	1.94	.064
Sex * Perspective	−0.02	0.05	175	−0.36	.721
Sex * Trial	0.04	0.05	175	0.77	.442
Perspective * Trial	0.09	0.05	175	1.58	.116
Sex * Task Phase	0.04	0.05	175	0.80	.424
Perspective * Task Phase	−0.05	0.05	175	−0.85	.395
Trial * Task Phase	−0.04	0.05	175	−0.79	.430
Sex * Perspective * Trial	0.04	0.11	175	0.40	.691
Sex * Perspective * Task Phase	0.09	0.11	175	0.85	.395
Sex * Trial * Task Phase	−0.13	0.11	175	−1.19	.238
Perspective * Trial * Task Phase	−0.10	0.11	175	−0.94	.347
Sex * Perspective * Trial * Task Phase	−0.35	0.22	175	−1.60	.112

Note. $p < .05$ are in bold.

Table D2
Parameter estimates (fixed effects) for accuracy for older children

Effect	Estimate	*SE*	*df*	*t*	*p*
Sex (female or male)	−0.06	0.03	110	−1.95	0.053
Perspective (map or video)	0.14	0.02	777	8.27	< .001
Trial (1 or 2)	0.01	0.02	777	0.81	0.42
Task phase (recall or description)	−0.32	0.02	777	−19.00	**<.001**
Age	0.03	0.01	110	3.57	**<.001**
Sex * Perspective	0.01	0.03	777	0.29	.774
Sex * Trial	0.03	0.03	777	0.76	.447
Perspective * Trial	0.02	0.03	777	0.48	.631
Sex * Task Phase	0.08	0.03	777	2.37	**.018**
Perspective * Task Phase	−0.05	0.03	777	−1.53	.126
Trial * Task Phase	−0.03	0.03	777	−0.94	.347
Sex * Perspective * Trial	−0.01	0.07	777	−0.12	.905
Sex * Perspective * Task Phase	0.01	0.07	777	0.08	.933
Sex * Trial * Task Phase	−0.07	0.07	777	−0.99	.324
Perspective * Trial * Task Phase	0.02	0.07	777	0.27	.786
Sex * Perspective * Trial * Task Phase	−0.07	0.14	777	−0.51	.608

Note. $p < .05$ are in bold.

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