Initiative 2.2.6: Cognitive and Anatomical Characteristics of the Learner Predict Performance in an Adaptive Math Intervention

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Abstract

The current study examined individual differences in cognition and anatomy that relate to performance on an adaptive math intervention in 7th graders. Cognitive measures include assessments of math skills, visuospatial abilities, working memory, language, and episodic memory. Global fractional anisotropy measures were also computed. The intervention, called ALEKS, guides students through "knowledge spaces" after an initial assessment (IA) that determines what parts of space they know and what they need to learn. Results indicate that the WJ III Calculation (Calc) score correlated highly with the IA, visuospatial reasoning (VR), working memory (WM), and vocabulary (Voc). ALEKS significantly predicted learning over the course of the intervention. However, the strongest predictor of learning was the intensity of the intervention. Those who spent more time practicing learned more independently of their cognitive functioning. Hemispheric asymmetry in FA correlated strongly with the left and right and to a lesser extent with SWM.

Introduction

In recent years cross-sectional studies of children have shown a protracted course of biological maturation in the brain's fiber tracts, often measured as increasing fractional anisotropy (FA) with diffusion tensor imaging (DTI) [1]. Associations have also been observed between measures of FA and performance on cognitive tasks, and these relationships remain significant even after controlling for age, suggesting that these measures may reflect individual differences in fiber tract maturation even in children of the same age [2, 3]. The tract parameters may reflect properties of connectivity in the brain with functional implications for circuit performance, but they also respond to training [4, 5]. This evidence of neuropsychiatric suggests that the properties of fiber tracts, along with their cognitive correlates, can be modified through explicit and extensive training that is sensitive to the individual differences in maturation. Traditional approaches to education have typically fallen short of providing these types of interventions due to the prohibitive costs of individualizing them. However, technological advances in recent years have led to the ability to optimize education by offering individualized lessons that are adapted more precisely to a child's profile of strengths and weaknesses in a given subject. Assessment and Learning in Knowledge Spaces (ALEKS; UC Regents and ALEKS Corporation) is one such intervention. The purpose of the current study is to examine the cognitive and anatomical factors that correlate with performance on this intervention in children of similar age.

Methods

Participants: Forty-one 7th graders (24 males; Mean Age = 14.2 (SD= 0.90) were included in the study at baseline. Twenty-nine of these students completed the baseline imaging protocol; 12 either refused imaging or could not be scanned.

Cognitive Measures

Woodcock Johnson Test of Achievement (WJIII): Calculation Subtest
Wechsler Individual Achievement Test (WASI): Block Design Subtest
Beery-Buktenica Developmental Test of Visual-Motor Integration, 5th Edition
NIH Toolbox: Vocabulary & Inattention-Based Assessment of Memory (IBM)
Between Search Error: Spatial Working Memory Task
Tallal Repetition Test of Rapid Auditory Processing: Serial Memory

Imaging: Fractional anisotropy (FA) was estimated within and between fiber tracts from whole hemisphere data and in each hemisphere separately [6]. FA hemispheric asymmetry was also computed using the following formula:

\[ \text{Lh/right} = \frac{\text{Lh} - \text{rcht}}{\text{Lh} + \text{rcht}} \]

Intervention: ALEKS was developed on the basis of Knowledge Space Theory [7]. It defines a space, represented by the pie below, that defines all possible problems that could be solved in a given area. Knowledge state is defined as the subset of those problems the student can currently solve. Students cannot progress through the knowledge space and practice items in the order that makes the most sense for them. ALEKS was the focus of the current study.

Procedure: Participants completed a baseline assessment, a 10 week intervention, and a follow-up assessment. Mean time between baseline and follow-up assessments was 3.8 months (SD=0.54).

Results

Participants completed from 2.6 to 35.2 hours in the intervention (M=24.8, SD=6.59), and practiced between 9 and 415 problems (M=23.2, SD=50.8). The latter variable is considered to be the best measure of intensity of (or engagement in) the intervention. The following table summarizes participants' performance on assessment variables, engagement in the intervention, and FA from diffusion weighted images. Because participant age range was narrow, raw scores for all assessments were used as the variables of interest.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>WJIII Block Design</td>
<td>41</td>
<td>26.0</td>
<td>12.02</td>
</tr>
<tr>
<td>WISC-IV Digit Span Subtest</td>
<td>43</td>
<td>26.3</td>
<td>3.06</td>
</tr>
<tr>
<td>WISC-IV Working Memory</td>
<td>43</td>
<td>26.3</td>
<td>3.06</td>
</tr>
<tr>
<td>Beery VR</td>
<td>44</td>
<td>27.6</td>
<td>1.94</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>43</td>
<td>26.5</td>
<td>1.05</td>
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</tbody>
</table>

FA Calculation correlates significantly with ALEKS' initial assessment of Algebra 1 skills. In addition, the following table indicates, in descending order of association strength, the cognitive measures that correlated significantly or marginally with ALEKS' initial assessment.

Cognitive Measures & ALEKS Initial Assessment

<table>
<thead>
<tr>
<th>Cognitive Measure</th>
<th>Correlation</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>WJIII Block Design</td>
<td>0.33</td>
<td>0.001</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>0.27</td>
<td>0.001</td>
</tr>
<tr>
<td>Working Memory</td>
<td>0.26</td>
<td>0.001</td>
</tr>
<tr>
<td>Block Design</td>
<td>0.25</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Predictors of Learning Outcome

Two predictors were entered into a model predicting the percentage of the knowledge space that was learned between the initial and final assessments: the strongest cognitive predictor of the initial assessment score, Block Design, and the number of items practiced throughout the course of the intervention (i.e., Intensity of Intervention).

As expected, Block Design was a significant predictor of learning. However, independent of participants' Block Design scores, intensity of Intervention was the strongest predictor of learning.

Conclusions

Taken together these findings suggest that this adaptive Algebra 1 intervention is a promising educational tool, and that both cognitive and neuromaternal individual differences may play a role in how learners engage with and perform in the intervention. The strong correlation between the WJ III Calculation score and the ALEKS initial assessment score adds external validity to the ALEKS as a valid estimate of students' math skills and Algebra 1 knowledge. Consistent with findings in previous studies of math skills, measures of visuospatial reasoning and spatial working memory were predictive of the ALEKS initial assessment score. In addition, vocabulary and language abilities are also significant predictors. This suggests that while higher cognitive functioning may improve learning rate to some degree, learning still occurs readily in students with relative weaknesses if they remain engaged in the intervention. Furthermore, the higher the intensity of engagement in ALEKS the higher the increase from pre- to post-intervention in an independent assessment of math skills, the WJ Calculation score. Finally, it is noteworthy that a measure of relatively lower left than right hemisphere white matter FA correlated significantly with the ALEKS initial assessment score, as with the highest cognitive predictor of that score, Block Design. Given the importance of practice and engagement in the learning process suggested by these findings, further analyses of these data will focus on emotional and motivational factors that predict engagement.

References


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