Beth Southwell Practical Implications Award

The Beth Southwell Practical Implications Award was initiated and sponsored by the National Key Centre for Teaching and Research in School Science and Mathematics, Curtin University, Perth, Western Australia. Curtin sponsored the “Practical Implications Award” (PIA), as it was then known, for the first 10 years. The Australian Association of Mathematics Teachers (AAMT) now sponsors the Award. In 2008, MERGA was honoured to be able to rename the PIA as the Beth Southwell Practical Implications Award (BSPIA), in honour of MERGA’s and AAMT’s esteemed late member, Beth Southwell. The award is designed to stimulate the writing of papers on research related to mathematics teaching or learning or mathematics curricula. Application for the award is open to all members of MERGA who are registered for the conference. Applications for the BSPIA are judged against specific criteria set by a four-member panel. The panel consists of two members from MERGA, two from AAMT, and is chaired by the MERGA Vice President (Development).

Turn Left, Turn Right: An Embodied Perspective on Children's Difficulties With Left/Right Spatial Orientations

Jennifer Way
University of Sydney
jennifer.way@sydney.edu.au

Katherin Cartwright
University of Sydney
katherin.cartwright@sydney.edu.au

In this paper we problematise the expectation that Year 1 (6/7 years) children can effectively discriminate left/right, enact left/right-turning directions and use the language of left/right to give directions. Results from task-based interviews with 36 Year 1 children are interpreted through the lens of embodied cognition and spatial frames of reference to reveal some of the complexities and cognitive demands of learning what it means to 'turn left' or 'turn right', as a basis for further investigation.

The Australian Curriculum: Mathematics includes the following achievement standard for Year 1 (the second year of schooling), "Children give and follow directions to move people and objects within a space." Further elaboration of the learning expectation emphasises the role of language and "understanding the meaning and importance of the words when giving directions: for example, using words like 'forwards' and 'backwards', straight ahead', 'left or right' to describe movement" (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2022). The learning requirement is mirrored in the NSW state Mathematics K–10 syllabus with the statement, "Give and follow directions, including directions involving turns to the left and right" (NSW Education Standards Authority [NESA], 2022). The presence of this learning expectation for 6/7-year-olds implies that the meaning of turning left and right is not innately developed and needs to be taught, and that it is reasonable to expect children of this age group to achieve competence in both following and giving such directions. Yet left/right confusion in people is common and research to inform the teaching of left/right discrimination and its application to navigating the environment is scarce.

The current curriculum clearly specifies the involvement of moving people, yet much of what we know about children's lateral left/right discrimination abilities comes from psychological research conducted decades ago involving inanimate objects and static tasks rather than dynamic tasks involving moving the body and turning left/right. The curriculum also emphasises the importance of understanding the meaning of *relative* directional words. Humans, like many other animals, have a natural 'front-facing' perspective that assists us in orienting ourselves in space. In the English language, a sense of 'front-facing' is essential for the understanding the *viewer-centric* terms left/right and turn-left/turn-right. However, some other cultures and languages make greater use of an allocentric frame of reference (FoR) in which locational and directional terms refer to objects and landmarks (Abarbanell & Li, 2021).

In this study we focused on situations where the viewer-centric perspective is central to the enactment of spoken directions and the production of spoken directions by children. We concentrated on two scenarios for utilising the viewer-centric perspective; one involved the egocentric FoR relating the child's own body and the other was where the child had to switch the FoR to the viewpoint of another front-facing entity. In the former scenario the child would be responding to verbal instructions to move their own body, and in the latter scenario, the child would be directing someone else to move. To reflect the exploratory nature of the investigation, the study was guided by the open-ended question: How do Year 1 children respond to, and give, verbal instructions to turn-left and turn-right?

(2024). In J. Višňovská, E. Ross, & S. Getenet (Eds.), *Surfing the waves of mathematics education. Proceedings of the 46th annual conference of the Mathematics Education Research Group of Australasia* (pp. 25–32). Gold Coast: MERGA.

Background Research

In previous research an important distinction has been made between the *discrimination and recognition* (awareness) of left and right and the *verbal identification* of left and right (Rigal, 1994; Roberts & Aman, 1993). Discrimination and recognition of the left and right of one's own body develops much sooner than verbal identification. Some children may correctly verbally identify their own left and right by 7 years, but verbal identification of someone else's left and right takes longer to develop. Half of the 11-year-olds in Rigal's (1994, 1996) study still could not correctly apply the words left and right to someone else's perspective. The long development period was attributed to the children's persisting egocentric spatial FoR and the cognitive demands of performing mental rotations to imagine other perspectives (e.g., Rigal, 1996; Roberts & Aman, 1993). Notably, studies in this era consistently used static two-dimensional displays of geometric shapes rather than dynamic and/or embodied situations in the three-dimensional world.

More recently, the broader acceptance of embodied cognition theory (e.g., Dackermann et al., 2017; Keifer & Trumpp, 2012) and evidence from neuroscience about spatial processing and memory (e.g., Ruggiero et al., 2016), has led to renewed interest in the development of spatial FoR, the role of body movement and the implications for education. A modest quantity of research on 'turning the body' has arisen from the field of technology and robotics education with children (e.g., Clements et al., 1996; Kocher et al., 2020).

Navigating Without Language

At a basic level, physically navigating oneself around a spatial environment involves an egocentric spatial FoR in which all orientations, positions, directions and movements are processed in relation to one's own body. We can achieve tasks such as walking across a room while navigating around tables and chairs, at an embodied level, with minimal cognitive demand. In essence, we can move forward and turn left and right, whenever required, without actually thinking about it or needing to connect our actions with language—we can just do it. Similarly, we could push an object around a structured spatial environment, much like a chess piece on a chess board, without connecting language to the movements. Perhaps it could be argued that the latter scenario also involves egocentric referencing because of its proximity (Ruggiero et al., 2016), and the direct manipulation of the 'object' may be perceived as an extension of oneself.

If we wanted to guide another person across the room following the same path (and they could see us) we could again use embodied modes to communicate by gesturing and pointing. Such a task appears to use an *allocentric spatial FoR*, where we consider the location of objects in relation to other objects. In this sense, we perceive the other person as an 'object' that we can move without actually touching because 'it' responds to our hand signals. Consider the effectiveness of directing a driver trying to reverse a vehicle into a parking space using gestures rather than calling out left and right directions. Without the use of language, it is not necessary to use a viewer-entered perspective and switch to the other's perspective.

Navigating with Language

In each scenario above, embodied modes are dominant in the navigation of the three-dimensional environment and language is redundant. The encoding of spatial frames of reference—the attachment of specific language to spatial and directional concepts—creates another layer of complexity. While some research suggests that increased exposure to spatial language supports the development of spatial skills (Casasola et al., 2020), we know little about how children learn frame-of-reference words (Shusterman & Li, 2016) and even less about how to effectively teach this aspect of spatial competence.

Being able to give left/right directions to someone else appears to be more difficult than following left/right directions. Waller (1986) reported that 5 to 6-year-olds could differentiate left/right but had difficulty in remembering left/right instructions and giving appropriate left/right directions to others. Giving effective directions requires the cognitive flexibility to utilise an allocentric spatial FoR in a way that requires switching spatial perspectives from one's own perspective to the perspective of the other person—plus an awareness of the need for accurate instructions (Waller, 1986). Cognitive science research provides at least a partial explanation for different levels of difficulty through establishing that spatial memory of egocentric-based experiences is easier to retrieve than spatial representations that involve allocentric referencing, which involves a different part of the brain (Ruggiero et al., 2016).

In recent years, educational research regarding children's interactions with computers and robotics has produced some insights into the development of navigational language through the use of verbal commands (Kocher et al., 2020). In their research with 4-to-9-year-olds, Kocher et al. (2020) asked the children to verbally guide an adult (acting as a robot) to find a 'treasure' the child had hidden in the room. The researchers categorised the navigational commands the children naturally used into three levels that illustrate increasing precision in spatial language, alongside decreasing dependence on embodied communication. Explication of the levels was intended to inform teaching and the choice of types of digital robot suitable for use with the children. The *Beginner level* featured the use of landmarks and gestures. For example, 'go to the chair' or 'walk round the table'. Such direction might utilise gesture to reduce the demand for language, and vague terms such as 'Go there' and 'Turn' needed to be accompanied by gesture to be effective in producing the desired movement by the robot-actor. At the *Intermediate level* more specific spatial terms were used such as 'left', 'right', 'turn-stop', 'forward' and 'diagonal'. Self-corrections were made following the feedback afforded by the robot-actor's response to a command (e.g., 'the other left'). *Advanced level* commands were more precise, such as 'turn-left' (sometimes with the angle specified), or the inclusion of distance (e.g., forward 5 steps) (Kocher et al., 2020).

An important language consideration is the meaning of 'turn' in different contexts, particularly in relation to the context of robotics. In most circumstances the command 'turn left' would be interpreted as rotating the front-face until the new front-face is 'looking' directly to the left-side of the original position, that is, a turn of 90º. However, depending on the context, the movement that achieves the turn can be quite different. For example, in the contexts of walking or driving a car, the command 'turn left' would be enacted gradually by moving forward simultaneously with the left-turn motion, creating a curved pathway (Clements et al., 1996). So, there is a change in both location and the front-face orientation. However, in the context of robotics the left turn would be achieved by a rotation of 90º on the spot, without any forward movement. The robot's location remains the same and only the orientation of the front-face changes. Bakala et al. (2021) suggest the method of turning in robotics is counterintuitive for children and so would require special attention in teaching.

Methods

Context and Participants

This study is situated within the *Embodied Learning in Early Mathematics and Science* project (2021–2024), the aim of which is to translate research on embodied cognition into classroom practice for Preschool through to Year 2 (4- to 8-year-olds). The participants for this study were randomly selected Year 1 children from three different schools (New South Wales, Australia) which had not been part of the professional learning intervention aspect of the larger project. A total of 36 children returned consent forms from their parents. School 1 is a medium-sized primary school with 409 children, 29% of children are from a LBOTE (Language Background other than English). School 1 has an ICSEA (Index of Community Socio-

Educational Advantage) score of 1121 indicating a higher SES (socio-economic status) compared with other schools in Australia. [Note: An ICSEA score of 1000 is set as the average benchmark with which other schools are valued as lower or higher levels of educational advantage of student populations (ACARA, 2020)]. School 2 is a medium-sized primary school with 301 children, 33% of children are from a LBOTE. School 2 has an ICSEA score of 1028 indicating it has a higher SES. School 3 is a medium-sized school with 553 children. School 3 is identified as having a high, 94%, LBOTE child population and lower level of educational advantage with an ICSEA of 950.

Task-Based Interviews

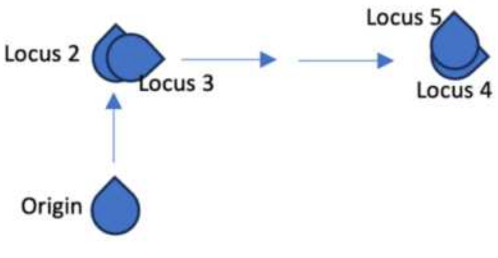
Task-based interviews (Goldin, 2000) were carefully designed for the purpose of the study and to elicit each child's embodied "representations of particular mathematical ideas" (Maher & Sigley, 2014, p. 821), in this case the concepts of right-turn and left-turn. The one-to-one task-based interviews were conducted by five different researchers. The delivery of the tasks was scripted and practiced for consistency of question-asking by the interviewers. However, it is acknowledged that some variations still occurred within the child-interviewer interactions, mainly due to the unpredictability of the child responses. The interviews were video recorded, with additional permission given by the children themselves before commencing the tasks.

Task 1: You be the Robot

Task 1 required the child to respond to spoken orientation and directional terms (turn-right, turn-left) by moving their own bodies, and therefore utilised a viewer-centric perspective and an egocentric spatial FoR. The task began by inviting the child to stand in a clear floor space, then the interviewer followed the script (Table 1), delivered one part at a time. No feedback was given to the child during the task and incorrect moves were simply followed by the next instruction. In the mapping of the correct movement responses (Table 1) the right-turn is represented by Locus 2 and 3, and the left-turn by Locus 4 and 5.

Table 1

Task 1 Details

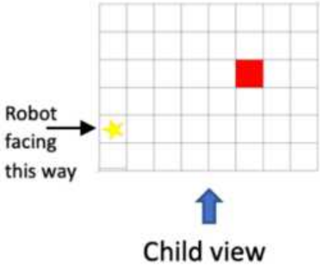
Task 1 script	Mapping of correct movements
Let's play a robot game. You be the robot. Stand up like a robot. I'm the robot controller. Robot, take 1 step forward (*pause*) Robot, turn right (*pause*) Robot, take 2 steps forward (*pause*) Robot, turn left (*pause*) Robot, sit on the chair (*point to child's interview chair*)	

Task 2: Direct the Robot

Task 2 required the child to give verbal commands to a toy robot (animated by the interviewer), and therefore required an allocentric spatial FoR and switching the viewer-centric perspective to the robot's viewpoint. The task began by placing a grid on the desk in front of the child (see Table 2 for the orientation) and showing the child the toy robot, followed by scripted instructions, all delivered at the beginning. The child was not permitted to touch the robot and the interviewer moved the robot as if it could hear the child's verbal instructions. Therefore, if the child did not give a verbal instruction the robot did not move, and the child was prompted to try again. Feedback was often (but not consistently between interviewers) provided if the child did not use the verbal prompt related to a specific direction. For example, if the child said, ‘go there’ or ‘take one step’, a prompt might have been ‘which way?’ Unavoidable feedback was also provided by the robot’s response to a command—which may or may not be the movement envisaged by the child.

Table 2

Task 2 Details

Instructions	**Robot grid and placement**
Now you be the controller for this little robot. The robot can only move one square at a time. It won’t turn left or right unless you tell it to. Your job is to tell the robot how to move from here (place robot on star) to here (point to red square). What’s your first order for the robot? (Interviewer moves the robot according to child’s instructions). (If child does not commence, demonstrate) Robot, take 1 step forward (move the robot one square). Your turn to tell the robot	 Toy robot 

Analysis

Both tasks included other concepts such as forward movement and distance, but the focus of analysis was narrowed to the instances of right (R) and left (L) turns for the purposes of this paper. Two analysis approaches were applied to viewing the videos. The deductive approach recorded whether each child could produce a ‘correct’ response (yes/no). The inductive approach recorded more information about the nature of each child’s response using descriptive text. An analysis spreadsheet was constructed and two members of the research team who had conducted the interviews analysed the videos, cross-checked each other’s analyses, and resolved any difficult interpretations through discussions.

Correct for Task 1: You be the Robot

Correct body movements in response to the verbal instruction Turn right (R), or Turn left (L):

- R/L awareness: Gave some indication that they know which is their R/L side, such as a gesture or other movement to the R/L (including turning);
- R/L Turn: Turned R/L a quarter turn (90º) to reorient their body to R/L of their original ‘front-facing’ position—and remains in that position and orientation.

Correct for Task 2: Direct the Robot

Correct verbal commands (on first attempt) given to the robot relative the robot’s Right (R) or Left (L).

R/L awareness: Gave some indication that they know which is the robot’s R/L side. To determine correctness the researcher must make a judgement about the child’s intent. For example, if a child says ‘Turn left’ but shows surprise when the interviewer turns the robot to the robot’s left, then the spoken direction did not match the child’s intent, so was recorded as incorrect. When incorrect, the command was classified as R or L according to the intended direction. Pointing to the grid square to the left of the robot or using a left gesture (with no accompanying verbal ‘left’) were recorded as incorrect, as these embodied actions ‘may’ have indicated L/R awareness, however they may also have simply indicated the child knew which way or path to take to the target square.

R/L Turn: Gave a verbal command to Turn R/L. Verbal instructions such as ‘Go Left’, or non-verbal instructions such as pointing were not recorded as correct.

Results

The results of the two Robot Tasks are first presented separately with a focus on specific findings in relation to egocentric (Task 1) and allocentric/view-switching (Task 2) spatial FoR. Second, findings from across the two tasks are presented as general findings highlighting connections and comparisons. Table 3 provides a summary of correct responses for L/R awareness and turn for each task. This table will be referred to throughout the results section in conjunction with the descriptive text regarding children's alternate incorrect responses.

Table 3

Deductive Analysis Summary: Number of Children with Correct Responses

	Task 1 (egocentric)					**Task 2 (allocentric/perspective switching)**				
School (*n*)	**R aware**	**R turn 90º**	**L aware**	**L turn 90º**	**All yes**	**R aware**	**R turn verbal**	**L aware**	**L turn verbal**	**All yes**
1 (10)	7	6	7	3	2	3	3	7	6	2
2 (15)	12	9	12	5	5	5	3	12	6	3
3 (11)	9	6	8	2	1	1	1	3	1	1
Total (36)	28	21	27	10	8	9[α]	7[α]	21	13	6[β]

[α] Some children did not have the opportunity to make a right turn command because the pathway they chose for the robot only required left turn/s.

[β] All yes in Task 2 only refers to children who provided commands for both R/L.

Task 1 Results

Across the three schools eight children obtained a complete correct (R and L) score for the egocentric task, and eight children we unable to complete any aspect correctly. Of the eight children who were unable to complete Task 1, most (7) turned, but turned the opposite direction, for example turned L for R, therefore they scored incorrectly on both awareness and turn. The remaining 20 children's responses were mixed. All except one showed both R and L awareness. Of the 19 that showed R and L awareness, 10 children could also turn R and turn L–but turned L 180° instead of 90°. It was noted that turning L from Locus 4 (see Table 1) would place children facing L if a L turn was completed facing the 'original' front (starting direction) of Task 1. Overall, children were more competent with R and L awareness than physically turning R or L 90° as indicated in Table 3. However, if interpreting correct 'turning' as correct directional turn, not necessarily correct rotation amount, then 18 children could be considered as scoring complete correct on Task 1. Where children scored incorrect for R or L turn, they either turned in the opposite direction or stepped sideways in the correct direction.

Task 2 Results

Six children obtained a complete correct (R and L) score for the allocentric task. As noted in the analysis, Task 2 could be completed without a R turn, therefore, an additional four children were correct for the turns they use to direct the robot. Observational notes made about these children revealed; two children made 'Ls' with their hands/fingers to know which way was left before stating their directions, and one child moved around the desk to position their body behind the robot's starting position. There were 13 children unable to give any correct verbal command for the robot to turn R and/or L. Eight of these children indicated to move/turn but said the opposite direction (e.g., R for L), half (4) then self-corrected after seeing the robot move/turn the opposite direction to what they intended. Table 3 shows that children from School 3 (high NESB, low SES school context) had the most difficulty in completing the allocentric/view-switching task. The majority (8) of the 13 children unable to complete the allocentric task were from School 3. Some children (16) used gestures or co-speech gestures. Gesturing alone was used to indicate/point to the square to move to or the possible direction—not specifically linked to L or R as no verbal 'left' or 'right' were uttered. Co-speech gesture was used in children's commands, for example 'go left [while pointing in a L direction]', or 'turn up [while gesturing L]'. Gesture or co-speech gesture were used more frequently by children from School 3 (8 of the 11 children from School 3).

General Findings

Four of the 36 children scored a completely correct score on both tasks. Five children who were unable to follow any directions in Task 1 (egocentric), could give some correct directions in Task 2 (allocentric/switching). One of those children made no errors in the directions they provided in Task 2. Six of the 10 children who correctly completed Task 2 had mixed results in the egocentric task. In the allocentric task, like the egocentric task, more children were L aware than able to provide a verbal L turn command. Children would often use alternate words for turn including 'go left', 'turn up', 'this way', 'turn that way [gesture]', 'go right', 'turn straight', 'one step left'.

Discussion

Our findings aligned with previous research related to the 5-to-7-year-old age range in several ways. The majority of children were successful in responding to the viewer-centric terms 'left and right' when operating with an egocentric FoR (Waller, 1986; Ruggiero et al., 2016). We suggest there is a relationship between the lower success rate in School 3 and the school's social/educational disadvantage and high non-English speaking population. It is possible that some of the children's home languages preference allocentric terminology based on landmarks and object-to-object relationships (with little use of left/right), rather than viewer-centric navigational terms (as in English), as discussed by Abarbanell and Li (2021).

The children found following left-right directions easier than giving left-right directions, aligning with Waller (1986). Compared with Task 1, fewer children were able to successfully take the viewer-centric perspective of the robot in Task 2, though the difference was not large. The success of some students in Task 2 could possibly be attributed to the availability of feedback through seeing the response of the robot to a command, and the availability of the grid for visualising a route to the target location. However, there were a few children who, surprisingly, performed better in Task 2 than Task 1, and this requires further investigation. Like Kocher et al. (2020), we found that the children tended to use gesture and vague directional terms rather than the precise commands of left/right or turn. Some children managed to produce the appropriate directions when prompted, but others found it beyond their current capability. The main focus of the study was the children's responses to the turning aspect of the tasks, and we found that the children interpreted the meaning of 'turn' in a variety of ways, with some children even responding in different ways within the same task. For example, in Task 1, 10 children correctly turned right 90°, but when asked to turn left inexplicably turned 180°. We are yet to find any explanation for this in previous research. Some children responded by turning 90°, but in the opposite direction, while others did not rotate their bodies at all, instead stepping sideways or just turning their heads or shoulders then resuming their front-facing orientation. In Task 2, many children were not able to give the verbal command 'turn' to the robot, which perhaps can be partly explained by the requirement in the robotics context to change the orientation of the robot by rotating on-the-spot before moving to a new location, as indicated by Clements et al. (1996) and Bakala et al. (2021).

Conclusion

This study investigated the question, 'How do Year 1 children respond to, and give, verbal instructions to turn-left and turn-right?' Keeping in mind the limitations of a small sample of children, we offer some tentative propositions for further investigation. First, the mastery of the viewer-centric terms of left, right, and turn is problematic for both spatial/cognitive and cultural/linguistic reasons. Second, the tendency of children to preference embodied representations and 'landmark' cues may offer a starting point for instructional practices. Third, further attention should be given to the differing meanings of 'turn' when enacted in different contexts. We refrain from making more specific recommendations until analysis of the much larger data set from the project has been completed.

Acknowledgments

The ELEMS project is funded by the NSW Department of Education, Strategic Research Fund (2021–2024). Ethics approval 2023/040 was granted by The University of Sydney and participants and parents/caregivers gave informed consent.

References

Abarbanell, L., & Li, P. (2021). Unraveling the contribution of left-right language on spatial perspective taking. *Spatial Cognition & Computation*, *21*(1), 1–38.

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2022). *Australian Curriculum: Mathematics (v9.0)*. ACARA. https://v9.australiancurriculum.edu.au/f-10-curriculum/learning-areas/mathematics/year-1

Bakala, E., Gerosa, A., Hourcade, J. P., & Tejera, G. (2021). Preschool children, robots, and computational thinking: A systematic review. *International Journal of Child-Computer Interaction*, *29*, Article 100337.

Casasola, M., Wei, W. S., Suh, D. D., Donskoy, P., & Ransom, A. (2020). Children's exposure to spatial language promotes their spatial thinking. *Journal of Experimental Psychology: General*, *149*(6), 1116.

Clements, D. H., Battista, M. T., Sarama, J., & Swaminathan, S. (1996). Development of turn and turn measurement concepts in a computer-based instructional unit. *Educational Studies in Mathematics*, *30*, 313–337.

Dackermann, T., Fischer, U., Nuerk, H. C., Cress, U., & Moeller, K. (2017). Applying embodied cognition: From useful interventions and their theoretical underpinnings to practical applications. *ZDM Mathematics Education*, *49*, 545–557. https://doi.org/10.1007/s11858-017-0850-z

Goldin G (2000). A scientific perspective on structures, task-based interviews in mathematics education research. In: R. Lesh, A. E. Kelly (Eds.), *Research design in mathematics and science education*. Erlbaum, (pp. 517–545).

Kiefer, M., & Trumpp, N. M. (2012). Embodiment theory and education: The foundations of cognition in perception and action. *Trends in Neuroscience and Education*, *1*(1), 15–20.

Kocher, D., Sarmiento, L., Heller, S., Yang, Y., Kushnir, T., & Green, K. E. (2020, October). No, your other left! Language children use to direct robots. *Joint IEEE 10th international conference on development and learning and epigenetic robotics* (pp. 1–6). IEEE.

Maher, C. A., & Sigley, R. (2020). Task-based interviews in mathematics education. In S. Lerman (Ed.), *Encyclopedia of mathematics education,* (pp. 821–824). Springer.

NSW Education Standards Authority. (2022). *Mathematics K–10 syllabus*. NSW Education Standards Authority.

Rigal, R. (1994). Right-left orientation: Development of correct use of right and left terms. *Perceptual and Motor Skills*, *79*(3), 1259–1278.

Roberts Jr, R. J., & Aman, C. J. (1993). Developmental differences in giving directions: Spatial frames of reference and mental rotation. *Child Development*, *64*(4), 1258–1270.

Ruggiero, G., D'Errico, O., & Iachini, T. (2016). Development of egocentric and allocentric spatial representations from childhood to elderly age. *Psychological Research*, *80*, 259–272.

Shusterman, A., & Li, P. (2016). Frames of reference in spatial language acquisition. *Cognitive Psychology*, *88*, 115–161.

Waller, G. (1986). The use of 'left' and 'right' in speech: the development of listener-specific skills. *Journal of Child Language*, *13*(3), 573–582.