Exploring Learning Supports in Virtual Reality-Based Flexibility Training for Adolescents With Autism

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Abstract: Using *Opensimulator*, this study implemented a 3D virtual simulation design-based training program to enhance the cognitive flexibility of adolescents with autism spectrum disorder (ASD). This study examined how using learning support promoted ASD adolescents' cognitive flexibility. We sampled a total of 22 one-hour virtual reality-based flexibility-training sessions of seven adolescents with ASD. We conducted both systematic behavior analysis and transition-probability-matrix analysis to explore how a packet of learning supports would promote flexibility-associated behaviors during the training. The study findings suggested that the learning supports used were effective in promoting ASD adolescents' performance of attention switching, multimodal representations, and pattern development.

Introductions

Adolescents with autism spectrum disorder (ASD) tended to be underrepresented in post-secondary STEM education (Wei, Yu, Shattuck, & Blackorby, 2017). ASD may mitigate the chance for the ASD learners to assign their potential talents in their academic performance and future career. Specifically, researchers stated that cognitive flexibility is a key attribute for predicting one's academic performance. Cognitive flexibility refers to the capability to switch attention and adapt behaviors in response to variations of given circumstances (Ionescu, 2012). Research evidenced that ASD adolescents tend to show a low sense of cognitive flexibility, which is associated with a negative consequence in their academic performance. A purposeful training to enhance ASD individuals' cognitive flexibility is hence warranted. Recently, autism research has introduced VR-based training environments that enable ASD individuals to practice scientific and social problem solving while completing 3D simulated design tasks (Ke & Lee, 2013). VR-based simulation design quests motivate and scaffold participants' enactment of flexible and situational design actions in a 3D lifelike environment.

During VR-based training, it remains an open question as to how to design and implement learning supports that foster ASD adolescents' cognitive flexibility practice and development during training. Because VR-based training contexts require ASD individuals to plan, design, and implement their design solutions, novice participants could be overwhelmed by the task complexity. However, empirical research exploring the impact of various learning supports is still limited in the context of VR-based training. This study, therefore, explored how learning support in VR-based training promoted participants practice of cognitive flexibility. The overarching research question of this study is: *How likely does using learning support facilitate ASD adolescents' cognitive flexibility enactment during VR-based training?*

Method

Training environment and participants

Using *Opensimulator*, we developed a VR learning environment in which ASD adolescents will design and encode a variety of scientific simulation games. In this study, the sampled design quest was the design and construction of an elevation bridge in a virtual farming village, based on the needs and requests of the current villagers. The task was designed to be aligned with the middle-school physics and math content and practice standards. It requires ASD adolescents to actively represent and apply the concept of Newtonian physics (i.e., force and gravity) to define different design variables when constructing mechanics of the elevation bridge. During the training, two facilitators offered context- and learner-adaptive prompts to support participants during the design-based flexibility-training sessions. We screen- and video-captured all participants' training sessions in VR. In this study, we examined a total of 22 one-hour videos of the training sessions of seven 12-19-year-old adolescents with ASD.

Data processing and analysis

We employed a systematic behavior analysis with the video recordings of participants' actions and reactions during training. We coded the occurrences of target flexibility competencies, including (1) attention switching, (2) multimodal representation, (3) pattern development, and (4) pattern contextualization (refers to Table 1). We also coded the occurrences of different learning supports used during the training, including environmental arrangement, agent scaffolding, facilitator scaffolding, and direct instruction. The coding framework, or the behavior ethogram, included modifiers that define core properties (e.g., guided practice and explanation) of each type of learning support. We employed a behavior-annotation tool to code ASD participants' enactment of cognitive flexibility as well as the delivery of the learning support, with time sampling (per 30 seconds). Following the ethogram, two coders conducted an initial coding with a random sample of training sessions, then discussed and refined coding results. After a 100% interrater agreement is achieved with the training dataset, we coded the rest of the video-recorded data. With the behavioral coding results, we conducted an exploratory transition-probability-matrix analysis (Bakeman & Quera, 2011). This analysis was aimed to predict how likely learning support promoted students' enactment of cognitive-flexibility competencies. We set our threshold value .05 to include behavior-transition results only with high likelihood. To confirm the statistical significance of each transition, we implemented the post-hoc random permutation test, which is non-parametric. We ran 1,000 permutations as a significance value at .05.

Table 1: Target competencies and their definitions

Target competency	Definition
Attention switching	Changing learners' perspectives between rules and given contextual demands
Multimodal representation	Using multi-channels to interact and implement artifacts
Pattern development	Inductive reasoning in problem-solving
Pattern contextualization	Deductive reasoning in problem-solving

Findings and discussion

We found a total of 8 statistically-significant behavior transitions from learning support to target competencies. No statistically-significant behavior transition from learning support to pattern contextualization appeared. First, for the category of environmental arrangement (as a learning support), haptic presentations were highly likely to promote ASD participants' enactment of cognitive-flexibility competencies (Attention switching= 32.3%, multimodal representation= 9.7%, and pattern development= 9.7%). Specifically, we found that providing 3D minigames (as an environmental aid) to support haptic representations facilitated participants' practice of cognitive flexibility. Second, for the category of agent-scaffolding learning support, delivering text messages positively promoted attention switching (27.3%) and multimodal representation (9.1%). As the context-sensitive cuing during the training, multiple non-player characters (NPCs) delivered the background and task-relevant information during a design quest. Interpersonal discussions with NPCs fostered the participants' switching behaviors, as well as elaborations of visual representations. Third, guided practices via the facilitator scaffolding was highly likely to promote ASD students' attention switching (50.0%). For example, in the design quest the participants were asked to collect evidence of contextual demands for the bridge construction. Facilitators' guiding increased an enhanced awareness of participants in seeking evidence for their bridge design decisions. Lastly, direct instruction was likely to promote both attention switching (advanced organizer = 27.8%) and multimodal representation (questioning= 9.7%). The analysis results indicated that providing advanced organizers and Socratic questioning helped ASD participants to recall their prior knowledge and skills that may transfer to different design contexts.

References

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