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Using Sequence Mining to Explore the Representational Flexibility Development of Adolescents with Autism Spectrum Disorder in Virtual Reality-Based Flexibility Training

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Abstract: We explored the representational flexibility development of adolescents with autism spectrum disorder (ASD) during VR-based simulation design and problem solving. We collected behavioral data of three adolescents with ASD from ten one-hour VR-based flexibility training sessions. The results of sequential data mining indicate that adolescents with ASD experienced different difficulties with representational flexibility during VR-based design problem solving. The study findings suggest that promoting the performance of attention switching and alternative representation tends to foster the performance of other representational flexibility processes.

Introduction

Representational flexibility is individuals' ability to flexibly switch attention between tasks, as well as identify and exploit various uses of representations (Rau, 2017). Recent research has studied the VR-based learning environment that engages adolescents with ASD in creative design and problem solving (Author, 2016). Despite the reported benefits of the VR-based training for adolescents with ASD (Didehbani et al., 2016), the 3D VR learning space tends to be visually-overwhelming and open-ended, and may create distraction and cognitive overload. It is critical to track students' competency development to provide learning supports adaptively and dynamically. However, there is a lack of empirical research that tracks the performance and development of representational flexibility in a digital learning setting. Using sequence mining, we aim to study the representational flexibility development of adolescents with ASD during VR-based design problem solving. Specifically, the study addressed the following research question: How did the representational flexibility performance of adolescents with ASD portray during VR-based design problem solving?

Method

VR-based flexibility training and data collection

Using Opensimulator—an open-source VR platform, we implemented ten VR-based flexibility training sessions that engaged adolescents with ASD in 3D scientific simulation design and encoding. Three adolescents with ASD (Average: 13.3 years old, SD = 1.24) attended nine 1-1.5-hour sessions during the training. In this study, the intervention task examined is developing computerized, non-player characters (NPCs or virtual agents). An NPC is a virtual character that conveys predetermined responsive or reactive behaviors. The adolescents with ASD needed to prototype the logics of computer scripts to encode NPCs that perform simplistic social interactions. During the NPC design task, the participants got to choose a preferred NPC simulation context (e.g., a cafeteria and a hotel reception) and designed an NPC tailored to the simulation context. An embedded scaffolding feature for representational flexibility is a 3D flow maker that assists participants in conceptualizing, visualizing, and designing the pathways of NPC interactions. Two facilitators observed and provided technical support as needed at every training session. For the data collection in the current study, we sampled the adolescents' computer logs that recorded their interaction behaviors with the 3D flow maker in all intervention sessions.

Data analysis

We conducted sequence mining procedures: (1) sequential pattern mining (SPM) and (2) sequential analysis. First, based on the collected computer logs, we implemented SPM to compute each individual's frequent behavior patterns, indicating how their performance of representational flexibility appeared (algorithm = SPAM, minimum support = 0.6). Using pre-defined behavior codes (Moon, Ke, & Sokolikj, 2020), we coded all behavior event transitions as either positive or negative occurrences related to the component facets of representational flexibility. Table 1 outlines the definition of each component facet of representational flexibility. Using the extracted sequences from SPM, we then conducted sequential analysis to identify how the adolescents' performance or states of representational flexibility (RF) changed during training. We calculated the transition probabilities of the RF states (cut-off probability: 30%).

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Table 1: Component facets of representational flexibility (RF)

Facets of RF	Definition
Attention Switching / Mental set-shifting (AS)	Ability to switch attention or action based on changed rules and contextual demands
Alternative Representation (AR)	Capability to identify and apply multiple representations
Pattern Development (PD)	Ability to identify and delineate a pattern (or rules) during design problem analysis and solving
Pattern Contextualization (PC)	Ability to either identify an implementation context of the endorsed pattern or customize the pattern.

Findings

Using SPM, we identified the study participants' states of RF. As shown in Figure 1-a, all three adolescents with ASD generally increased the performance of attention switching and pattern development during the training. On the other hand, both participants A and B showed higher negative portrayals of attention switching and pattern contextualization; participant C showed worse performance in alternative representation.

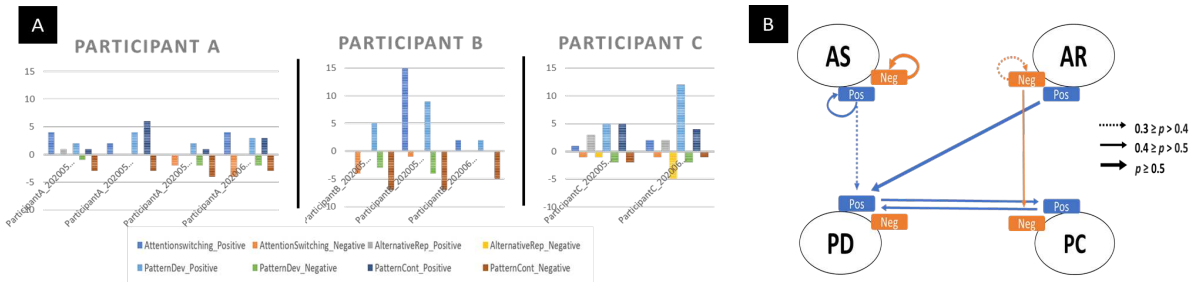


Figure 1. Competency development states of the study participants in the VR-based training (a) / Transition probability estimation of the competency states (b)

In addition, we calculated the transition probabilities of representational flexibility in terms of the four component facets. The transition probability estimation result confirms that adolescents with ASD were likely to show the iterative and unsuccessful performance of attention switching and alternative representations (Figure 1-b). On the other hand, if they performed successfully in attention switching and alternative representations, they had more chances to perform pattern development and pattern contextualization successfully.

Implication and limitation

The study findings indicate that adolescents with ASD experienced different difficulties with representational flexibility during VR-based design problem solving. It is necessary to present learner-adaptive, individualized supports in the VR-based learning environment. Promoting and scaffolding participants' performance of both attention switching and alternative representation will potentially promote the performance of other representational flexibility processes.

Reference

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