Diagnosis of Mathematics Disorder using Mental Chronometric Tasks

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Introduction

The purpose of this study is to determine if mental chronometric tasks can be used to predict the diagnosis of a mathematics disability, in conjunction with, or in lieu of, traditional psychometric tasks.

According to the DSM-IV-TR (American Psychiatric Association, 2000), a learning disorder (LD) is "characterized by academic functioning ... substantially below that expected given the person's chronological age, measured intelligence, and age-appropriate education" (p. 39).

Research indicates that students with mathematics disorders differ in their executive function patterns from students with other academic disorder (Benton, 2001), in that they exhibit delays in "automatizing" basic numerical facts, which can lead to delays in providing solutions to problems that other students retrieve automatically from long term memory (Kulak, 1993). These cognitive differences may be due to visual-spatial deficits (Rourke & Fuerst, 1996; Silver, Pennett, Black, Fair & Balise, 1999; Jordan & Hanich, 2000), and more difficulty with novel, complex, and meaningful material than students with other LDs (Rourke & Fuerst, 1996).

Traditional psychometric testing may not be enough to capture these underlying processing deficits. One potential, and cost effective, alternative to paper-and-pencil assessment is mental chronometry. Because they only require minimal psychological processing for successful completion, mental chronometric (MC) tasks are so simple that there is close to 100% accuracy, yet are complex enough that the time taken to complete them reveals individual differences (Kranzler, 1993). Consequently, it appears that performance on chronometric tasks, in addition to psychometric tasks, would be helpful in forming a more complete knowledge base of the individual learner (Jensen, 1987), especially in understanding the differences between children with and without a diagnosed LD (Kulak, 1993; Weiler et al., 2000).

Method

To determine whether chronometric tasks can predict diagnosable mathematics difficulties, a pilot sample was obtained consisting of two groups of college students who: (a) were diagnosed with math learning disability and (b) who had math difficulties, but did not meet *any* DSM-IV-TR criteria. Both groups were given three psychometric batteries (Wechsler Memory Scale-Third Edition [WMS-III], Wechsler Adult Intelligence Scale-Third Edition [WAIS-III], and select subtests of the Woodcock Johnson-Third Edition Tests of Achievement [WJ-III]), and two chronometric batteries (Cognometer, and the Computer Based Academic Assessment System [CAAS]).

The *Cognometer* battery consists of eight different reaction time (RT) tasks (measured in milliseconds), ranging in complexity from one to several bits of information. The *Computer-Based Academic Assessment System* (CAAS; Royer, 1999) collects RTs (also in milliseconds) while participants perform simple mathematics tasks. For this study, participants took the mathematics Triple Multiplication subtest, which measures mathematics fluency for complex multiplication facts, such as 6 x 4 x 2 = ____ . The subject responds into a microphone, and the computer registers and calculates the time (in milliseconds) between the presentation of the problem on the computer screen and the correct verbal answer provided by the participant.

Participant scores were analyzed using a logistic regression to see if any combination of the chronometric and psychometric instruments could predict math disability. Multiple models were fit, but the model with best fit consisted of only the CAAS RT (Table 1). The results from this model suggest that for each increase in 1 millisecond, the odds of being diagnosed with a Math LD increases more than fourfold (Table 2). Two informal indices of goodness-of-fit were used to assess the model (Figure 1). The first plots the average logit values of the sample (quadri-partitioned based on logit values) against the probability of having a participant with a Math LD in the that particular group. The result is a monotonic sigmoid-like line, which indicates relative goodness-of-fit. The second index is a classification table, showing both correct and incorrect classifications. The table indicates that the model predicts *not* having a Math LD with over 95% accuracy, which is significantly greater than random chance.

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Table 1: *-2 Log_e Likelihood Values for the Fitted Models*

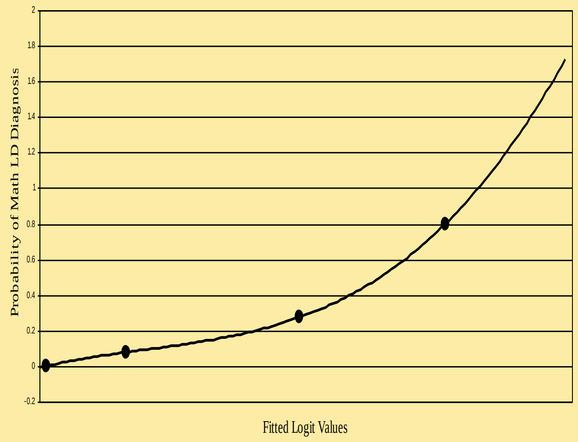
Model	Variables						Deviance[a]	Deviance	*df*	*p*
1	CaasRT						16.005			
2	CaasRT	CaasSD					14.991	1.014	1	0.29
3	CaasRT	FSIQ					15.978	0.027	1	0.87
4	CaasRT	WMS Gen Mem					15.781	0.224	1	0.64
5	CaasRT	Cog WM Speed	Cog Percept Thresh	Cog WM Capacity			15.755	0.25	3	0.617
6	CaasRT	Cog Vis/Spat Reflex	Cog Cog Reflex	Cog WM Speed	Cog WM Capacity		11.324	4.681	4	0.1967
7	CaasRT	Cog Running Memory					13.62	2.385	1	0.1225
8	CaasRT	WJ-III Total Ach					16.002	0.003	1	0.9563

Note. a = Deviance equals –2Log Likelihood of the variables, so the differences in Deviances are distributed as chi-squares.

Table 2: *Parameter estimates using model 1*

Regression Coefficient	Estimated Regression Coefficient value	Estimated SE	Odds Ratio
B_0	-13.615	0.82	----
B_1	1.504	6.93	4.50

Figure 1: Model indices



		Predicted		% Correct
		No Dx	Math LD	
Observed	No Dx	21	1	95.5
	Math LD	3	3	50
Overall Percentage				85.7

Results and Implications

In our pilot study, chronometric tasks involving mathematics correctly predicted group membership in the **No Diagnosis** group significantly better than by random chance. This provides initial evidence that mathematics-related chronometric tasks might be useful in the field of school psychology as clinical screening instruments. Additionally, these findings suggest that further research should be done that investigates the role of chronometry in better understanding the processing differences of individuals with mathematics learning problems.

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