Northern Illinois University

A 2x2 Study of Spatial Feedback to Improve Topographic Map Skill Using The Augmented Reality (AR) Sandbox

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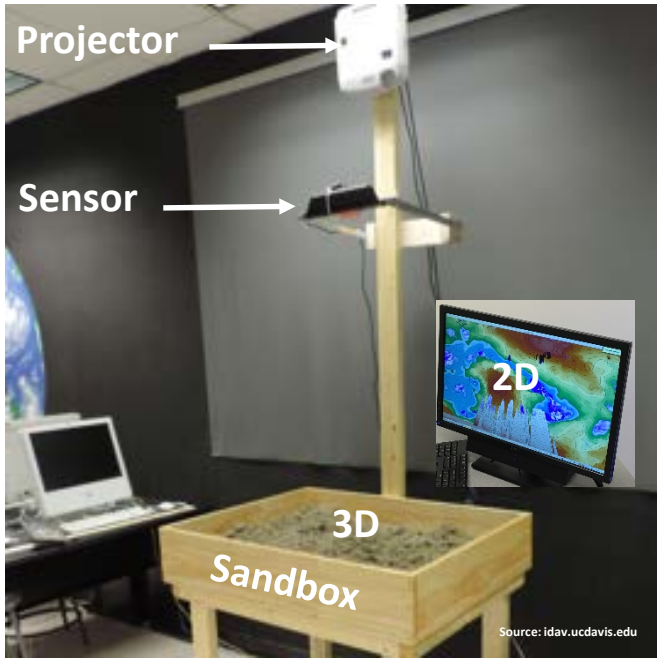
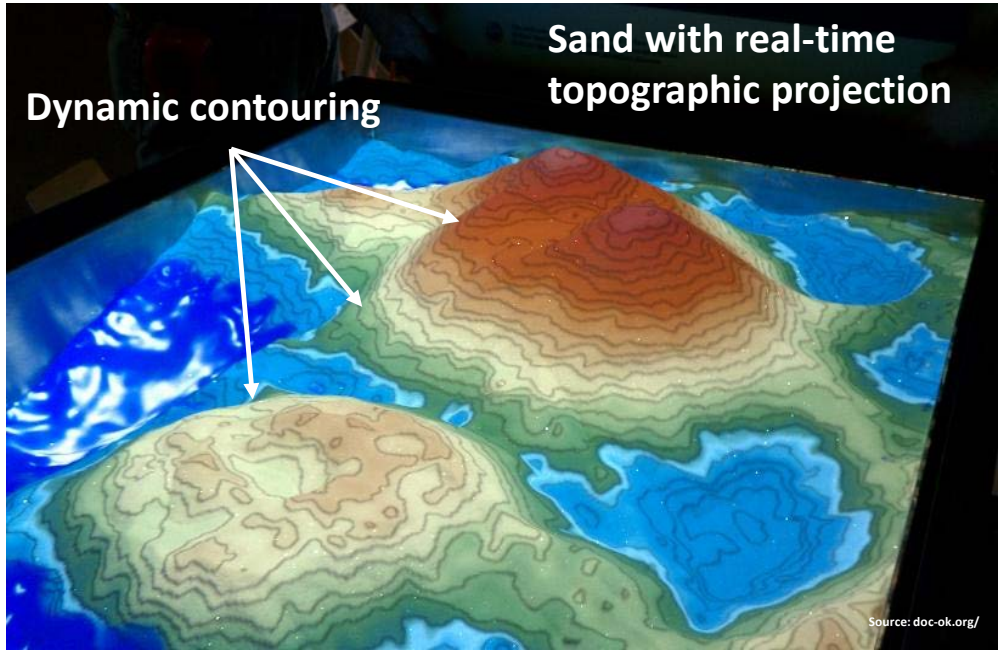
Introduction: AR Sandbox & Current Findings

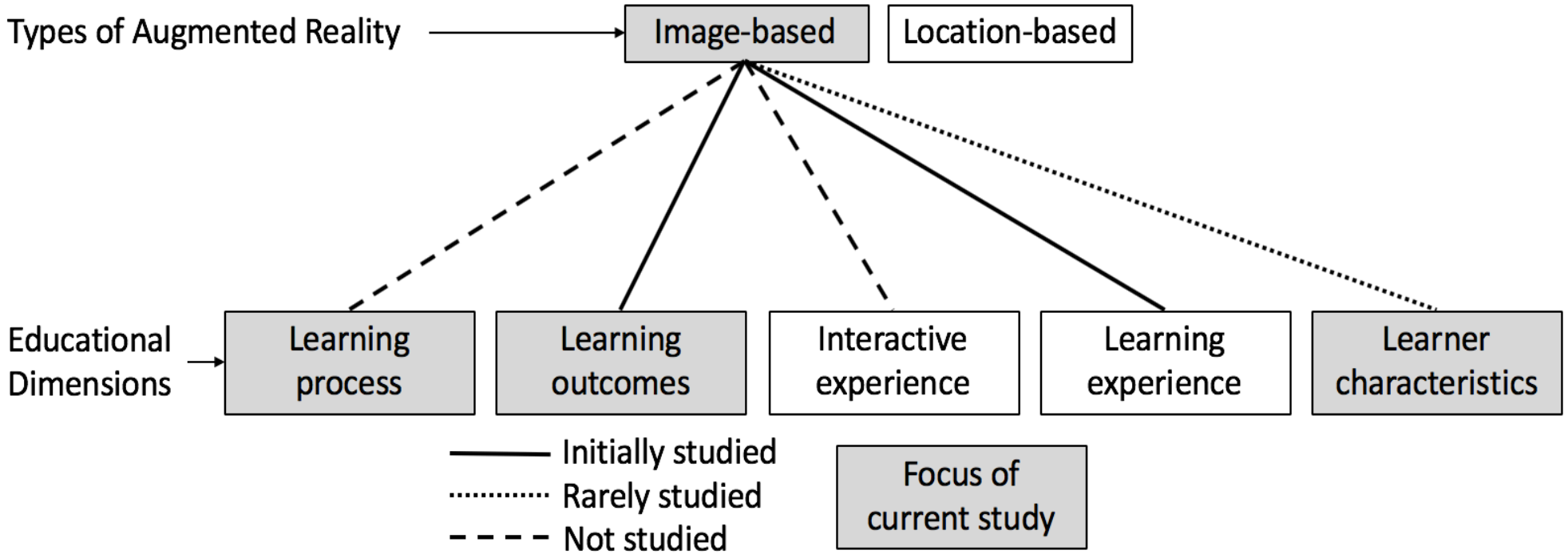




- Classroom studies: no significant learning gains[1,2], high engagement[1,4]
  - Free play[3], group[4] and instructor-led[4] activities in group settings

Giorgis et al., 2017[1], Ryker et al., 2017[2], Ryker et al., 2016[3], Woods et al., 2016[4]

Present Study

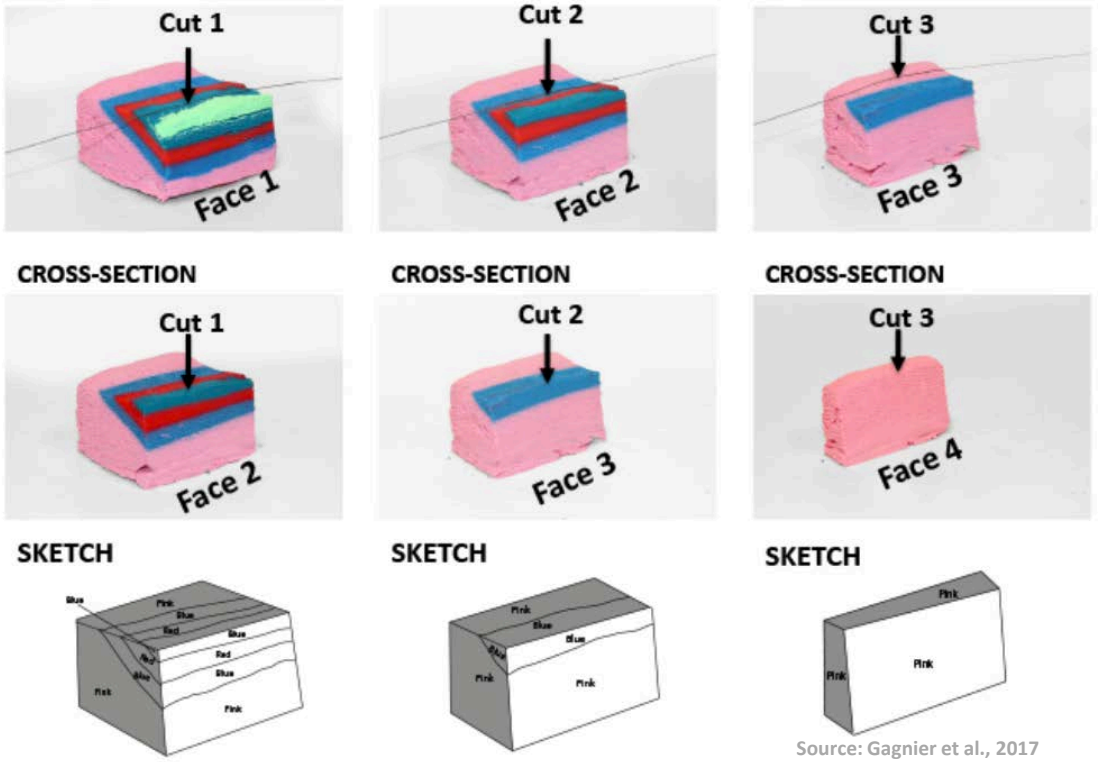


Modified from Cheng and Tsai (2013)

- Learning Process: Spatial Feedback
- Learning Outcomes: Topographic Map Assessment
- Learner Characteristics: Spatial Skill

Spatial Feedback

- Create and revise mental representations of a concept[1]
- Predict, externalize, and receive feedback[1]
    - Sketching 3D diagrams[2]



Source: Gagnier et al., 2017

Chi, 2008[1], Gagnier et al., 2017[2]

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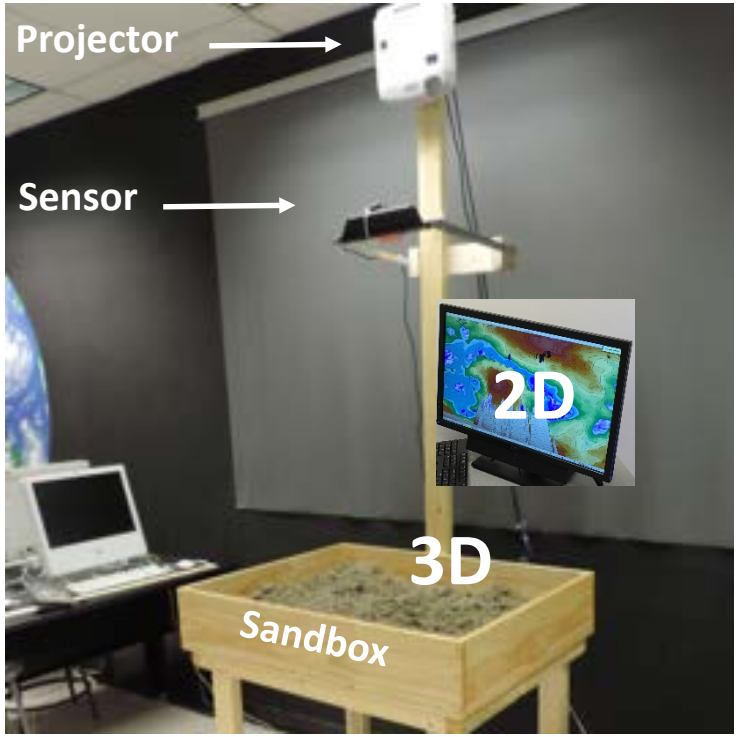


Chi, 2008[1], Gagnier et al., 2017[2]

Research Questions

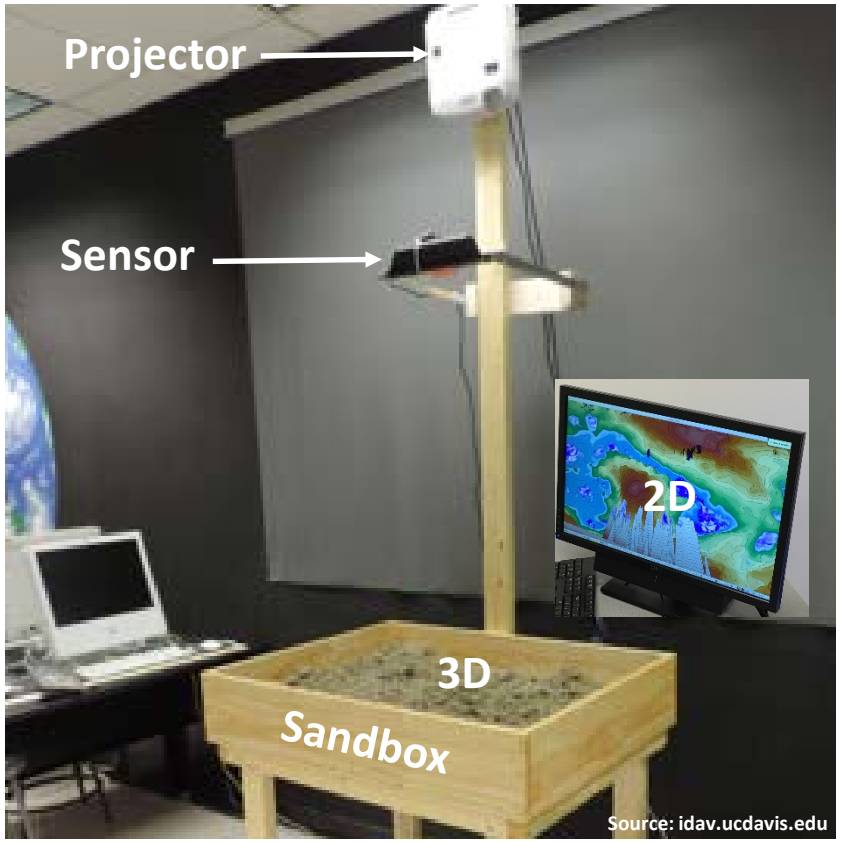
1. Does spatial feedback using the AR Sandbox improve topographic map skill?

2. Does 2D or 3D feedback lead to greater gains?

3. Which feedback condition is favorable for practical classroom application?

Methods: Study Design

- Laboratory setting
- 1 on 1 structured intervention, student-led
- Modeling with feedback and correction
- Feedback condition (IV)
- Pre- and post-assessment (DV)



2 x 2 Study Design

- Four feedback conditions in the 2x2:
  - 2D vs. 3D groups
  - Continuous vs. Discrete groups

Dimensionality of Feedback	Continuity of Feedback During Landform Adjustments: On	Continuity of Feedback During Landform Adjustments: Off
Projector	3D Continuous	3D Discrete
Monitor	2D Continuous	2D Discrete

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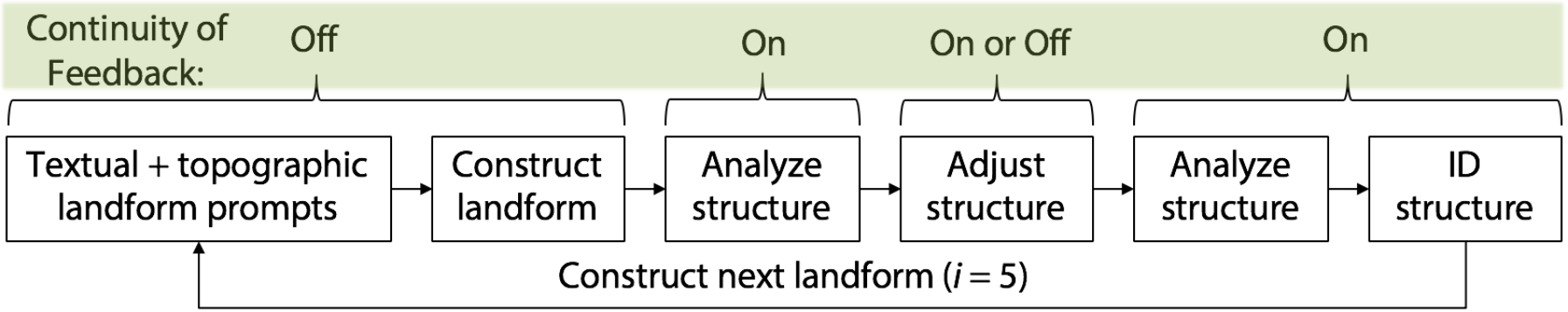

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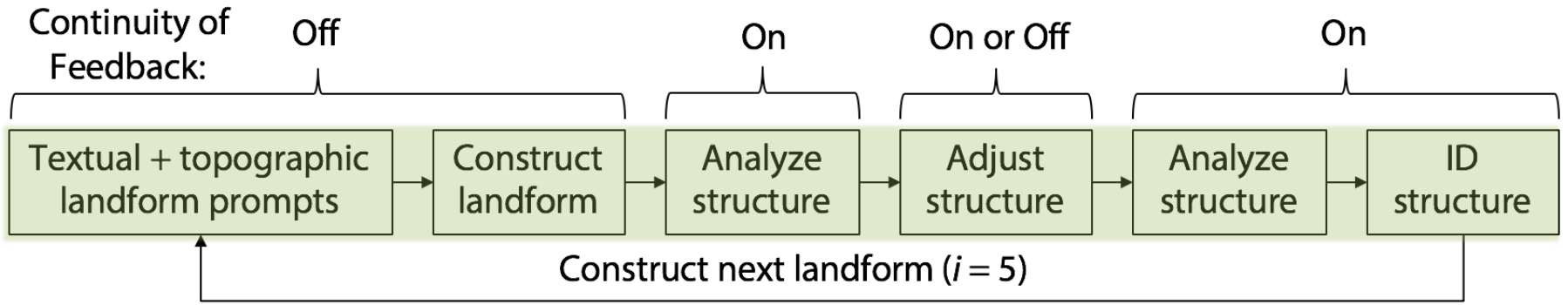

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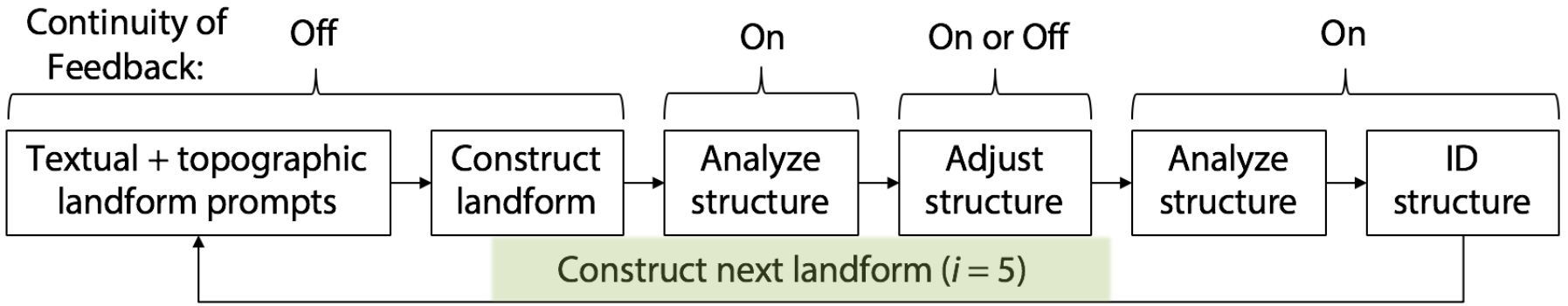
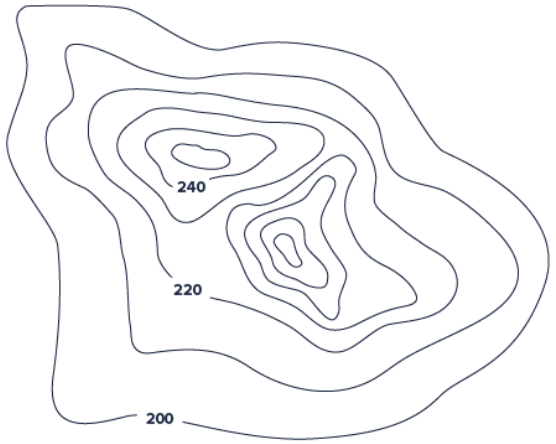


Methods: Participants

- NIU Internal Review Board (IRB) approved (#HS17-0362)
- NIU undergraduates, campus-wide
- Recruited low topographic map skill
  - Eligibility Survey via Qualtrics
- Stipend for 90 minutes ($20)



Source: Ferdio, 2017

Sample Sizes

	Continuous	Discrete	Total
3D	20	20	40
2D	20	18	38
Total	40	38	78

Demographics

	Value
Age, mean (*SD*)	20.4 ± 1.8
Sex	
Male	43 (42%)
Female	57 (56%)
Not Available	2 (3%)
Education Level	
Undergraduate	99 (97%)
Graduate	3 (3%)

Methods: Instruments

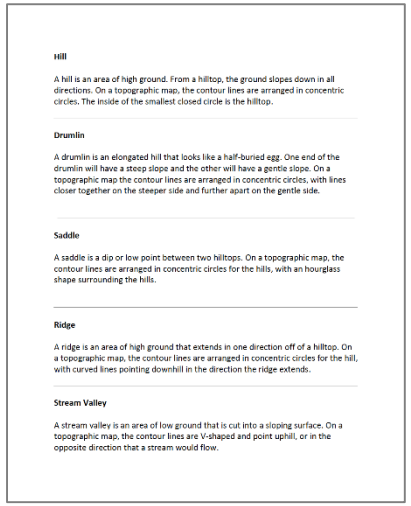
Instrument

- Pre- and Post- topographic map assessment: TMA-B[1]

Procedures

- Topographic map training[2]
- Think aloud training
- Landform prompts: text + map

Landform Prompts



Hill

A hill is an area of high ground. From a hilltop, the ground slopes down in all directions. On a topographic map, the contour lines are arranged in concentric circles. The inside of the smallest closed circle is the hilltop.

Drumlin

A drumlin is an elongated hill that looks like a half-buried egg. One end of the drumlin will have a steep slope and the other will have a gentle slope. On a topographic map the contour lines are arranged in concentric circles, with lines closer together on the steeper side and further apart on the gentle side.

Saddle

A saddle is a dip or low point between two hilltops. On a topographic map, the contour lines are arranged in concentric circles for the hills, with an hourglass shape surrounding the hills.

Ridge

A ridge is an area of high ground that extends in one direction off of a hilltop. On a topographic map, the contour lines are arranged in concentric circles for the hill, with curved lines pointing downhill in the direction the ridge extends.

Stream Valley

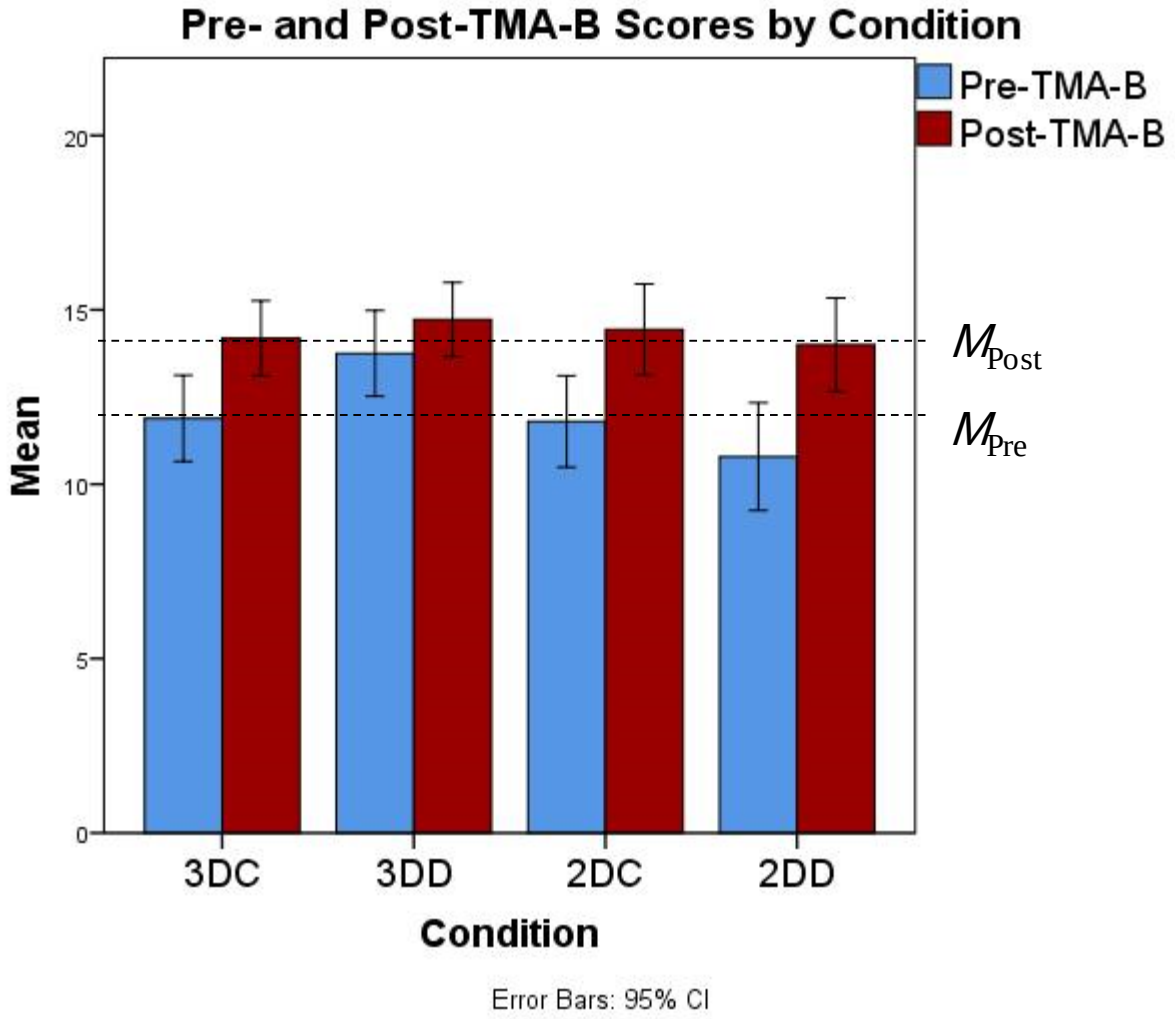
A stream valley is an area of low ground that is cut into a sloping surface. On a topographic map, the contour lines are V-shaped and point uphill, or in the opposite direction that a stream would flow.

+

Jacovina et al., 2014[1], Atit et al., 2015[2]

Results: Pre- to Post-TMA-B Improvement

- TMA-B scores increased pre to post
  - M_{Pre} = 12.1, SD = 2.9
  - M_{Post} = 14.4 , SD = 2.5



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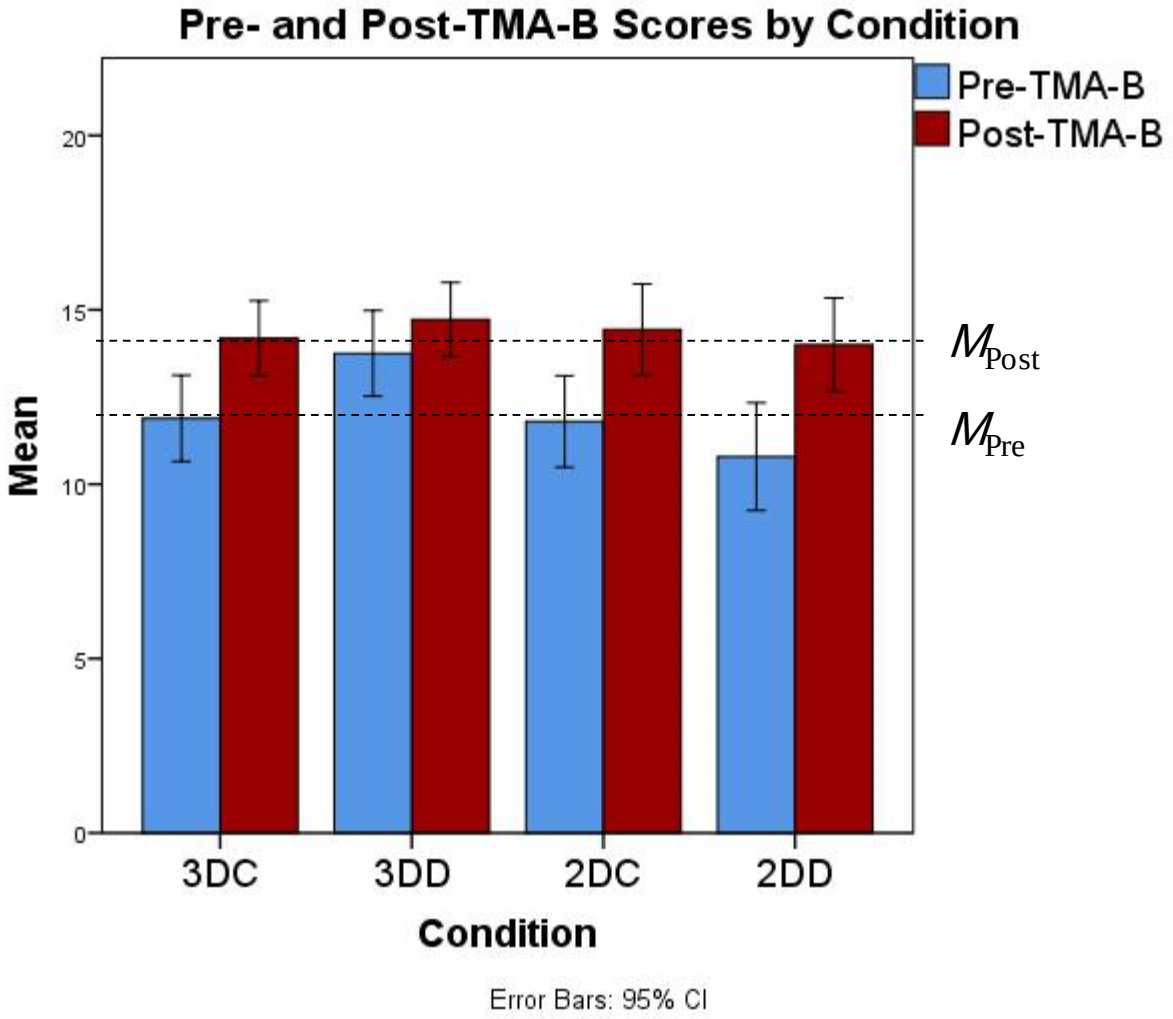
  - $F(1, 74) = 80.34, p < .001$



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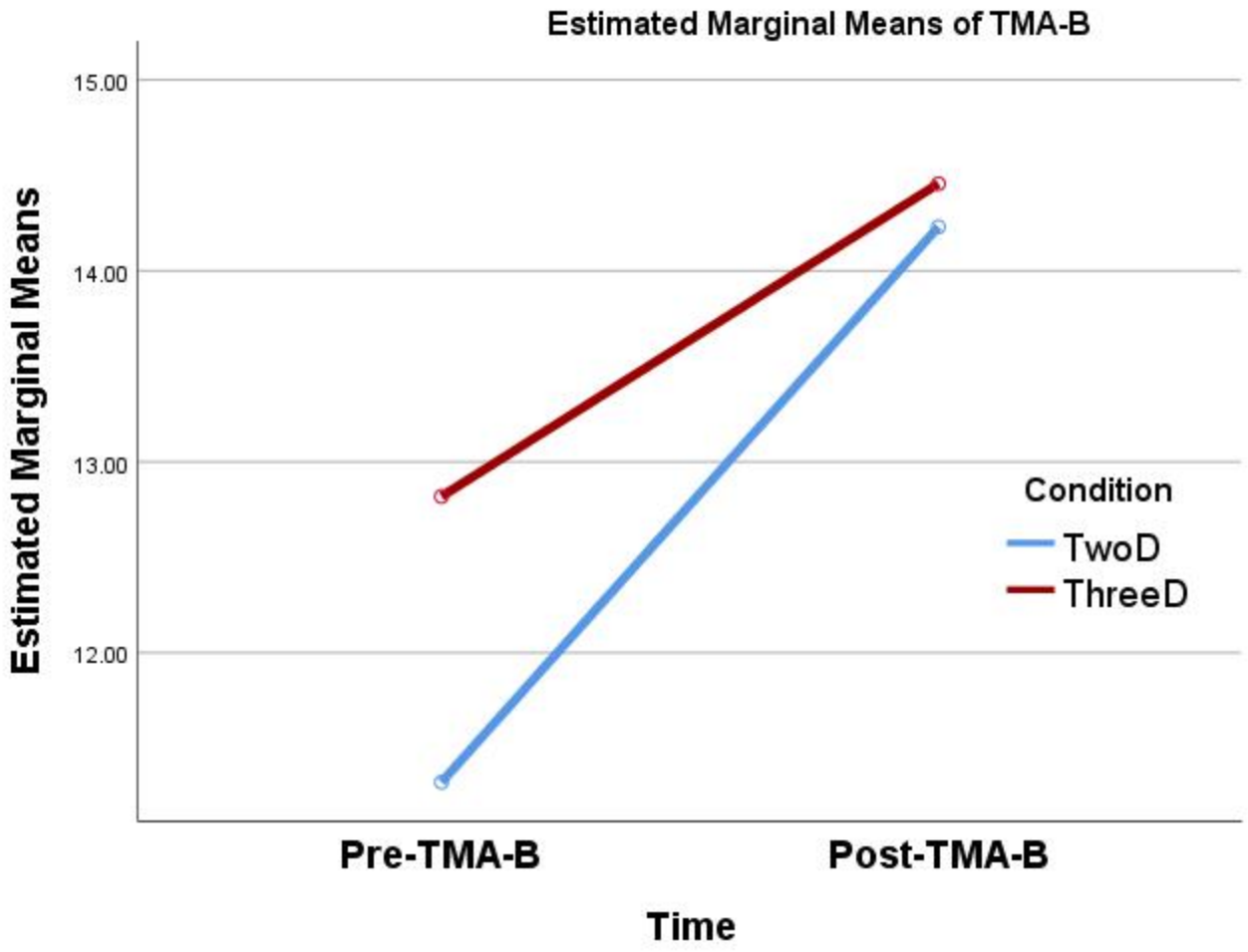
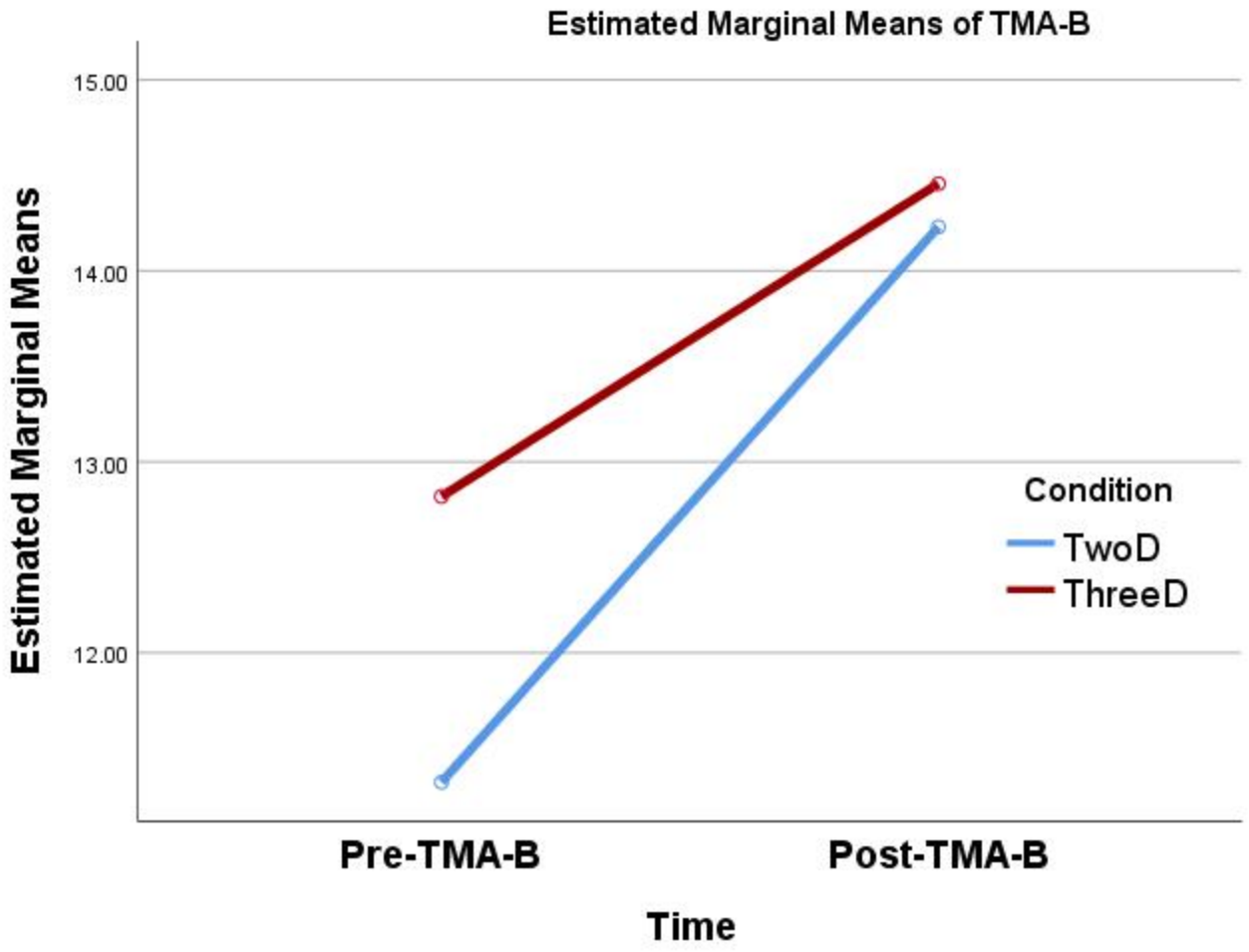
- Significant interaction effect:
  - $F(1, 74) = 6.38, p = .014$



Results: 2D vs. 3D Gains

- 2D had different gains than 3D
  - $M_{2D} = 2.91$, $SD = 2.48$
  - $M_{3D} = 1.64$, $SD = 2.07$



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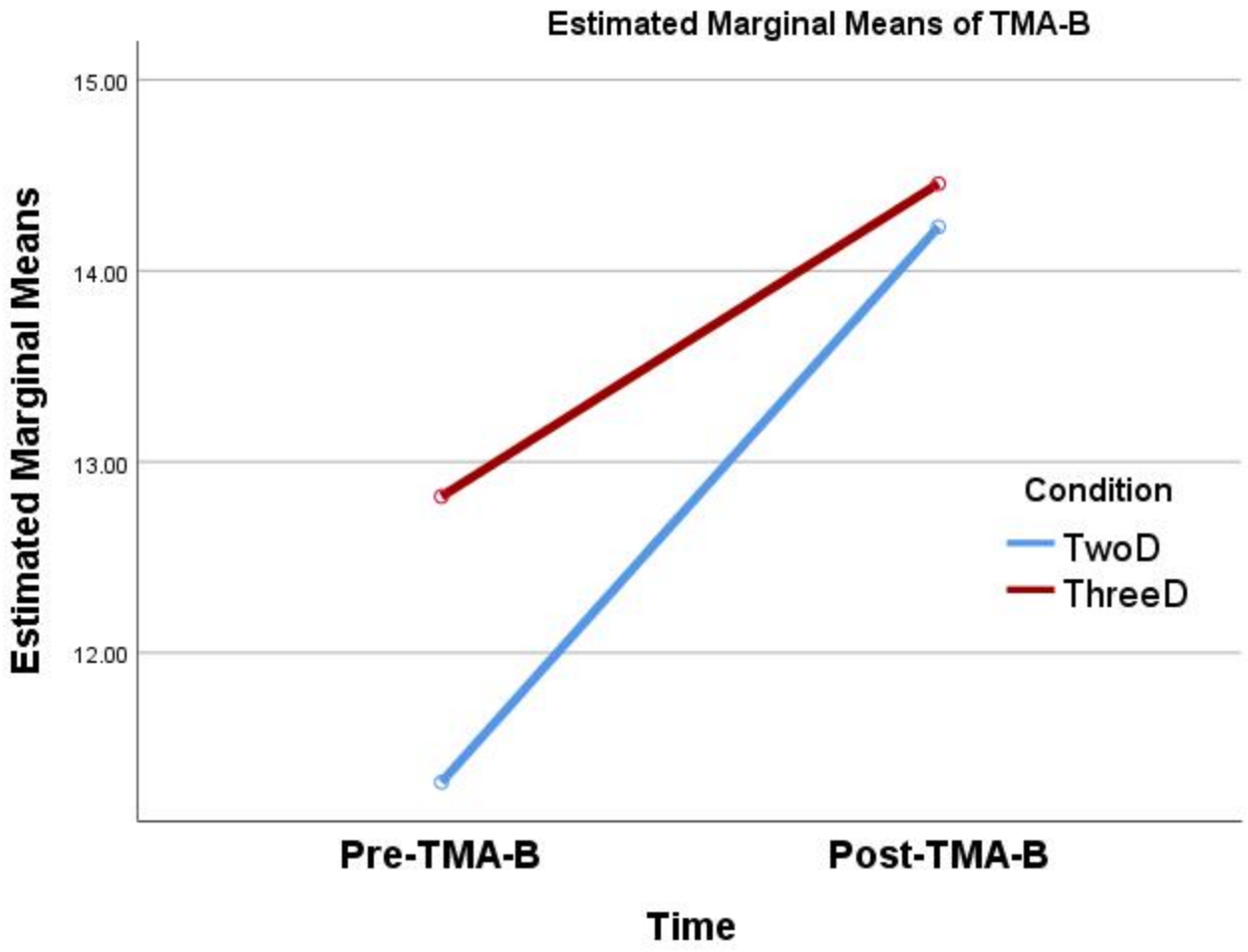
- 2D & 3D groups had significant gains
  - $t_{2D}(37) = 7.24$, $p < .001$, $d = 1.02$
  - $t_{3D}(39) = 5.01$, $p < .001$, $d = 0.64$



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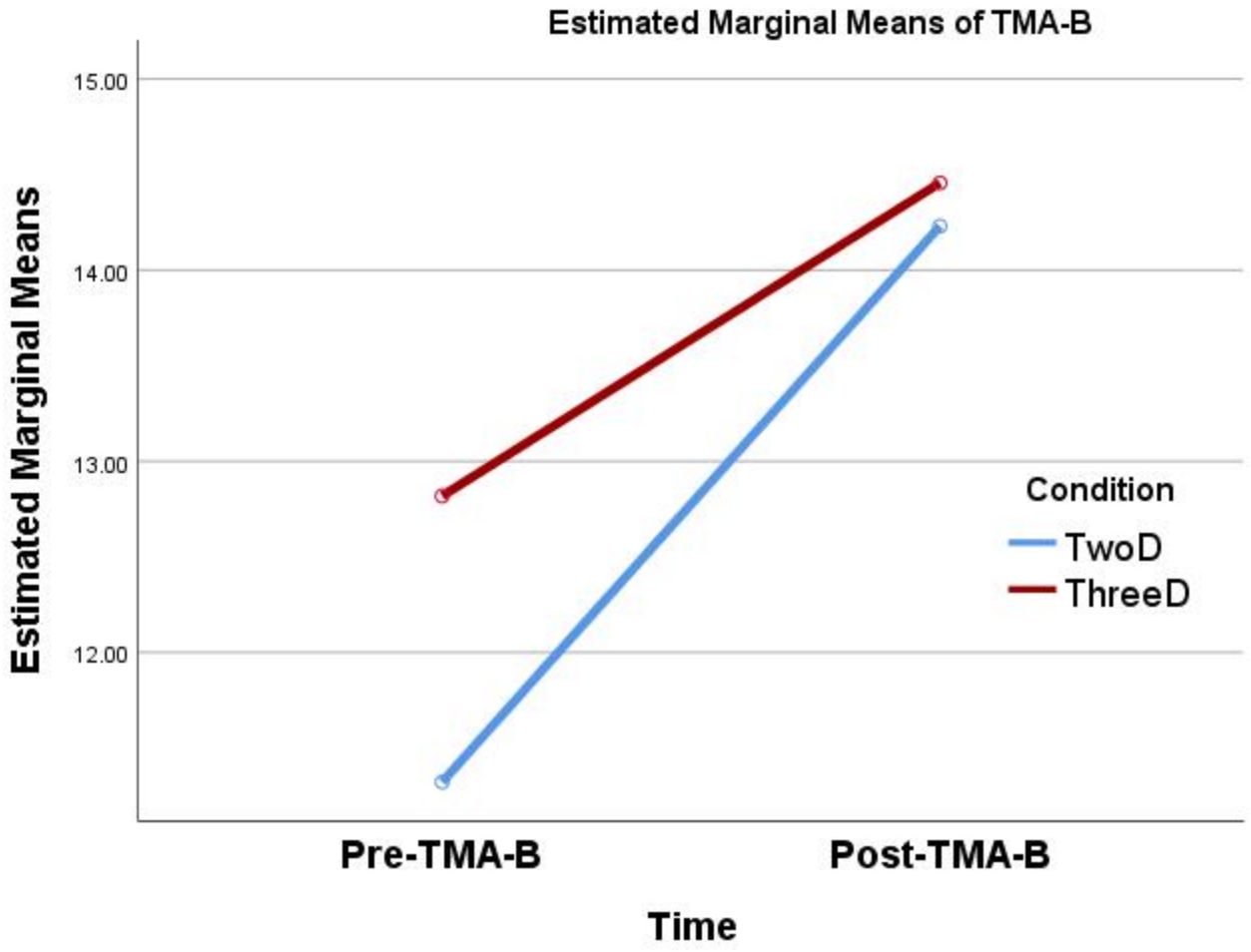
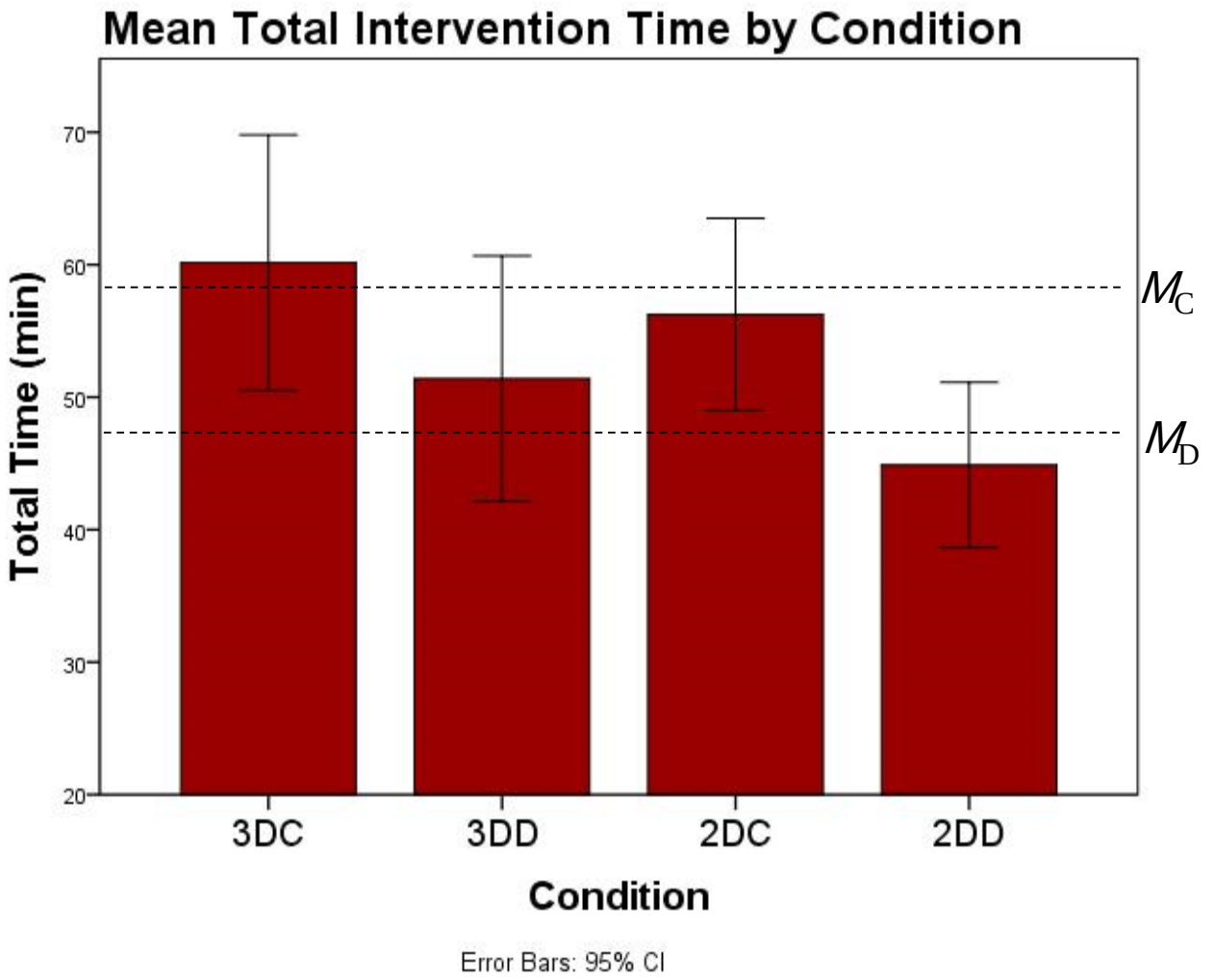
- 2D had a greater effect size than 3D



Results: Total Intervention Time

- Discrete group spent significantly less time than Continuous:
  - $F(1, 76) = 6.20$, $p = .015$
    - $M_D = 48.3$, $SD = 16.9$
    - $M_C = 58.2$, $SD = 18.1$



Discussion: Research Question 1

Does AR Sandbox use improve topo map skills?

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✓ Does AR Sandbox use improve topo map skills?

Why?

- Controlling potentially confounding variables
- Intervention: cycles of student-led prediction and feedback

Discussion: Research Question 2

Does 2D or 3D feedback lead to greater gains?

Discussion: Research Question 2

Does 2D or 3D feedback lead to greater gains?

Both significant but,

✓2D is better

Why?

- In 2D, more opportunity to practice visualizing 3D from 2D
- In 3D, difficulty differentiating feedback from the model

Discussion: Research Question 3

Which feedback condition is favorable for the classroom?

Discussion: Research Question 3

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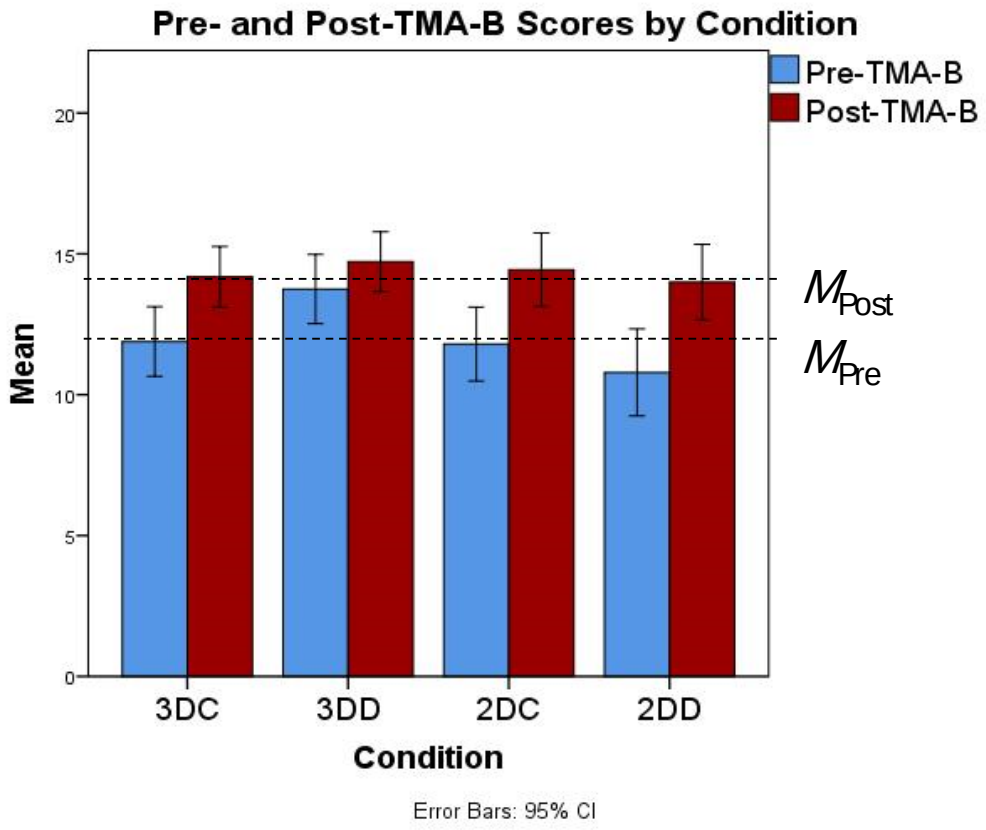
✓ 2D Discrete – highest gains, least intervention time

Rank	Condition	Performance Gain	Total Intervention Time
1	2DD	highest	lowest
2	2DC	moderate	high
3	3DC	moderate	highest
4	3DD	lowest	moderate

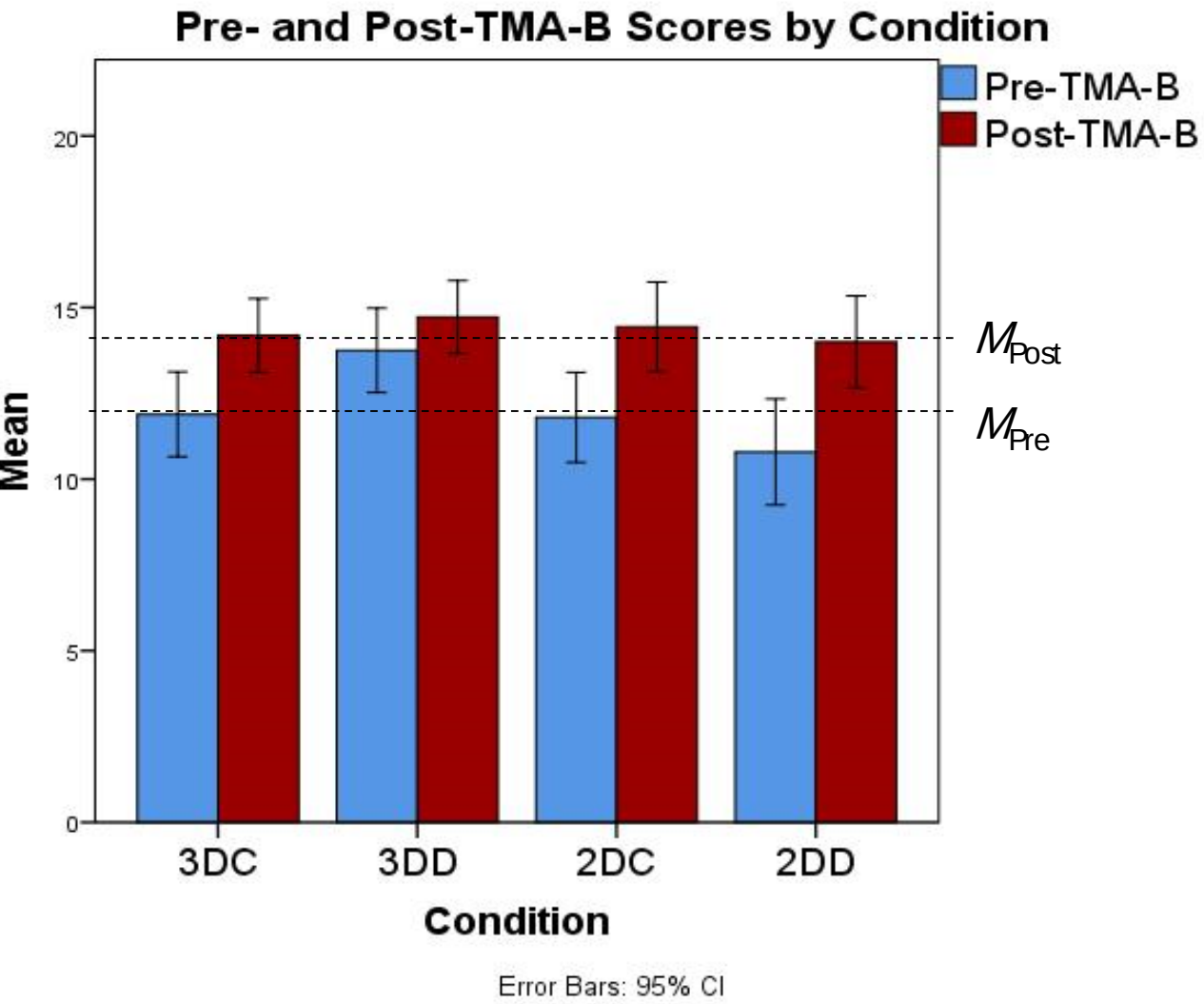
Limitations

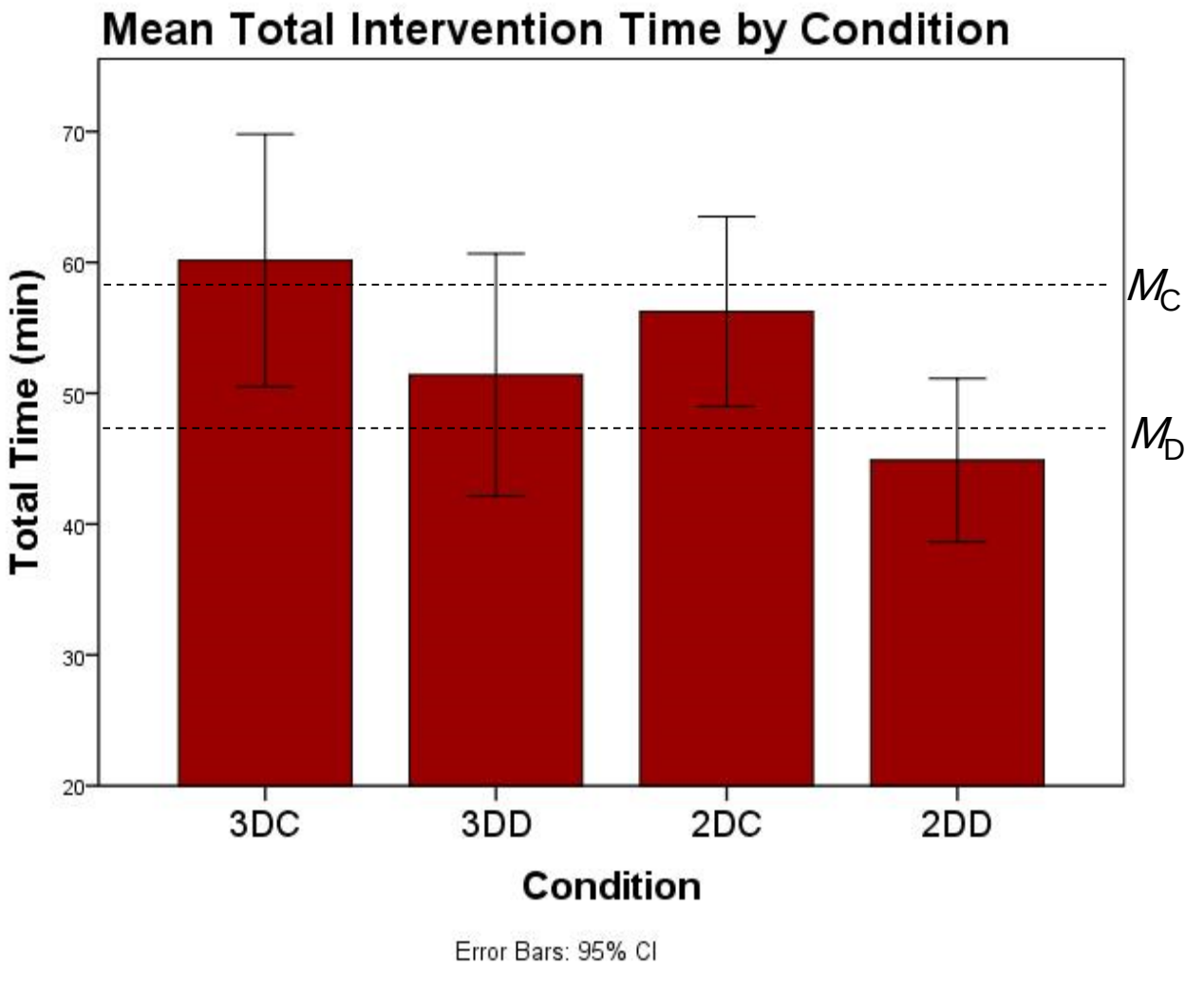
- Sample sizes small, but sufficiently powered
- Test-retest group[1] not similar enough for comparison
- Ceiling effect:
  - TMA-B gains inversely related to Pre-TMA-B scores (r = -.579**)
- Time of intervention may be a confounding variable



(Uttal et al., 2013)[1], **p < .001

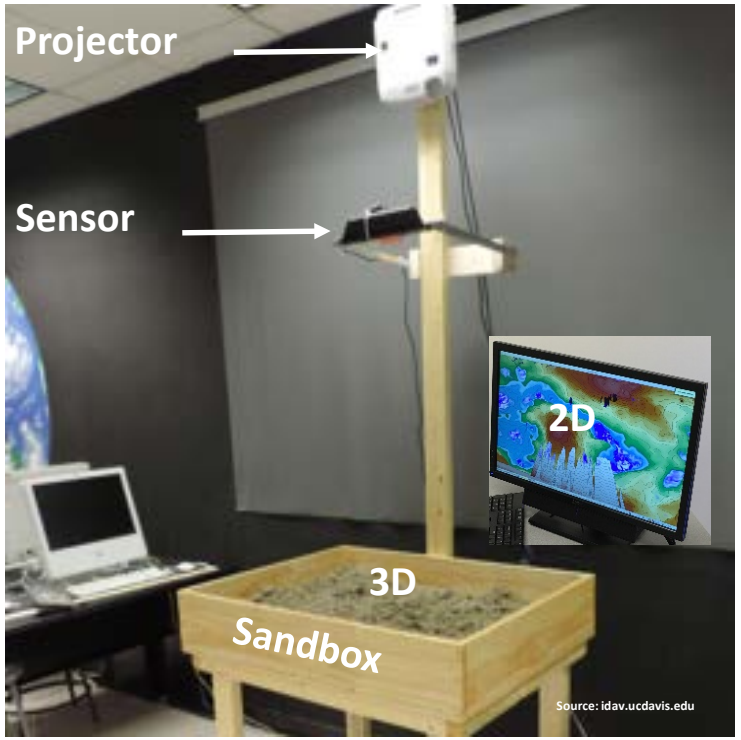
Conclusions





Teaching Implications

- Use in 1-on-1 setting, especially for struggling students
- Use cycles of prediction and feedback
- Use 2D monitor for the feedback



Future Work

- 80+ hours of video and audio recordings
  - Gestures, language, and point-of-view footage

- Accuracy data between topographic maps & landforms
  - Self-assessment, researcher assessment
  - Screenshots of maps & DEMs of landforms

AR Sandbox & Topographic Map Literacy

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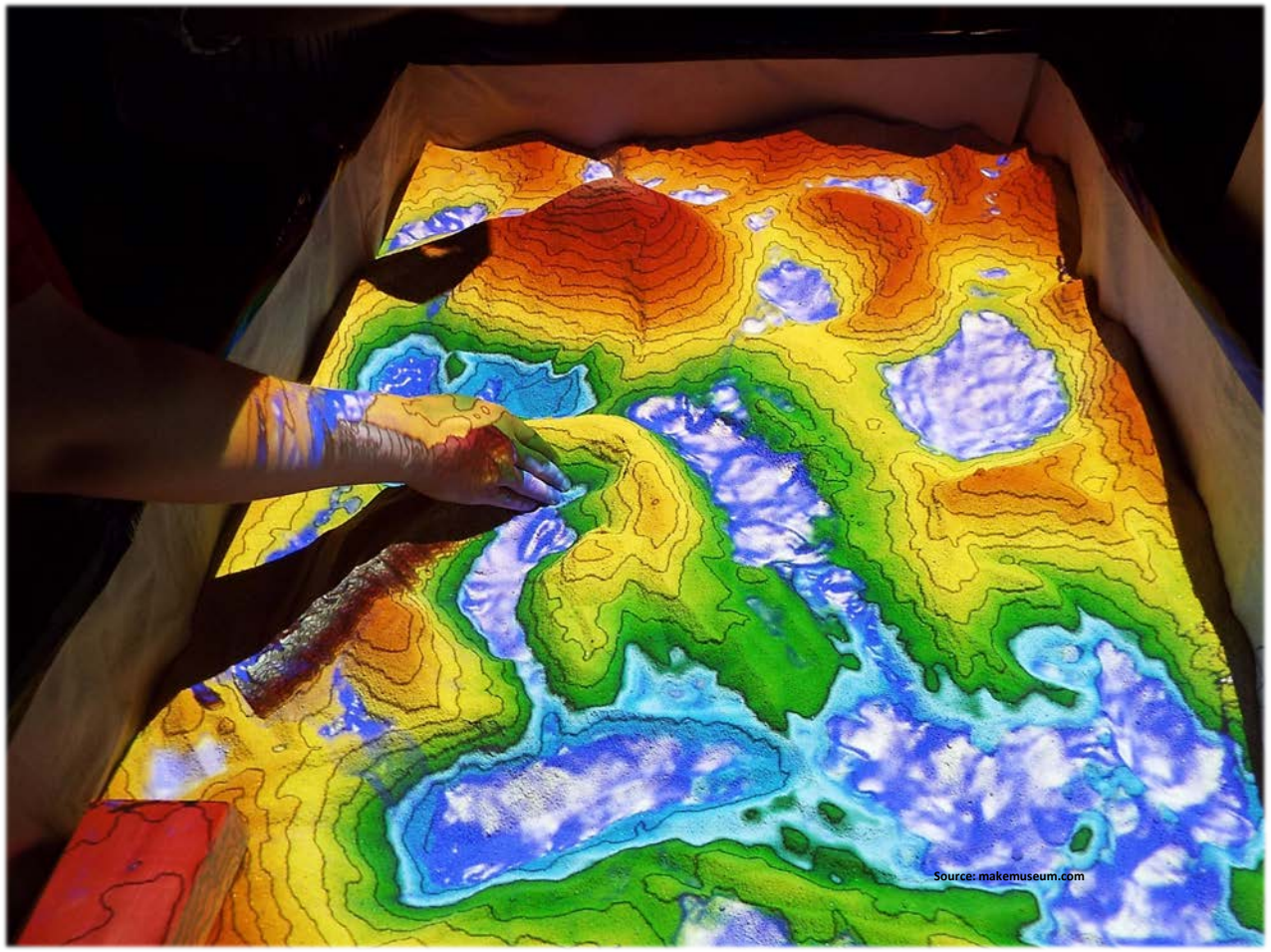
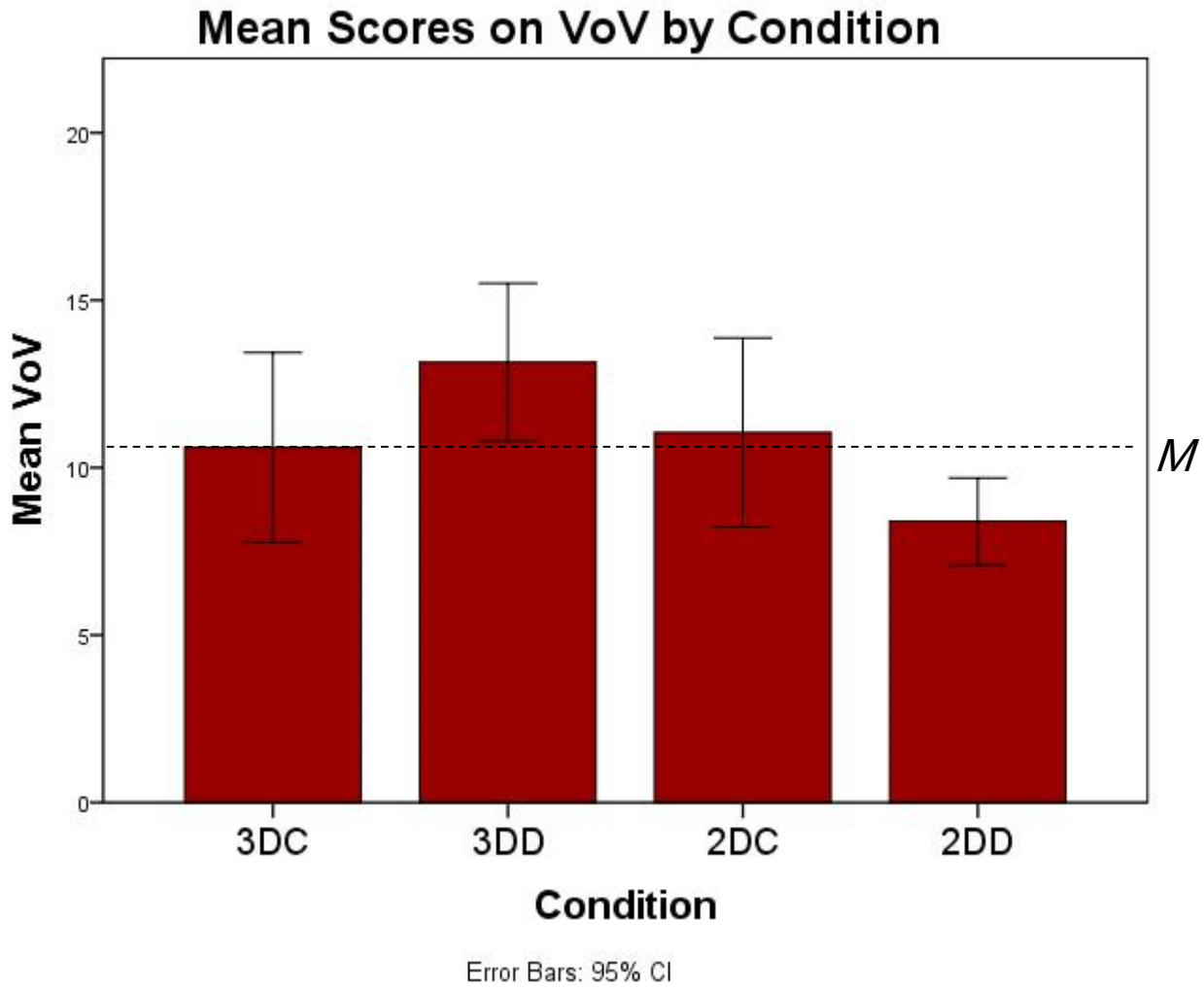
A special thanks:
Tim Shipley; Alecia Santuzzi;
Tom Pingel built the AR Sandbox;



Results: Spatial Scores by Condition

- VoV Scores: *M* = 10.9, *SD* = 5.4
- Significant correlations:
  - Pre-TMA-B & VoV
  - Post-TMA-B & VoV
- Non-significant correlation:
  - TMA-B difference scores & VoV

	1	2	3	4
1. Pre-TMA-B	-			
2. Post-TMA-B		-		
3. TMA-B Difference			-	
4. VoV Scores	.423**	.516**		-

* $p < .05$; ** $p < .01$