**Title**: Spatial Ability Development in Adolescents and Young Adults with Down Syndrome

**Authors**: Samantha Zakrzewski1, Matthew Baker1 , Stephanie Grinshpun 1, Yingying Yang1, Frances Conners2 & Edward Merrill2

**Introduction**: Down syndrome (DS) is one of the most common causes of intellectual disability. Individuals with DS often experience deficits in speech and language (Abbeduto, Warren, & Conners, 2007), cognitive development (Weijerman & De Winter, 2010), and the acquisition of social/personal skills (National Down Syndrome Society, 2007). In their extensive literature review, Yang, Conners, & Merrill (2014) found that certain spatial abilities in individuals with DS may be an area of weakness compared to typically developing (TD) children matched for mental age. Spatial abilities aid in manipulating, constructing, and navigating the physical world (Newcombe & Shipley, 2014). According to the framework set forth by Newcombe & Shipley (2014), spatial abilities can be distinguished as intrinsic (within objects) or extrinsic (among and between objects) and statically (stable) or dynamically (movement). Mental rotation, an intrinsic-dynamic skill, is the ability to rotate a 2 or 3-dimensional object in one’s mind (Shepard & Metzler, 1971). Perspective taking, an extrinsic-dynamic skill, is the ability to mentally represent a viewpoint different from one’s own (Frick, Möhring, & Newcombe, 2014). These two spatial abilities involve common processes, such as encoding spatial images and keeping these representations in memory (Kosslyn, 1994). However, they differ in that mental rotation uses object-based transformations, while perspective taking uses egocentric transformations (Hegarty & Waller, 2004). The goal of this study was to evaluate similarities and differences in mental rotation and perspective taking abilities between people with DS and TD children matched on nonverbal ability.

**Method**: Twenty-three individuals with DS (14 males; Age: *M* = 18.49 years, *SD* = 4.02; range: 11 - 26) and twenty-three TD children (12 females; Age: *M* = 6.34 years, *SD* = 1.27; range: 4 - 8) were matched using the Raven’s Progressive Matrices, a measure of nonverbal ability (Raven, 2003). See Table 1 for descriptive statistics. Participants were individually tested over two days via Zoom. To assess mental rotation, two assessments were utilized: the Ghost Task patterned after Frick et al. (2013) and Puzzle Assessment created for this study. In the Ghost Task, participants were shown an upright ghost shape and needed to determine whether a rotated ghost shape or its mirror image would fit into the space. In the Puzzle Assessment, participants were shown a puzzle with one piece missing and needed to choose between a rotated piece and its mirror image which would fit into the open space of the puzzle. Stimuli in both assessments were rotated between 30 and 180 degrees. To assess perspective taking, two assessments were used: the Three Mountain Task and the Dog Task (see Bracken et al., 2024). In the Three Mountain Task, participants were shown three cones of different sizes and colors, which represented mountains. A stuffed dog would move in 45-degree increments around the mountains and participants were tasked with determining which of 4 pictures represented the dog’s new viewpoint. In the Dog Task, four different colored stuffed dogs were arranged at 0, 90, 180, and 270 degrees forming a diamond shape on the center of a table. Participants were instructed to pretend to be one of the four dogs and choose which of the other dogs was on their right, left, or farthest away.

**Results**: The percentage correct for two assessments for two abilities was averaged to compute a composite score for each ability. This resulted in a mental rotation composite score (average score for Ghost Task and Puzzle Assessment) and perspective taking composite score (average score for Three Mountain Task and Dog Task). See Table 1 for descriptive statistics. To assess performance between the two groups, a 2 (ability: mental rotation composite score vs perspective taking composite score) x 2 (group: typically developing vs Down syndrome) repeated measures ANOVA was conducted with ability as a within-subjects factor and group as a between-subjects factor. The main effect of ability was not significant, *F* (1, 44) = 1.51, *p* = .226, ηp2 = .033. However, there was a significant interaction between ability and group, *F* (1, 44) = 10.34, *p* = .002, ηp2 = .190. Post hoc tests corrected with the Bonferroni adjustment showed that performance on perspective taking did not significantly differ (*p* = .75) between TD (*M* = 66.24, *SE* = 3.23) and DS (*M* = 64.76, *SE* = 3.23) participants. For mental rotation, the TD group (*M* = 77.78, *SE* = 3.55) performed significantly better (*p* < .001) than the DS group (*M* = 59.60, *SE* = 3.55). See Figure 1.

**Discussion:** Our results suggest that when matched on Ravens Ability, performance on our perspective taking tasks was not significantly different for the DS and TD participants. However, TD participants performed significantly better than participants with DS on the mental rotation tasks. This may be because mental rotation is an earlier developing ability for TD children, and hence, we see that individuals with DS lag behind as the ability develops. Regardless, this result does suggest the importance of focusing on mental rotation skills as an important component of cognitive training for those with DS.

**References:**

Abbeduto, L., Warren, S. F., & Conners, F. A. (2007). Language development in Down syndrome: From the prelinguistic period to the acquisition of literacy. *Mental retardation and developmental disabilities research reviews*, *13*(3), 247-261.

Bracken, A., Hauss, J., Grinshpun, S., Lasc, D., Hershkovich, A., & Yang, Y. (2024). A profile of spatial abilities in people with Down syndrome. *Journal of Intellectual Disability Research*, *68*(3), 223-236.

Frick, A., Hansen, M. A., & Newcombe, N. S. (2013). Development of mental rotation in 3-to 5-year-old children. *Cognitive Development*, *28*(4), 386-399.

Frick, A., Möhring, W., & Newcombe, N. S. (2014). Picturing perspectives: development of perspective-taking abilities in 4-to 8-year-olds. *Frontiers in psychology*, *5*, 386.

Hegarty, M., & Waller, D. (2004). A dissociation between mental rotation and perspective-taking spatial abilities. *Intelligence*, *32*(2), 175-191

Kosslyn, S. M. (1994). Image and brain. Cambridge, MA: MIT Press.

National Down Syndrome Society. (2007). Down Syndrome Facts. Available at: http://www.ndss.org [accessed April 26, 2009].

Newcombe, N. S., & Shipley, T. F. (2014). Thinking about spatial thinking: New typology, new assessments. In *Studying visual and spatial reasoning for design creativity* (pp. 179-192). Dordrecht: Springer Netherlands.

Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science*, *171*(3972), 701–703. <https://doi.org/10.1126/science.171.3972.701>

Thomas, M. S., Annaz, D., Ansari, D., Scerif, G., Jarrold, C., & Karmiloff-Smith, A. (2009). Using developmental trajectories to understand developmental disorders.

Weijerman, M. E., & De Winter, J. P. (2010). Clinical practice: The care of children with Down syndrome. *European journal of pediatrics*, *169*, 1445-1452.

Yang, Y., Conners, F. A., & Merrill, E. C. (2014). Visuo-spatial ability in individuals with Down syndrome: Is it really a strength?. *Research in developmental disabilities*, *35*(7), 1473-1500.

Montclair State University

2 University of Alabama

**Table 1**

*Descriptive Statistics*

|  |  |  |
| --- | --- | --- |
|  | *M* | *SD* |
|  | Typically Developing |  |
| Perspective Taking Composite Score | 66.24 | 18.17 |
| Mental Rotation Composite Score | 77.78 | 14.93 |
| Ravens Ability | 449.39 | 32.44 |
|  | Down syndrome |  |
| Perspective Taking Composite Score | 64.76 | 12.52 |
| Mental Rotation Composite Score | 59.60 | 18.85 |
| Ravens Ability | 449.57 | 35.67 |

**Figure 1**

*Spatial Ability Performance by Group*

