Visuospatial Tests Correlate with STEM Animation Learning: Perspectives to Cognitive Load Measurement?

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evidence
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Outline

- Cognitive Load and Visuospatial Abilities
- Gender and Visuospatial Abilities
- STEM and Visuospatial Abilities
- The Transient Information Effect
- Project PAI 82140021
  - Battery of 9 visuospatial tests
  - Novel Card Rotations, Corsi Tapping, Visual Patterns
- Experiment
  - Design, Hypotheses, Methods
  - Results & Conclusion

Cognitive Load and Visuospatial Abilities

- How to measure cognitive load or working memory load?(1)
- Working memory includes a visuospatial subcomponent(2)
- The subprocessor is related to spatial ability(3)

  "Skill in representing and transforming symbolic or nonlinguistic information through space."(4)

(1) Kirschner, P. A., Ayres, P., & Chandler, P. (2011). Contemporary cognitive load theory research: The good, the bad and the ugly. *Computers in Human Behavior*, *27*(1), 99-105. doi: 10.1016/j.chb.2010.06.025

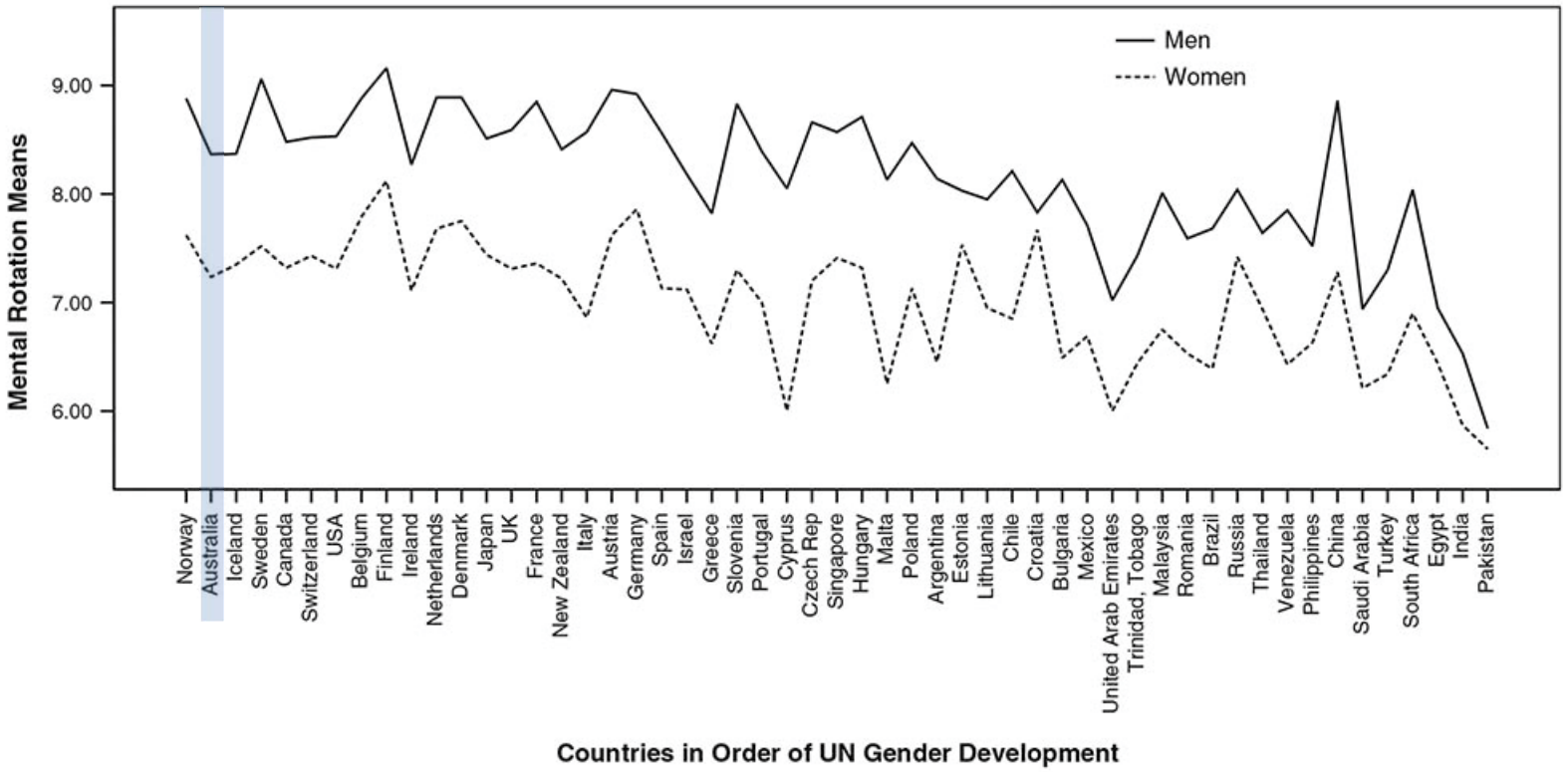
(2) Baddeley, A. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology, 63*(1), 1-29. doi: 10.1146/annurev-psych-120710-100422

(3) Salthouse, T. A., Mitchell, D. R. D., Skovronek, E., & Babcock, R. L. (1989). Effects of adult age and working memory on reasoning and spatial abilities. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*(3), 507-516. doi: 10.1037/0278-7393.15.3.507

(4) Terlecki, M. S., & Newcombe, N. S. (2005). How important is the digital divide? The relation of computer and videogame usage to gender differences in mental rotation ability. *Sex Roles*, *53*(5-6), 433-441. doi: 10.1007/s11199-005-6765-0

Gender and Visuospatial Abilities

- 53 countries (*N* > 200.000, 2010)[(1)]



(1) Lippa, R. A., Collaer, M. L., & Peters, M. (2010). Sex differences in mental rotation and line angle judgments are positively associated with gender equality and economic development across 53 nations. *Archives of Sexual Behavior*, *39*(4), 990-997. doi: 10.1007/s10508-008-9460-8

STEM and Visuospatial Abilities

- STEM learning is aided by spatial ability[(1)]
- Mental rotation

  Canada (*N* > 600, 1995): STEM students (biology, physics, and engineering) > non-STEM students (arts, social sciences, and humanities)[(2)]

(1) Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, *101*(4), 817-835. doi: 10.1037/a0016127

(2) Peters, M., Laeng, B., Latham, K., Jackson, M., Zaiyouna, R., & Richardson, C. (1995). A redrawn Vandenberg and Kuse Mental Rotations Test: Different versions and factors that affect performance. *Brain and Cognition*, *28*(1), 39-58. doi: 10.1006/brcg.1995.1032

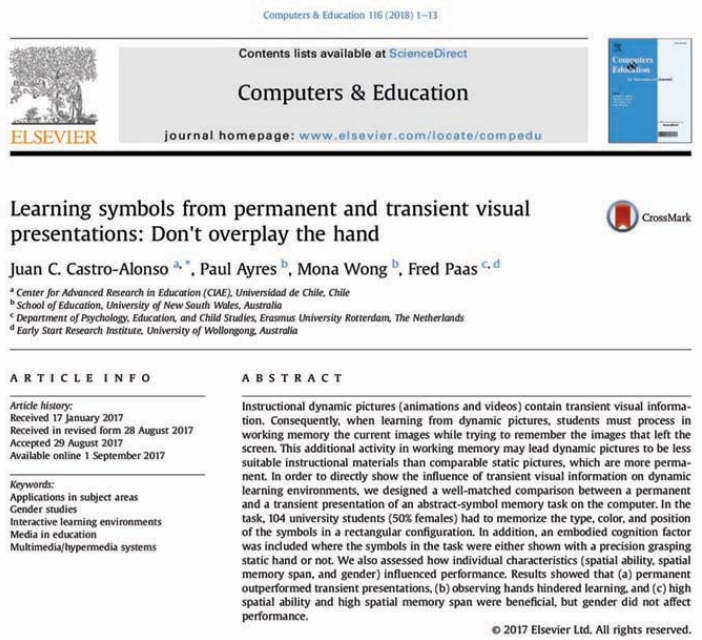
The Transient Information Effect

- Three Demanding Tasks for Working Memory[1,2]

  Process the current visible information

  Remember the previous elements (no longer visible)

  Integrate both streams of information in order to comprehend the material



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Learning symbols from permanent and transient visual presentations: Don't overplay the hand

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ABSTRACT

Instructional dynamic pictures (animations and videos) contain transient visual information. Consequently, when learning from dynamic pictures, students must process in working memory the current images while trying to remember the images that left the screen. This additional activity in working memory may lead dynamic pictures to be less suitable instructional materials than comparable static pictures, which are more permanent. In order to directly show the influence of transient visual information on dynamic learning environments, we designed a well-matched comparison between a permanent and a transient presentation of an abstract-symbol memory task on the computer. In the task, 104 university students (50% females) had to memorize the type, color, and position of the symbols in a rectangular configuration. In addition, an embodied cognition factor was included where the symbols in the task were either shown with a precision grasping static hand or not. We also assessed how individual characteristics (spatial ability, spatial memory span, and gender) influenced performance. Results showed that (a) permanent outperformed transient presentations, (b) observing hands hindered learning, and (c) high spatial ability and high spatial memory span were beneficial, but gender did not affect performance.

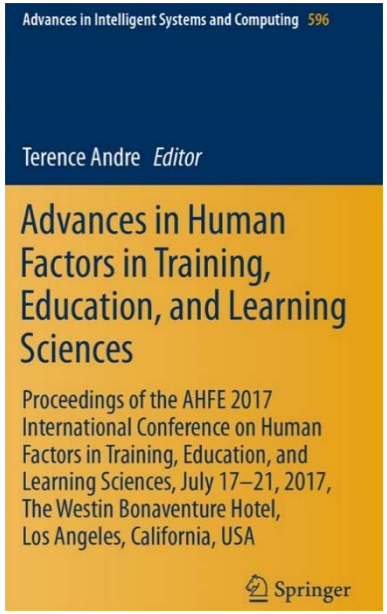
(1) Ayres, P., & Paas, F. (2007). Making instructional animations more effective: A cognitive load approach. *Applied Cognitive Psychology*, *21*(6), 695-700

(2) Lowe, R. K. (1999). Extracting information from an animation during complex visual learning. *European Journal of Psychology of Education*, *14*(2), 225-244. doi: 10.1007/BF03172967

(3) Castro-Alonso, J. C., Ayres, P., Wong, M., & Paas, F. (2018). Learning symbols from permanent and transient visual presentations: Don't overplay the hand. *Computers & Education*, *116*, 1-13. doi: 10.1016/j.compedu.2017.08.011

PAI 82140021 Project

- Battery of 9 computer instruments



Computerized and Adaptable Tests to Measure Visuospatial Abilities in STEM Students

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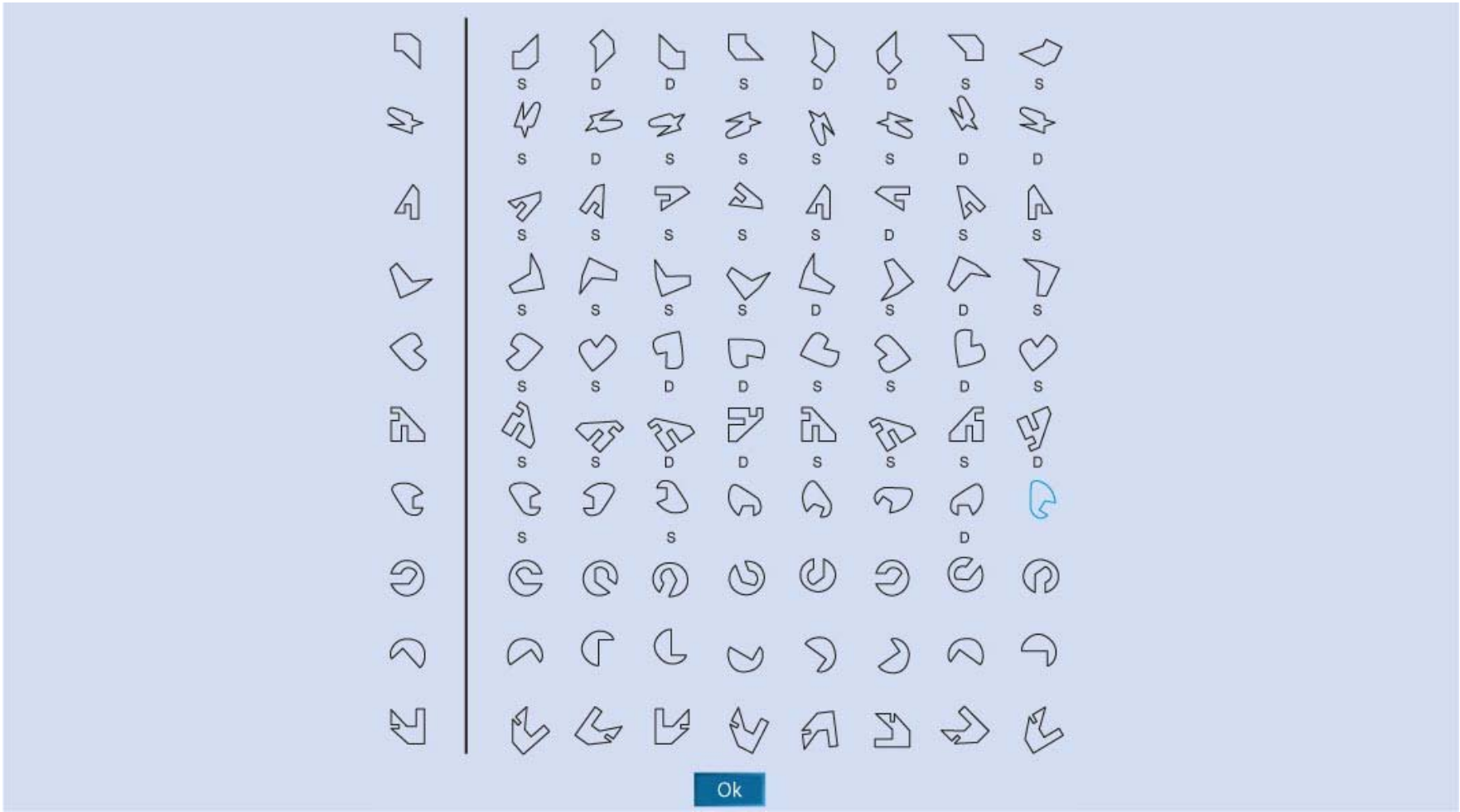
Abstract. Performance in Science, Technology, Engineering, and Mathematics (STEM) disciplines can depend on the sub-abilities of spatial ability and visuospatial working memory. According to the STEM task, certain sub-abilities may be more important than others in predicting achievement. Similarly, some individual characteristics (e.g., gender) moderate some of these sub-abilities. For example, males on average have higher mental rotation spatial ability than females, whereas spatial working memory tends to be less prone to gender effects. In addition, the results of the tests measuring these sub-abilities can be changed by manipulating certain variables. We present a battery of nine computerized and adaptable instruments to measure these sub-abilities, with the aim of informing cognitive researchers about the processing abilities most vital for undertaking STEM tasks, and how they can be modified to suit learner characteristics.

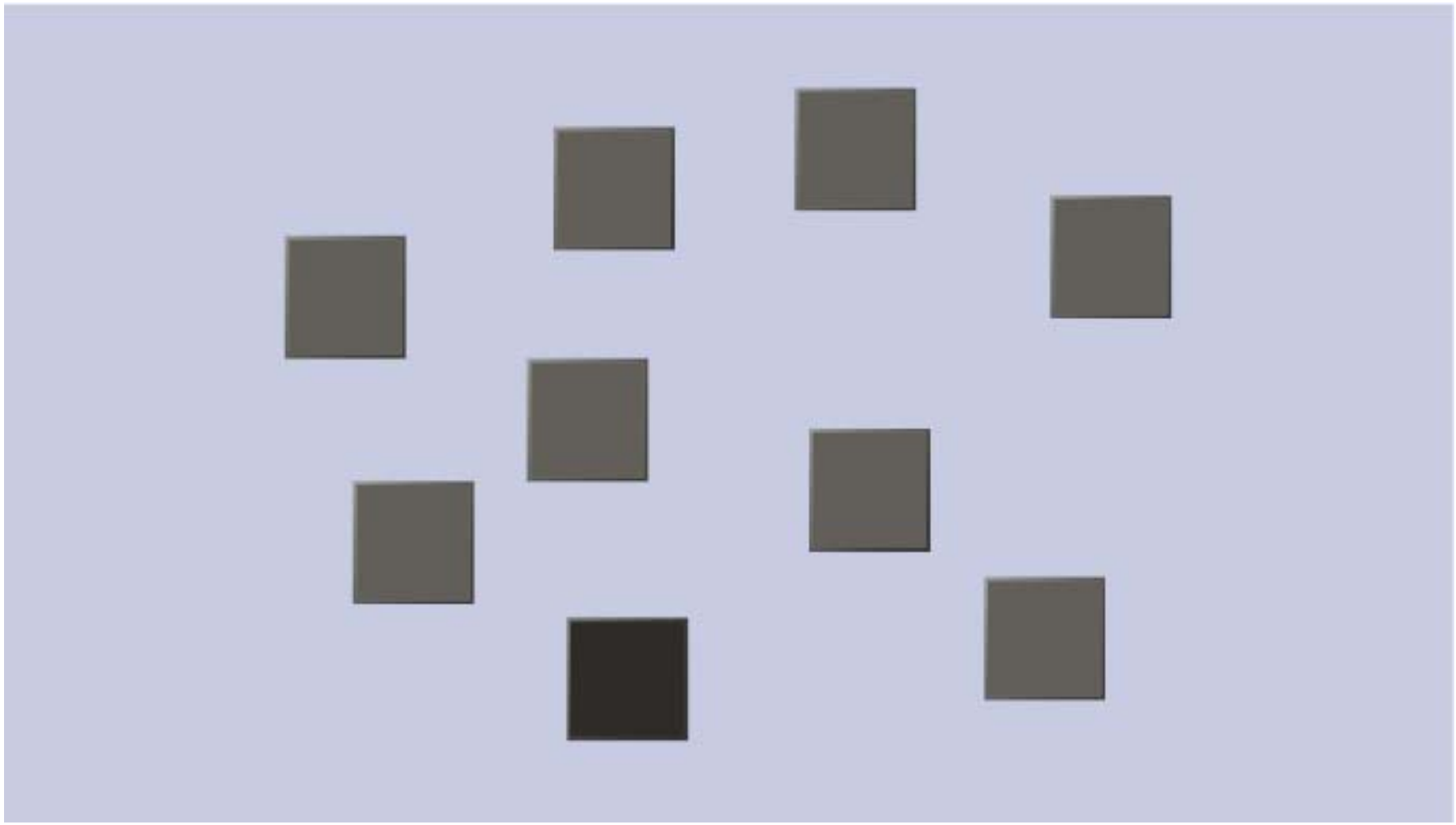
Keywords: Spatial ability · Visuospatial working memory · STEM · Gender · Computer-adapted test

Castro-Alonso, J. C., Ayres, P., & Paas, F. (2018). Computerized and adaptable tests to measure visuospatial abilities in STEM students. In T. Andre (Ed.), *Advances in Human Factors in Training, Education, and Learning Sciences: Proceedings of the AHFE 2017 International Conference on Human Factors in Training, Education, and Learning Sciences* (pp. 337-349). Cham, Switzerland: Springer. doi: 10.1007/978-3-319-60018-5_33

1 - Novel Card Rotations Test



2 - Corsi Tapping Test(1)

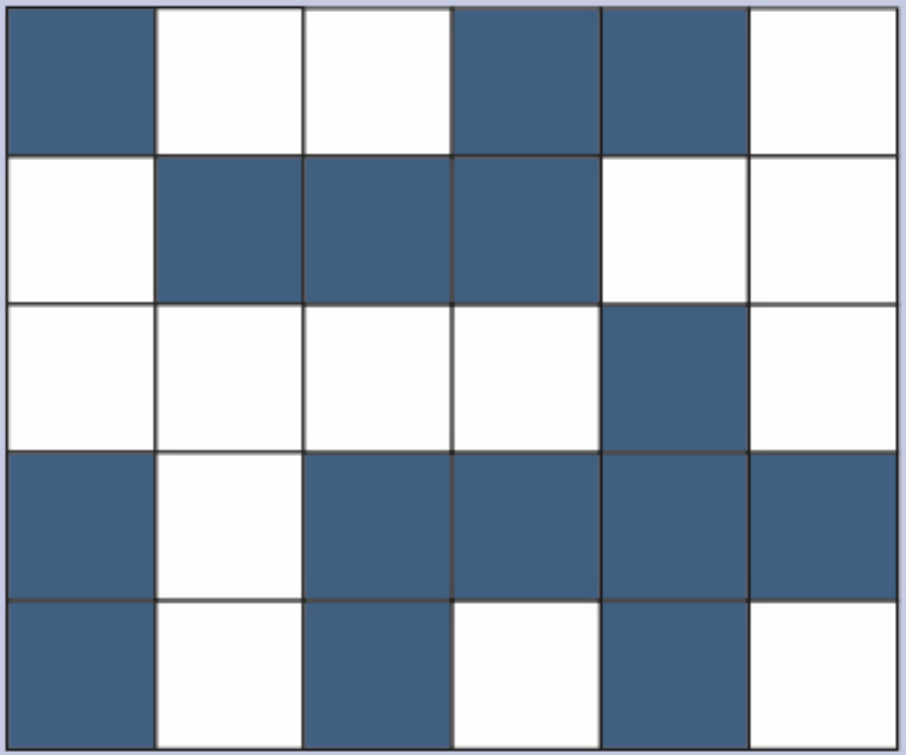


(1) Milner, B. (1971). Interhemispheric differences in the localization of psychological processes in man. *British Medical Bulletin*, *27*(3), 272-277.

Corsi Tapping Test

- Other variables
  - Backward test
  - Block positions
  - Block color
  - Display time
  - Sequences
  - Language
  - Instructions
  - Practices

3 - Visual Patterns Test(1)



(1) Della Sala, S., Gray, C., Baddeley, A., Allamano, N., & Wilson, L. (1999). Pattern span: A tool for unwelding visuo–spatial memory. *Neuropsychologia*, *37*(10), 1189-1199. doi: 10.1016/S0028-3932(98)00159-6

Experiment

- Mixed Design

  Within-subjects:

  3 tests (Novel CRT, Corsi, VPT)

  + STEM task (vinification)

Between-subjects:

Male	Pause
	No Pause
Female	Pause
	No Pause

Hypotheses

- H1: Males > Females in the 3 Tests + STEM task
- H2: Positive correlations between the STEM task and the 3 Tests
- H3: For the STEM task, Pause > No Pause

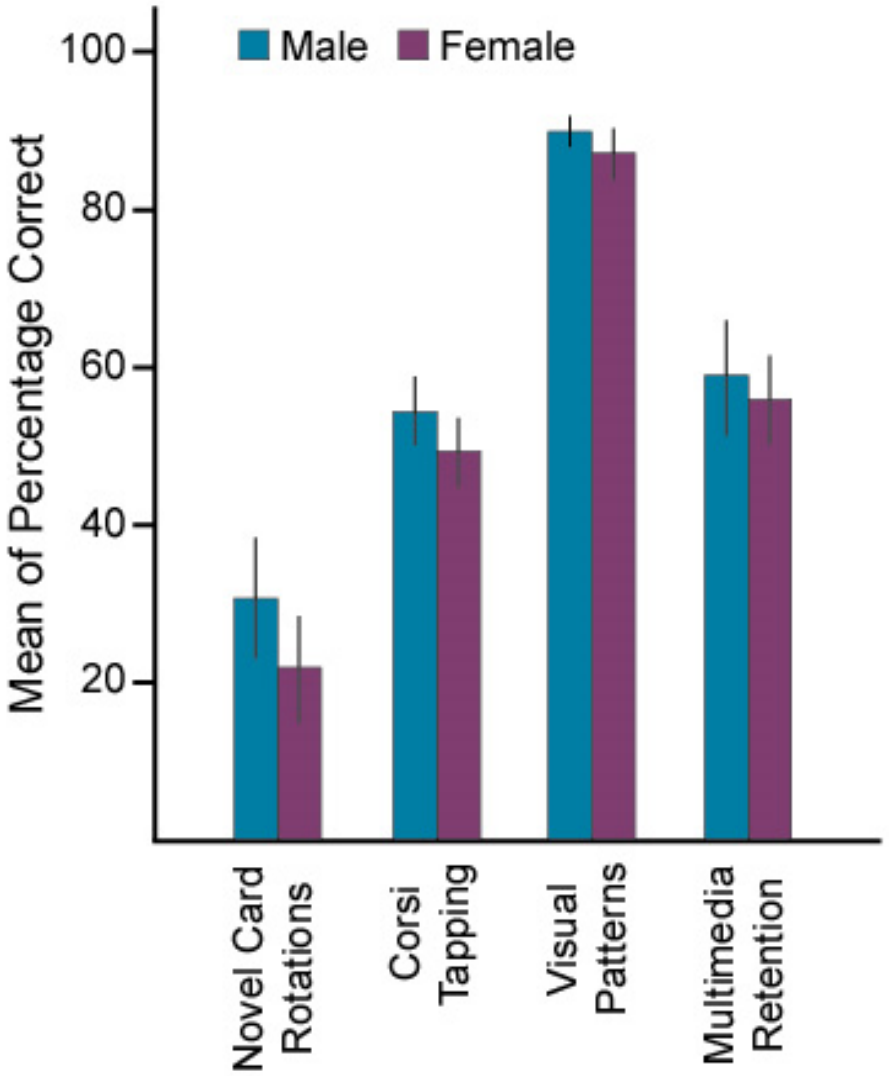
Methods

- 80 Chilean STEM technical students (50% W, *M* = 21.43 years)
- Not all did backward Corsi, so *N* = 75:

  18 Male/Pause, 19 Male/No Pause, 20 Females/Pause, 18 Females/No Pause
- Order:
  1. Novel Card Rotations Test
  2. Corsi Tapping Test
  3. Visual Patterns Test
  4. Animation (Pause vs No Pause)
  5. Multimedia Retention Test

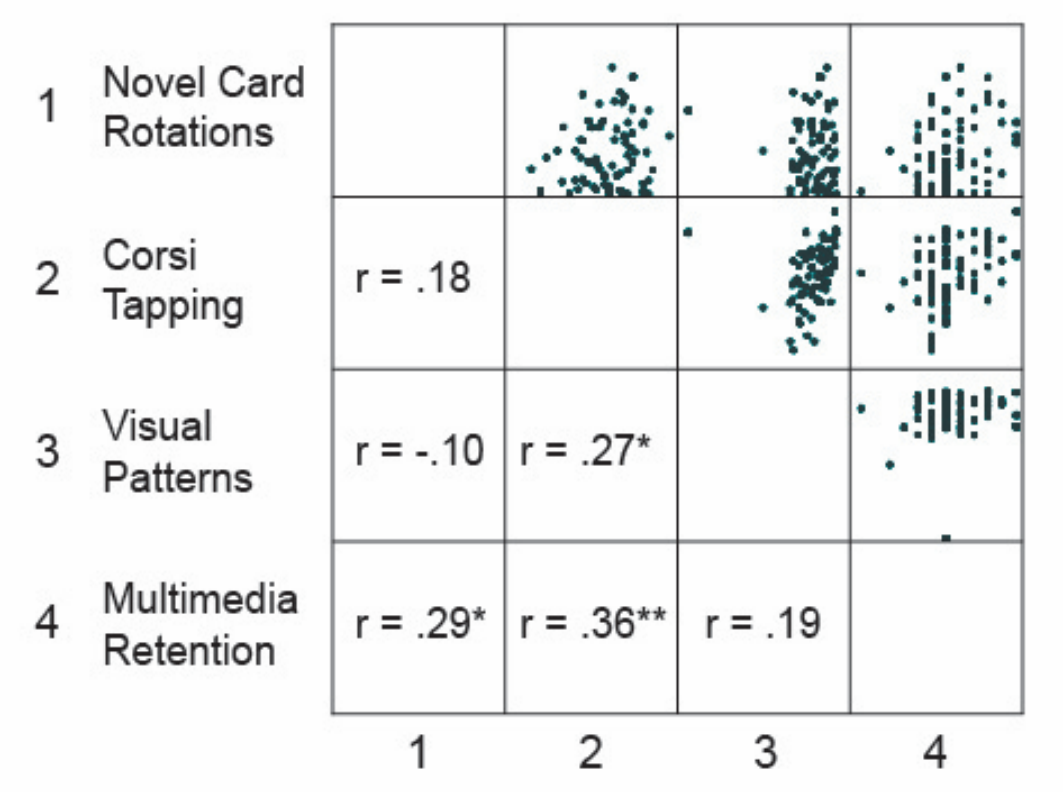
Results

- Within-subjects
  - $F = 218.15$, $p < .001$, $\eta_P^2 = .75$
- Between-subjects
  - $F = 4.43$, $p = .039$, $\eta_P^2 = .06$
  - Males $M = 58.16$ [54.85–61.46]
  - Females $M = 53.25$ [49.99–56.52]



Results

- Correlations



Conclusion

- In order of difficulty:
  Visual Patterns Test < Retention Test = Corsi Tapping Test < Novel Card Rotations Test
- H1: Males would show higher scores than females in the four tasks ✓✗
  Overall male advantage, but not for individual tasks
- H2: The scores in the three visuospatial tests would be positively correlated with the scores in the retention test ✓✗
  Visual Patterns Test did not correlate with the Multimedia Retention Test
- H3: The pause animation condition would show higher scores in the retention test than the no pause condition ✗

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