Virtual Training:
Learning Transfer of Assembly Tasks

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Introduction

- Training costs in industry can be high
- Retention of learning is important

This study examines

- Learning transfer between training in the virtual environment and performing in the real environment

Learning Transfer

- Transfer of practice: Thorndike and Woodworth (1901)
- Relies on task similarity and domain knowledge and a person's ability to perceive the similarity: Gick and Holyoak (1987)
- Transfer occurs when similar affordances and constraints are present in two dissimilar environments: Greenco et al. (1993)

Skill Acquisition and Learning

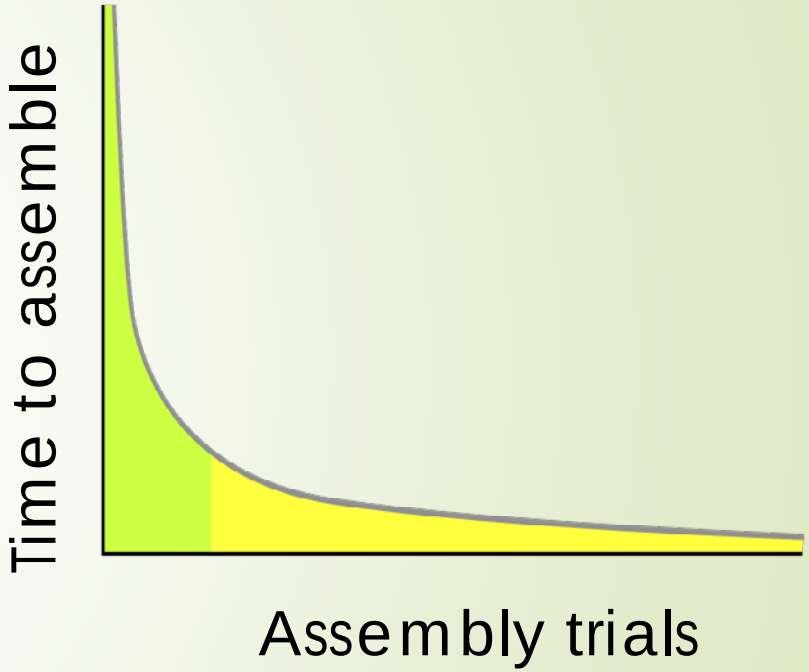
Fitts three-stage skill acquisition

- 1) cognitive stage: learner identifies how something works
- 2) associative stage: learner corrects errors in cognitive stage
- 3) autonomous stage: learner gradually improves

P. Fitts, "Perceptual-motor skills learning," in *Categories of human learning*, A. Melton, Ed. New York: Academic Press, 1964.

Learning Curve

- Rapid improvement in assembly over time
- Learning hits a “plateau” or stabilization point



Learning Transfer in VR

- Virtual training: pilots, military, medical, sports, routing and mapping
- Assembly
  - Real world training was more effective than virtual training (Hamblin, 2005)
  - Haptics feedback was necessary for more efficient learning transfer (Adams et al., 1999)
  - No significant difference in performance between virtually trained and physically trained, (Hall and Horwitz, 2001)
  - Gerbaud et al. created a rich software platform GVT for teaching procedural tasks (2008)

Previous Study – IEEEVR 2012

M. Oren, P. Carlson, S. Gilbert, and J. M. Vance, “Puzzle Assembly Training: Real World vs. Virtual Environment,” in *Proceedings of the IEEE 2012 Virtual Reality Conference*. Orange County, California: IEEE, 2012, pp. 1–4.

This Study ….

Expand on the previous study to:

- Control for training time – compare assembly performance
- Examine how color influences assembly performance
- Examine retention of learning

Burr Puzzle Assembly

- Use 6 piece burr puzzle assembly
- Required specific assembly sequence with only one path
- Puzzle doesn't require domain knowledge for assembly

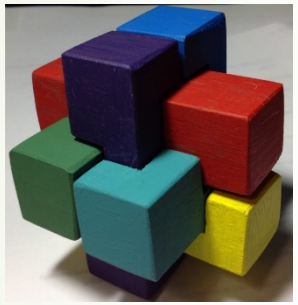
Fishtank VR with Haptics and Glove

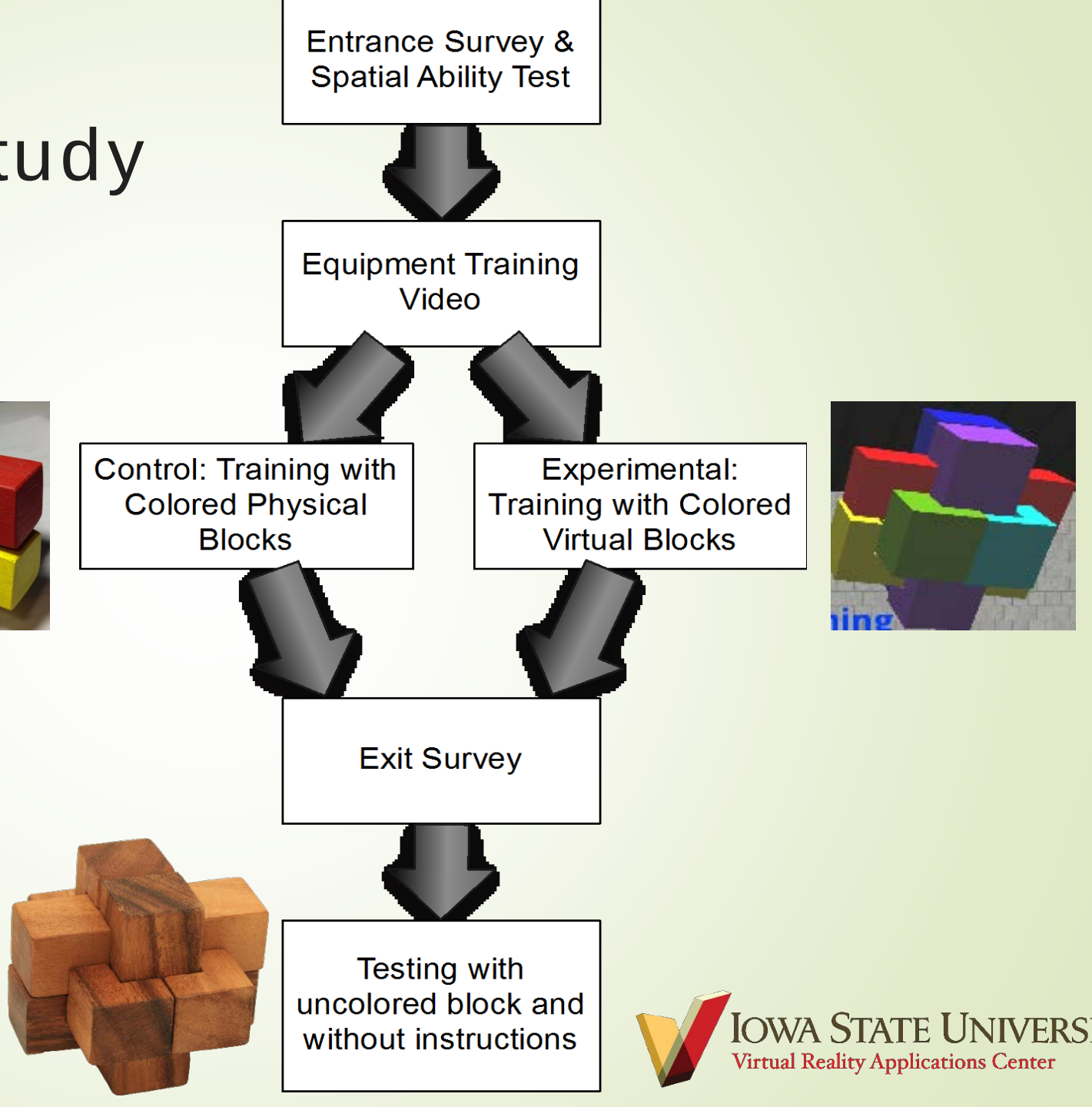
Video

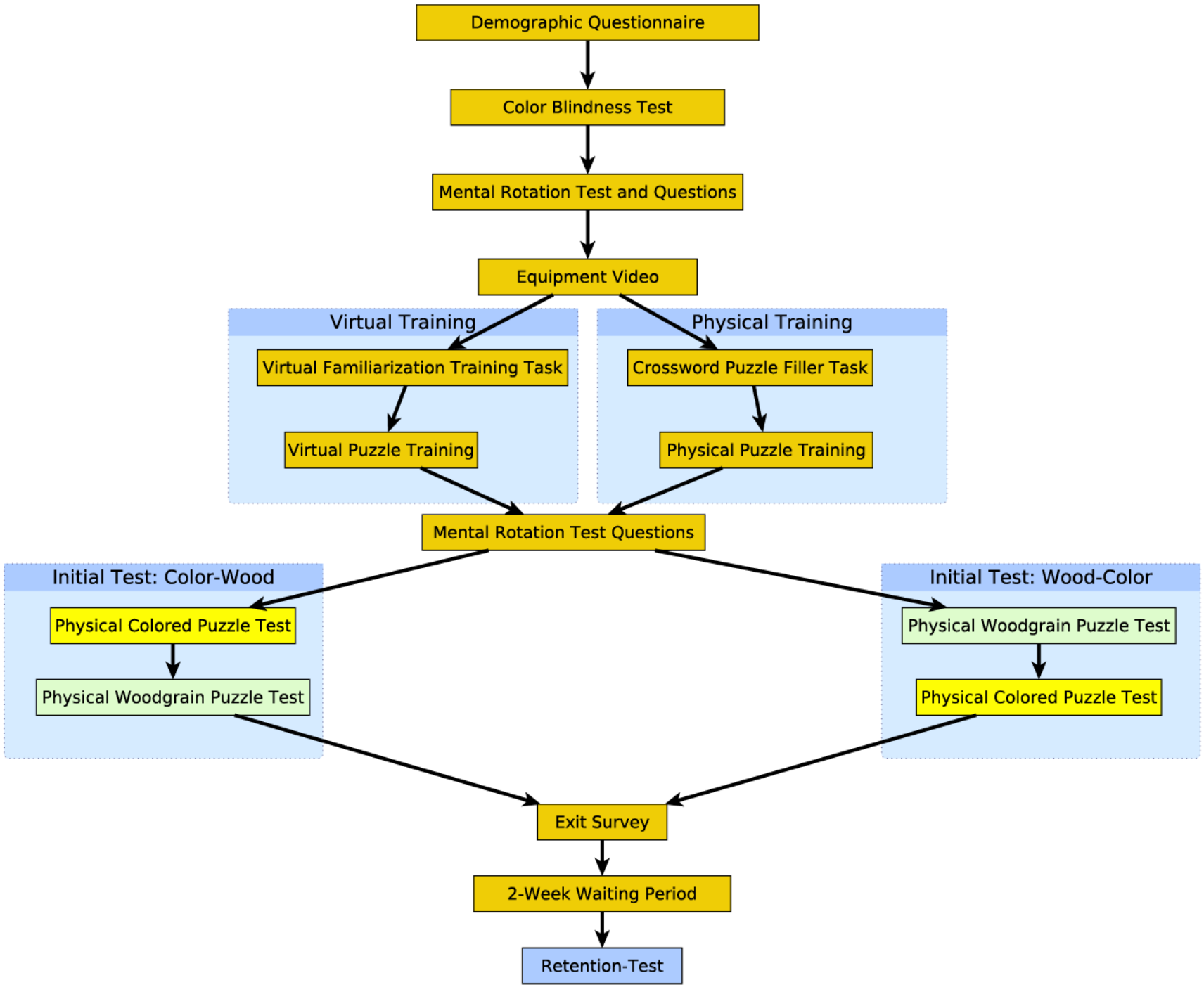
Software

- SPARTA (Scriptable Platform for Advanced Research in Teaching and Assembly)
  - VR Juggler
  - VR JuggLua
  - Voxmap Pointshell (VPS)

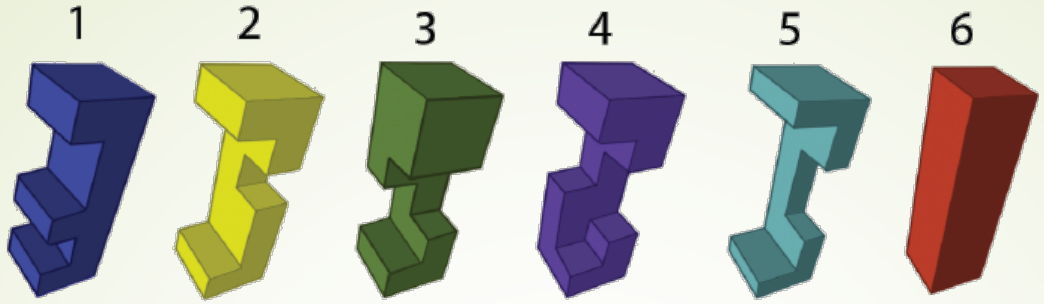
Original Study



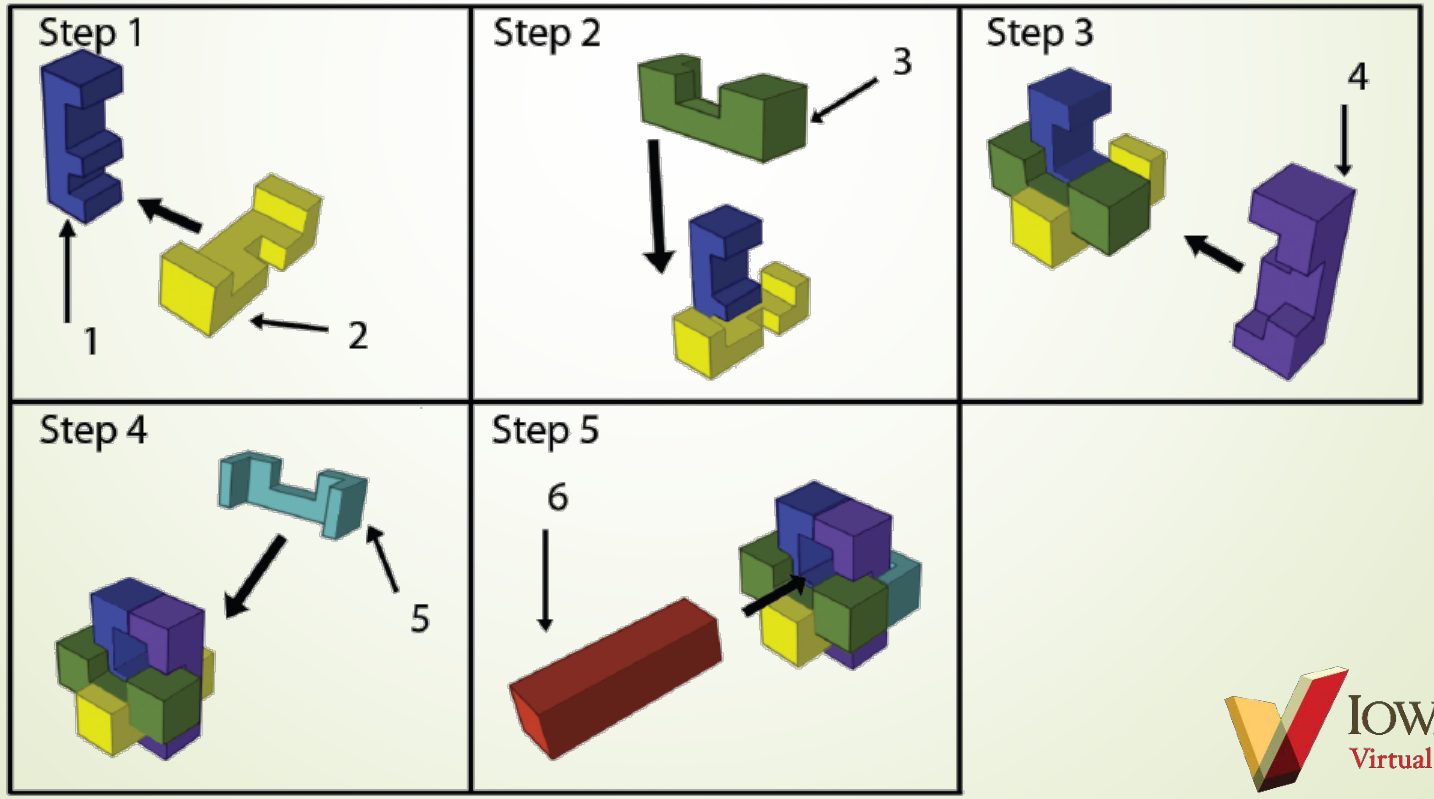



Demographic Questionnaire
Color Blindness Test
Mental Rotation Test and Questions
Equipment Video
Virtual Training
Virtual Familiarization Training Task
Virtual Puzzle Training
Physical Training
Crossword Puzzle Filler Task
Physical Puzzle Training
Mental Rotation Test Questions
Initial Test: Color-Wood
Physical Colored Puzzle Test
Physical Woodgrain Puzzle Test
Initial Test: Wood-Color
Physical Woodgrain Puzzle Test
Physical Colored Puzzle Test
Exit Survey
2-Week Waiting Period
Retention-Test

The puzzle is made of these six pieces:



Solution



Study Variables

Independent Variables

Independent Variable	Classification	Group
Training Condition	Between	Physical, Virtual
Color Order	Between	Color First, Wood First
Test Order	Within	Initial Test, Retention Test

Participants and Conditions

- 63 participants (22 female, 41 male)

	Color First Testing	Wood First Testing
Physical Training	Female: 4, Male: 13	Female: 6, Male: 10
Virtual Training	Female: 6, Male: 10	Female: 6, Male: 8

Gender Differences

	Male Mean (Std. Dev.)	Female Mean (Std. Dev.)	*df*, *t*	*p*	Overall Mean (Std. Dev.)	Measurement Unit
Number of Engineering Courses Taken	2.80 (0.90)	2.95 (1.50)	$t(61) = -0.09$	0.92	2.85 (6.22)	Range: 0-30
Computer Technical Expertise	3.45 (0.10)	3.23 (0.09)	$t(60) = -1.39$	0.16	3.37 (0.60)	Likert (1=low to 5=expert)
Video Game Playing	3.18 (0.18)	1.86 (0.20)	$t(60) = -4.43$	$<.001$	2.70 (1.27)	Likert (1=never to 5=play daily)
Mental Rotation Score	12.98 (0.92)	10.77 (1.34)	$t(61) = -1.38$	0.17	12.21 (6.09)	Score Range: 0-20 (low-high)

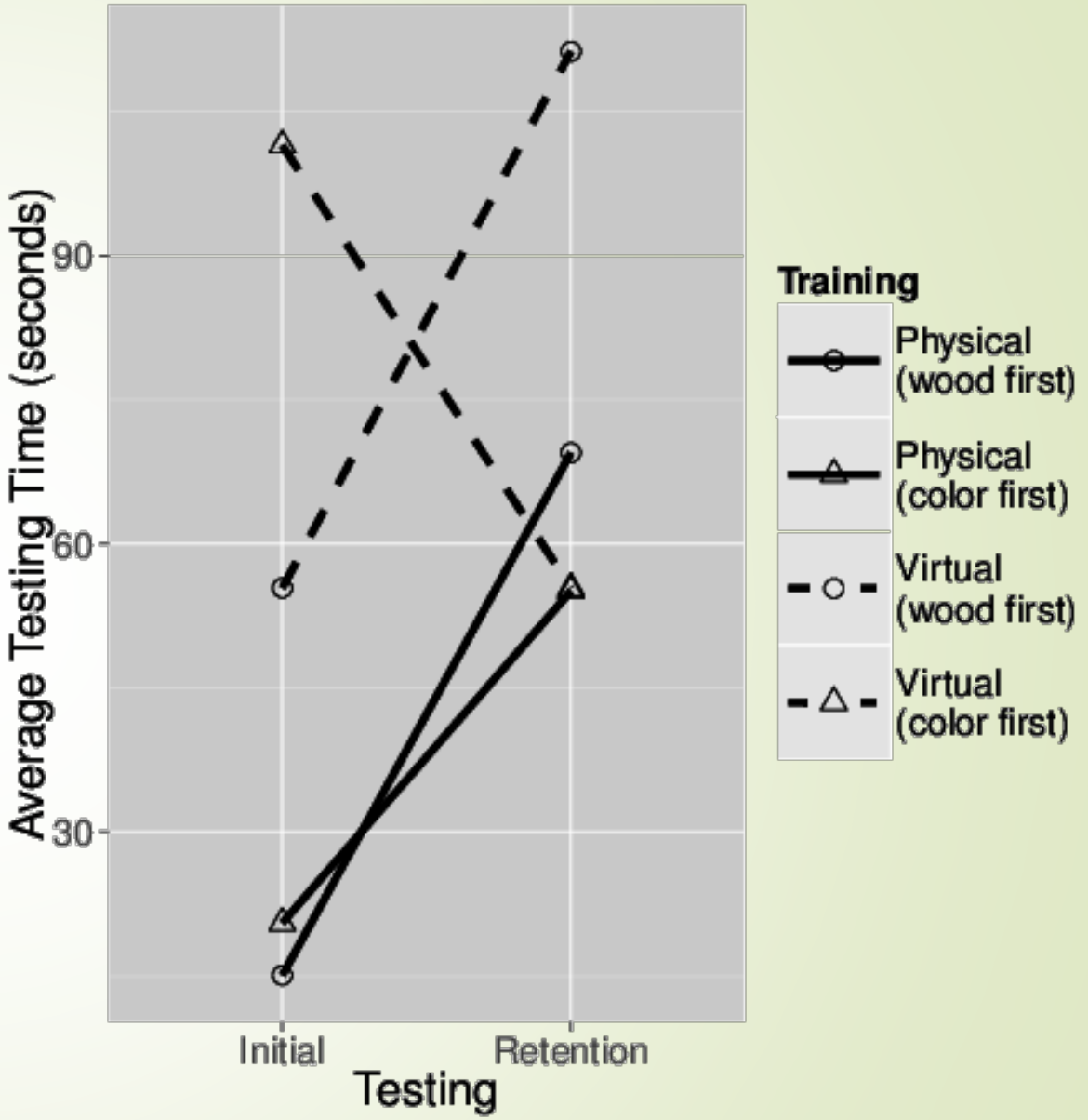
Findings

- Initial test: Physical training outperformed virtual training
- Retention test: The virtually trained participants who trained with color first actually improved their assembly times considerably, while all other groups took longer than their initial test times

Results

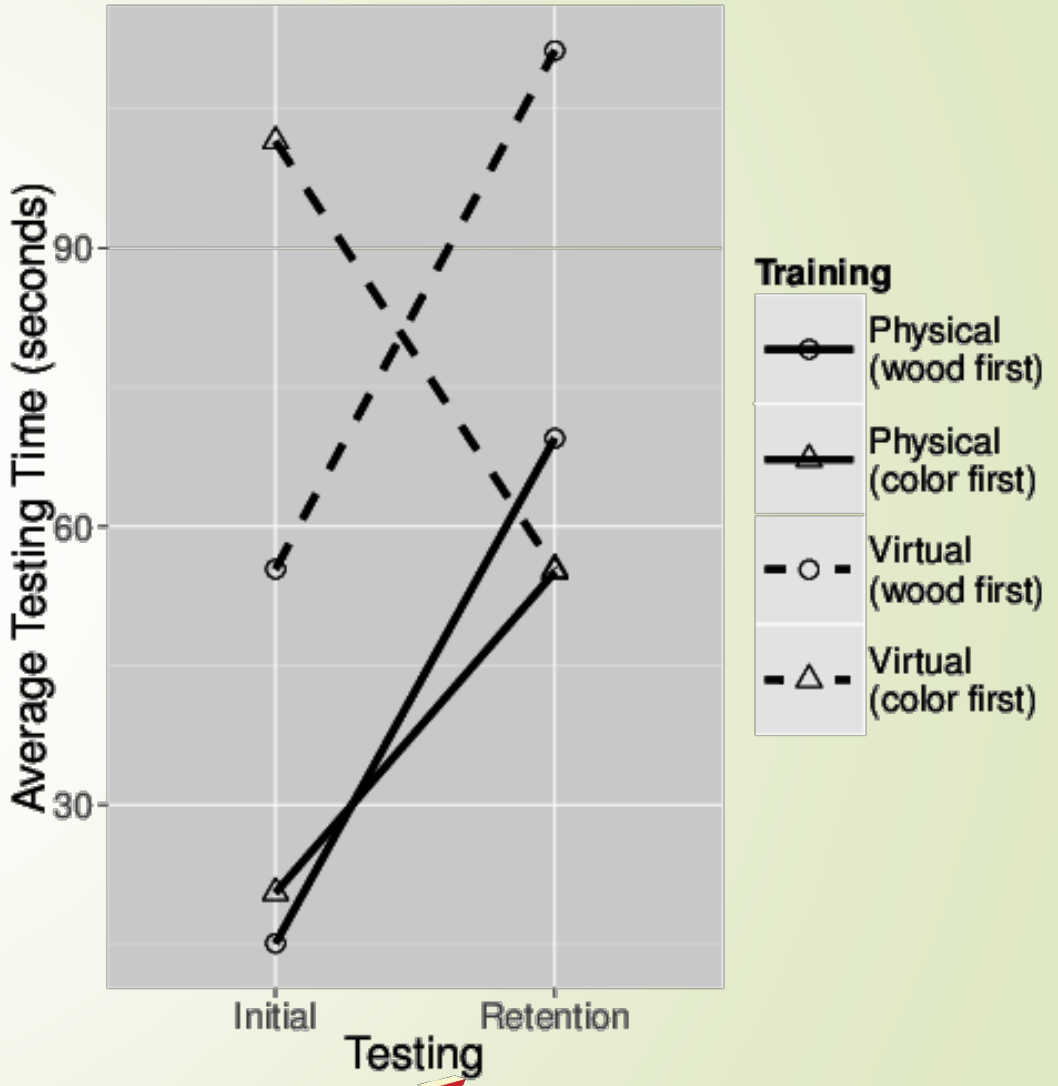
- A significant three-way interaction exists between the three independent variables on the dependent variable of time

$t(28) = 2.26$, $p = 0.03$



Two-way Interactions (Training Environments)

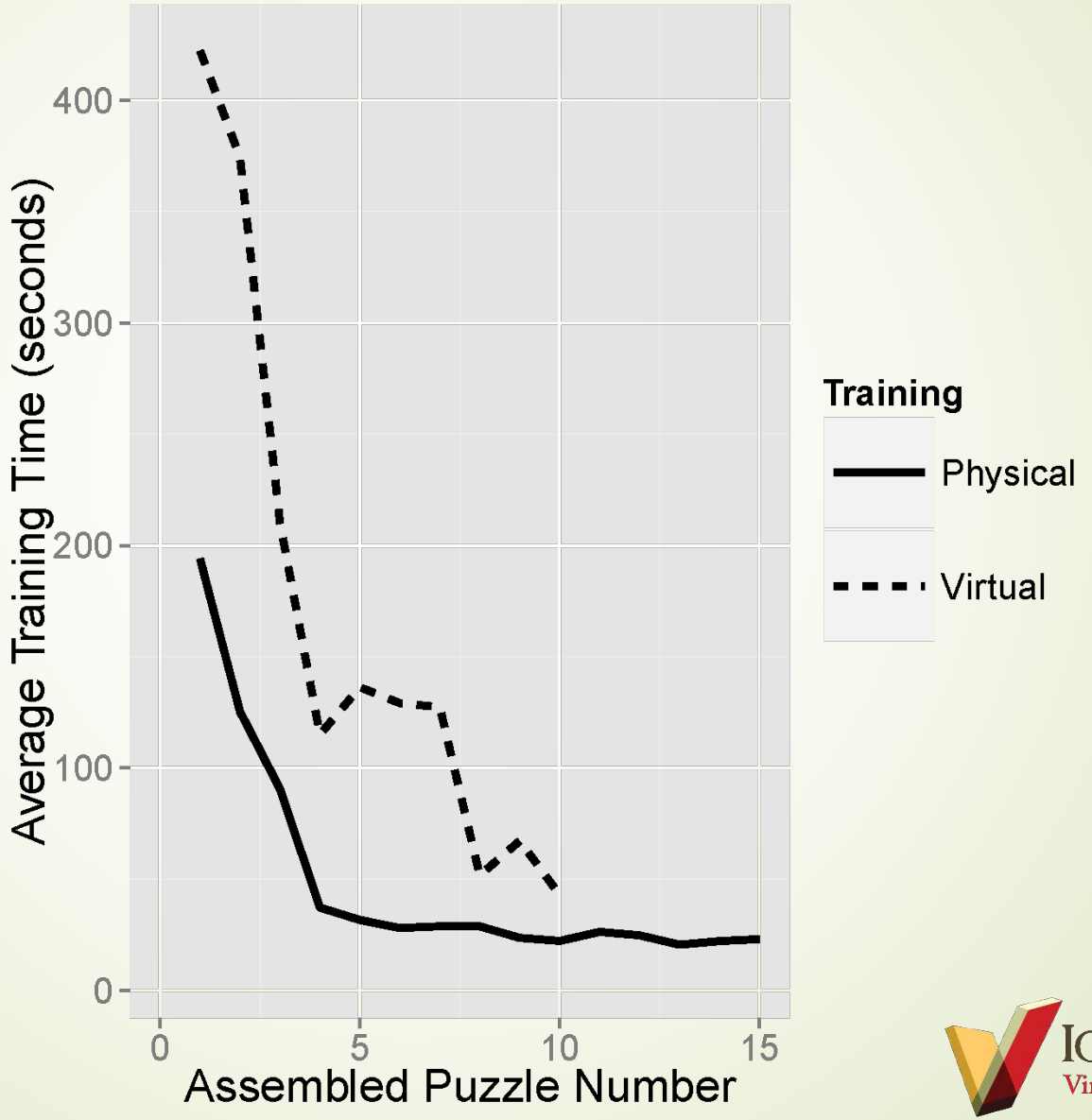
- Physically trained
  - Testing session and color order not significant
- Virtually trained
  - Testing session and color order is significant



Recall Strategy (self reported)

- Physically trained: primarily shape
- Virtually trained: primarily color

Learning Curve



Strategies Employed

	Physical Training	Virtual Training	Test	p value
Comparison to Target After Training (Vandenberg and Kuse #5)	number of participants			
I always compared the options to the target figure.	16	24	χ^2 (2, N=63) = 7.29	p = 0.02
Once I found the matching puzzle piece, I compared the rest of the options to the match.	6	1		
I did a bit of both.	11	5		
Problem Solving Approach After Training (Vandenberg and Kuse #6)	number of participants			
I developed a specific approach to solve the problems.	23	9	χ^2 (2, N=63) = 13.30	p = 0.001
I tried various approaches to solve the problems.	4	16		
I did a bit of both.	6	5		

Observations – Virtual Training

- Higher cognitive load (software and hardware)
- Lack of gravity
  - Didn't require two hands
  - Pieces didn't have to fit together perfectly

Conclusion

- Training in virtual environment
  - Outperformed by physical training in initial tests
  - In retention, there were mixed results

Recommendations

- While virtual training is outperformed by physical training on initial tests, appropriate use of color cues in virtual training can make it equally effective to physical training on performance testing after time has passed.
- The learning curves produced by physical and virtual training can differ, requiring different numbers of training iterations for each mode to avoid overlearning and premature skill degradation.

Recomendations

- When designing training, it is important to consider not only the training time, but the anticipated time spet in Fitts' cognitive stage within that overall time.

Future Work

- Add snap-to-fit for virtual assembly
- Improve part grouping in virtual assembly
- Design a task that requires two hands in both environments
- Test after several longer periods to explore learning retention

Acknowledgements

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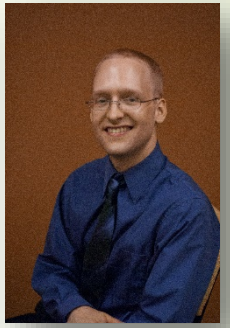

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