Virtual Building Blocks: Exploring Children's Digital Spatial Play

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Touchscreens are Ubiquitous
Spatial Skills

- Transform & remember visual images
- Mentally manipulate structures
- Consider spatial properties (shape, size)
- Notice spatial relations (upside down, next to)
- Cut pizza pies, locate oneself on a map

(Brosnan, 1998; Carroll, 1993; Casey et al., 2008; Newcombe & Shipley, 2015; Uttal & Cohen, 2012; Wai, Lubinski, & Benbow, 2009)
Spatial Skills & STEM

- Spatial concepts underlie STEM principles
  (Atit et al., 2020; Gaudreau et al., 2020; Gentner et al., 2016; Haden et al., 2014; Hodgkiss et al., 2018)

- Spatial skills highly predictive of STEM success
  (Newcombe, 2013; Uttal et al., 2013; Wai et al., 2009)

- Link appears early in development
  (McCrink & Opfer, 2014; Mix et al., 2016; Verdine et al., 2014)
Spatial Skills & Young Children

• Developmental trajectory of spatial skills is shaped by early spatial experiences (Levine et al., 2012; Newcombe & Frick, 2010; Newcombe & Huttenlocher, 2000; Pruden et al., 2019)

• Not taught in formal school curricula (Newcombe & Frick, 2010)

• Play!
Spatial Play

• Blocks, puzzles, board games
• Frequency predicts spatial abilities
• Notice spatial relations through physical engagement with toys
• Physicality may be important

(Caldera et al., 1999; Jirout & Newcombe, 2015; Levine et al., 2012; Siegler & Ramani, 2008)
Digital Spatial Play

- Engagement with blocks, shapes, & puzzles on touchscreens
Digital & Physical Spatial Play

• Physical - manipulate objects in hands
• Digital - manipulate objects on screen
• Digital lacks physicality
Is Lack of Physicality Detrimental?

• May not be problematic

• Children can learn from digital media \((\text{Xie et al., 2018})\)

• Environment changes way in which learning unfolds \((\text{Pouw et al., 2014})\)

• Digital spatial play may diversify types of spatial information children experience & notice
Theoretical Framework

- Apps have unique spatial affordances

(Gibson, 1979; Norman, 1999)
Endless Objects & Shapes

- Present endless shapes, objects, & arrangements
- Unconstrained
- Non-canonical shapes
Manipulate Objects

• Manipulate objects in a way that may be impossible in real life
Flexibly Manipulate Perspective

• Change perspective
• Zoom in & out
• Bird’s-eye point of view
Context for Spatial Skill Development

• How do children engage in digital spatial play?

• What factors may be associated with this play?
Individual Characteristics

- Children’s age & spatial abilities
- Both characteristics associated with physical spatial play

(Caldera et al., 1999; Casey et al., 2008; Reifel, 1984; Goodson, 1982)
Type of Digital Spatial Play App

• Many types of digital spatial play apps
  • Shapes & puzzle games
  • Games with clear goals
  • Open-ended building games

• Apps have different affordances

• Goals influences physical spatial play

(Ferrara et al., 2011; Polinsky et al., 2017; Polinsky, Pagano, Acosta, Haden, & Uttal, in prep.)
Current Research

Explore how children engage in digital spatial play & consider the role of age and spatial abilities in this play across three different apps.

- Busy Shapes
- RelationShapes
- Toca Blocks
Busy Shapes: a shape sorting game

- Sort shapes
- Involves shapes
- Clear goals & levels
- Affordances:
  - Endless objects
RelationShapes: a puzzle game

- Make both sides look the same
- Involves shapes
- Clear goals & levels
- Affordances:
  - Endless objects
  - Manipulate objects
Toca Blocks: an open-ended game

- Use blocks to build worlds for avatars
- Open-ended building
- Affordances:
  - Endless objects
  - Manipulate objects
  - Flexibly manipulate perspective
Research Questions

• How do children play with digital spatial apps?
• Is there developmental change in children’s digital spatial play?
• Is there an association between spatial skills & children’s digital spatial play
Participants

- 111 children
- 3- to 6-years-old ($M = 4.95$ years)
- 53% females
- 73% Caucasian
- 60.36% parent with some graduate education or more
Procedure

Spatial Skills Assessment

iPad Game 1: Busy Shapes

iPad Game 2: Relation-Shapes

iPad Game 3: Toca Blocks

order counterbalanced
Assessment Issues

• Very few spatial skills assessments for children

• None span age range 3 to 6

• Used two assessments
  • Assessment for 3- to 4-year-olds
  • Assessment for 5- to 6-year-olds

• Performance on assessments not correlated
Procedure

Spatial Skills Assessment

iPad Game 1: Busy Shapes
iPad Game 2: Relation-Shapes
iPad Game 3: Toca Blocks

order counterbalanced

TOSA 3- & 4-year-olds
CMTT 5- & 6-year-olds
Test of Spatial Assembly (TOSA)

- Match to sample spatial assembly task
- 14 trials
  - seven 2D trials
  - seven 3D trials
- Trials are untimed
- Pictures of construction taken for later coding
  - Scored based on accuracy of recreated spatial relations in target model

Verdine, Golinkoff, et al., 2014
Procedure

Spatial Skills Assessment

iPad Game 1: Busy Shapes

iPad Game 2: Relation-Shapes

iPad Game 3: Toca Blocks

order counterbalanced

TOSA 3- & 4-year-olds

CMTT 5- & 6-year-olds
Look at these pieces. Look at these pictures. If you put the pieces together, they will make one of the pictures. Point to the picture the pieces make.

(Ehrlich et al., 2006)
Spatial Skills Assessment

iPad Game 1: Busy Shapes

iPad Game 2: Relation-Shapes

iPad Game 3: Toca Blocks

order counterbalanced

TOSA 3- & 4-year-olds

CMTT 5- & 6-year-olds
Research Questions

• How do children play Busy Shapes and RelationShapes?

• Is there developmental change in children’s Busy Shapes and RelationShapes play?

• Is there an association between spatial skills & children’s Busy Shapes and RelationShapes play?
Busy Shapes & RelationShapes
Game Performance

• Measure of *how children played*
• Screen recorded game play
• Average time to complete # levels played
• Busy Shapes: $M = 10.39$ secs, $SD = 2.69$
• RelationShapes: $M = 49.82$ secs, $SD = 37.43$
Research Questions

• How do children play Busy Shapes and RelationShapes?

• Is there developmental change in children’s Busy Shapes and RelationShapes play?

• Is there an association between spatial skills & children’s Busy Shapes and RelationShapes play?
Developmental Change

Busy Shapes & Age

Relation Shapes & Age

$r(107) = -.37, p < .001$

$r(109) = -.68, p < .001$
Research Questions

• How do children play Busy Shapes and RelationShapes?

• Is there developmental change in children’s Busy Shapes and RelationShapes play?

• Is there an association between spatial skills & children’s Busy Shapes and RelationShapes play?
Younger Children: Spatial Skills & Play

Busy Shapes & Spatial Skills

Relation Shapes & Spatial Skills

$r(52) = -0.49, p < 0.001$

$r(53) = -0.39, p < 0.01$
Older Children: Spatial Skills & Play

Busy Shapes & Spatial Skills

Relation Shapes & Spatial Skills

$p > .8$

$p > .2$
Busy Shapes & RelationShapes Summary

• Is there developmental change in children’s Busy Shapes and RelationShapes play? ✓
• Is there an association between spatial skills & children’s Busy Shapes and RelationShapes play?
  • Younger children? ✓
  • Older children? ✗
Developmental Change

• There are developmental changes in play
• Parallels patterns found in physical spatial play

(Casey et al., 2008; Goodson, 1982; Reifel, 1984;
Older Children & Spatial Skills

- Assessment issue
- Ceiling effect
- Circumvention of limits hypothesis (Hambrick et al., 2011)
Exploring Toca Blocks
Research Questions

• How do children play with Toca Blocks?
• Is there developmental change in children’s Toca Blocks play?
• Is there an association between spatial skills & children’s Toca Blocks play?
Quantifying Open-Ended Play

- Continuously coded 3 play behaviors
- Proportion of time variable for each behavior

Perspective Changes
- Adjust view on screen

Block Play
- Engage with Blocks

Avatar Play
- Explore with Avatar

(Marsh et al., 2016; Ramani et al., 2014)
How Do Children Play Toca Blocks?

Greater proportion of time engaging in Block Play than any other play type, p’s < .001
Research Questions

• How do children play with Toca Blocks?

• Is there developmental change in children’s Toca Blocks play?

• Is there an association between spatial skills & children’s Toca Blocks play?
Developmental Change

- No association between age & block play
- No association between age & perspective changes
- Significant association between age & avatar play, $r = .37, p = .01$
Research Questions

• How do children play with Toca Blocks?
• Is there developmental change in children’s Toca Blocks play?
• Is there an association between spatial skills & children’s Toca Blocks play?
  • No association with spatial skills
Toca Blocks Summary

• Is there developmental change in children’s Toca Blocks play? ✔

• Is there an association between spatial skills & children’s Toca Blocks play?
  • Younger children? ✗
  • Older children? ✗
Developmental Change & Toca Blocks

• Increased engagement with avatars
• Not more building with age
• Does not follow prior research (Goodson, 1982; Reifel, 1984)
Toca Blocks & Spatial Skills

- No association
- Open-ended play
- Potential value of goals
- Particularly important for digital spatial play
Discussion

• Practicing spatial skills while playing (Uttal et al., 2013)

• Necessity of goals to support children’s spatial engagement

• Play must be sufficiently challenging
Continued Research

• Theoretical paper & framework on affordances of digital spatial play and potential learning benefits

• Empirical research on how affordances influence spatial thinking & learning

• How design of playful activities supports spatial engagement & learning
Thank You!

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Results Summary

• Is there developmental change in children’s digital spatial play?
  • Busy Shapes √
  • RelationShapes √
  • Toca Blocks √

• Is there an association between spatial skills & children’s Toca Blocks play?
  • Younger children: it depends
    • Busy Shapes ✓
    • RelationShapes ✓
    • Toca Blocks ✗
  • Older Children: no
Does Game Type Matter?

• Busy Shapes & Relation Shapes similarities
  • Shapes
  • Specified goals
• Open-endedness influences spatial play
• Game type might matter

(Ferrara et al., 2011; Polinsky et al., 2017; Polinsky, Pagano, Acosta, Haden, & Uttal, in prep.)