Tangible and Virtual Interactions for Supporting Spatial Cognition

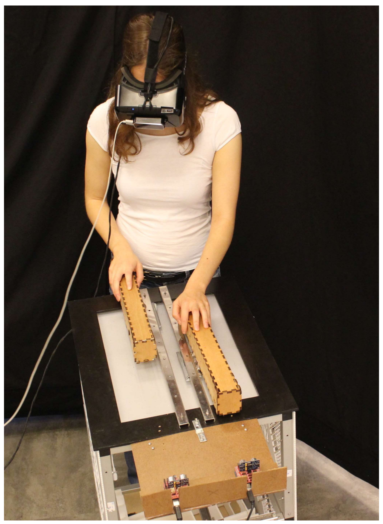

Figure 1: The system setup of TASC – engaging spatial perspective taking ability from established embodiment: head-tracking (Oculus Rift), hand-tracking and rendering (Leap Motion), and moving tangible blocks.

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Abstract
Manipulating objects spatially is important to post-WIMP interaction design. Meanwhile, spatial ability has been shown to be a strong predictor for STEM learning and career success. However, many current training or testing materials for spatial ability are still paper- or surface based. My research is about how establishing embodiment for spatial problem solving, using tangible and virtual interactions, can lead to new design opportunities and even spatial ability improvement. I envision my research to benefit interaction design and STEM education.

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H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
We live in a world constructed and situated in space. Per Newcombe and Shipley, “a world without space is literally inconceivable” [5]. Eliot also argued that spatial intelligence is pervasive [3], i.e., it is a cognitive activity that is required all the time. Spatial ability, an ability to characterize spatial intelligence, has been shown to be important to STEM education. Many longitudinal and very large-scale studies displayed that spatial ability is a strong predictor to STEM learning and career success (e.g., [6]). Design frameworks in HCI also emphasize the importance of spatial manipulation, e.g., the seminal Reality-Based Interaction [4]. While many of the existing spatial ability training or evaluation materials are well-tested by cognitive scientists, and broadly-used by educators, they are mostly paper- or monitor/WIMP-based (windows, icons, menus, and pointers), which still results in several limitations, e.g., 1) not engaging a target spatial ability entirely; 2) lacking appeal to students; 3) most

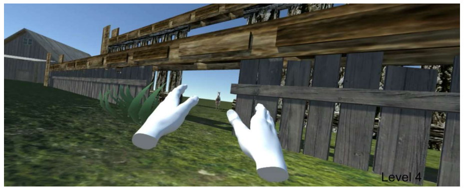

Figure 2: TASC's Ground View (GV) in the virtual environment: The puzzle in this level is solved when the openings on the two fences are aligned, allowing the horse to run toward the user.

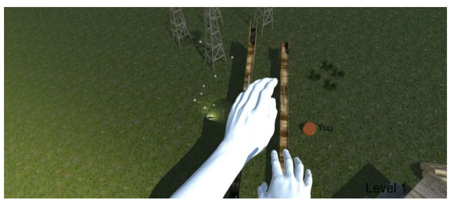

Figure 3: One of TASC's Aerial Views (AV) in the virtual environment: The user sees a better overview of the objects' spatial relationship, including the GV's position (the orange cylinder). However, in this view, the fences' openings are hidden from the user.

importantly, surface-based material just does not best present spatial-based tasks to encourage spatial problem solving.

Method & Research Questions

My research aims to use embodied cognition as a theoretical foundation to design, implement, and evaluate tangible and virtual interactions built for supporting spatial ability. Note: By embodied cognition, I particularly mean the link between perception, action, and cognition that can be triggered/strengthened from bodily movements, e.g., Common Coding theory (Ideomotor Theory). (I am less focused on the embodied cognition that is from philosophical or phenomenological areas.) My research questions are: **R1.** What are the (re)design process for TEI systems built for supporting spatial ability? **R2**. What are the spatial ability effects that can be evaluated from using such systems? **R3.** Since my team and I have been working with cognitive scientists and educators – How can our design and evaluation lessons learned benefit STEM education?

TASC (Tangibles for Augmenting Spatial Cognition) is the flagship project of my research. TASC engages the user's perspective taking ability with embodiment established from virtual and tangible interactions. To solve levels of spatial puzzles (align the openings on the virtual fences to let the virtual horse come to the user), the user keeps switching between two points of view to move the two tangible blocks which control the positions of the virtual fences. To date, Clifton et al. (our team) have published a framework [2], arguably the first of its kind, to generate design possibilities by connecting spatial cognition and TEI. Also, TASC's redesign and evaluation process I led, resulting many enhancements from the 1st generation, is accepted to DIS 2017 full paper [1]. Moving forward, I will continue to study how TASC and other projects can lead to improvement in spatial ability and other effects.

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