Does the speed of automatization predict differences in linguistic ability in children with developmental language disorder?

Ashley Blake[1], Ewa Dąbrowska[1,2], Nick Riches[3]
[1]University of Birmingham; [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen; [3]Newcastle University

INTRODUCTION

Question:

How do cognitive abilities predict differences in children's linguistic development?

The aim of this study is to establish cognitive predictors of group membership between children with typically developing language and children with language difficulties (developmental language disorder).

We investigate four cognitive predictors:

Cognitive predictors:

- **non-verbal intelligence**
- **working memory**
- **speed of automatization**
- **implicit statistical learning**

Language measures:

- **Grammar**
- **Vocabulary**
- **Syntactic complexity and fluency/dysfluency measures**

METHODS

Individual differences design, comprising:

- children with typically developing language (language typical: LT)
- children with developmental language disorder (DLD), classified by scores of -1.25 *SD*s or more below the mean on standardized language measures of receptive and expressive language ability.

77 participants (mean age: 8;3 years)

- 54 language typical children
- 23 children with DLD

Hybrid method of data collection:

- We posted children a Tower of Hanoi puzzle in the post in advance of the first session.
- 3 online sessions via Zoom.

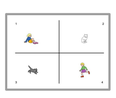
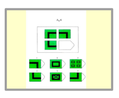
Session 1:

Children completed the Multiple-trial Tower of Hanoi task (MToH):

- 25 trials of the MToH
- 5 trials – secondary task

Sessions 2 and 3:

Children completed a battery of language and cognitive tasks:

Session 2		Session 3	
	**Narrative task** 'Frog, Where Are You? (Mayer, 1969)		**The British Picture Vocabulary Scale 3** (Dunn, Dunn & Styles, 2009)
	**Test for the Reception of Grammar** (Bishop, 2003)		**Ravens Coloured Progressive Matrices** (Raven, 1995)
	**Expository Discourse** (see Nippold, Hesketh, Duthie & Mansfield, 2005)		**Backwards Colour Span Task** (Riches, 2012)
	**Recalling sentences sub-test: CELF-5** (Wiig, Semel & Secord, 2013)		**Embedded triplets' task** (adapted from Arciuli & Simpson, 2011)

LEXICAL DIVERSITY AND FLUENCY MEASURES

Speech samples were transcribed, coded and analyzed in CLAN (MacWhinney, 2000). Audio files were analyzed in Praat (Boersma & Weenink, 2022) using the Syllable Nuclei script v.2 (de Jong & Wempe, 2009) for fluency measures.

- Syntactic complexity
- Fluency
- Dysfluency

RESULTS

Summary statistics and effect sizes (Cohens *d*) are reported in Table 1.

Variables	Mean: LT (SD)	Mean: DLD (SD)	*t*-test	Cohen's d	p-value
Language measures					
Receptive grammar	17.07 (1.39)	7.26 (3.14)	*t*(25.73) = 14.42	4.76	<.001
Productive grammar	52.96 (7.43)	22.35 (8.97)	*t*(35.47) = 14.40	3.87	<.001
Receptive vocabulary	129.94 (14.25)	92.17 (12.36)	*t*(47.61) = 11.71	2.75	<.001
Productive vocabulary	36.57 (6.73)	28.94 (8.92)	*t*(33.14) = 3.68	0.69	0.00
Subordination index	1.27 (0.10)	1.10 (0.06)	*t*(61.38) = 9.00	1.31	<.001
MLU morphemes	8.98 (1.04)	6.63 (1.18)	*t*(37.30) = 8.29	2.17	<.001
Speech rate	2.82 (0.45)	2.23 (0.39)	*t*(47.69) = 4.89	1.15	<.001
Dysfluency	18.93 (7.83	20.42 (9.00)	*t*(37.12) =-0.68	-0.18	0.49
Cognitive measures					
Nonverbal IQ	29.39 (4.35)	21.57 (5.33)	*t*(35,09) = 6.21	1.68	<.001
Working memory	15.05 (2.68)	10.39 (2.69)	*t*(41.49) = 6.93	1.73	<.001
Implicit learning %	51.37 (10.41)	50.43 (5.58)	*t*(39.84) = 0.45	0.09	0.06
Coefficient of variation	0.04 (0.04)	0.06 (0.05)	*t*(36.69) = -1.78	-0.47	0.08

Table 1. Summary statistics (Mean and SD) and Cohens-d (based on raw scores)

The measure of the speed of automatization (CV) is expressed as a coefficient of variation (calculated by dividing the *SD* by the mean number of moves on the MToH), where automatization reflects a decrease in the coefficient of variation (following Segalowitz & Segalowitz, 1993). Strongly automatized behaviours show very little within-participation variation.

Logistic regression was used to analyse the relationship between language difficulties (language typical children, coded as '0" and children with DLD, coded as "1"), and four cognitive predictors: non-verbal IQ, working memory, implicit learning, and the speed of automatization. The final model is shown in Table 2.

The predictive ability of our model is demonstrated through the ROC curve displayed in Figure 1. The value of the area under the curve (AUC) is 0.92 which demonstrates excellent predictive properties of the model.

Variable	β	St Error	Z-statistic	95% CI[1]	*p*-value	OR[2]
Intercept	-1.99	0.58	-3.44	0.03, 0.35	***	0.14
Nonverbal IQ	-0.14	0.44	-2.58	0.12, 0.72	**	0.32
Working memory	-2.57	0.80	-3.18	0.01, 0.29	**	0.08
Automatization	0.76	0.38	2.02	1.05, 4.91	*	2.15

Table 2. Logistic regression

[1]OR = Odds Ratio, [2]CI = Confidence Interval
*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1'*

RESULTS (continued)

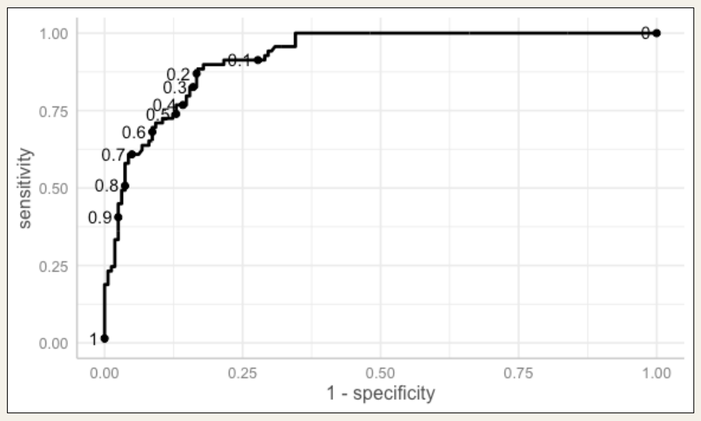


Figure 1: ROC curve demonstrating predictive ability of our logistic regression model

DISCUSSION

- The two groups show significant differences in cognitive abilities and language measures.
- Nonverbal IQ is the strongest predictor of language outcomes in our sample, followed by working memory and the speed of automatization.
- 61% of children in the DLD group have a combination of low nonverbal IQ, low working memory, and slow speed of automatization, in comparison to median scores of the LT group.
- These findings suggest that language difficulties in children are additive, caused by a combination of cognitive factors which impact linguistic outcomes.
- Children with DLD showed slower automatization on the MToH task. This could suggest difficulties with proceduralization, as previous literature has shown.

TAKE HOME MESSAGE

Non-verbal IQ, working memory, and automatization are significant predictors of group membership.

Children with language difficulties show slower speed of automatization as reflected in the MToH task.

REFERENCES

- Bishop, D. (2003). *Test for reception of grammar: TROG-2: manual*. London: Pearson.
- Boersma, P. Weenink, D. (1992–2022): Praat: doing phonetics by computer [Computer program]. Version 6.2.09, retrieved 15 February 2022 from https://www.praat.org.
- de Jong, N.H., Wempe, T. (2009) Praat script to detect syllable nuclei and measure speech rate automatically. *Behavior Research Methods* 41, 385–390 (2009)
- Arciuli, J. & Simpson, I. C. (2011). Statistical learning in typically developing children: The role of age and speed of stimulus presentation: Statistical learning. *Developmental Science*, *14*(3), 464–473
- Dunn, L. M., Dunn, D. M., & Styles, B. (2009). *British Picture Vocabulary Scale* - 3 (3rd ed). London: GL Assessment Ltd.
- MacWhinney, B. (2000). *The CHILDES project: Tools for analyzing talk: Transcription format and programs*, Vol. 1. *(3rd ed.)*. Lawrence Erlbaum Associates Publishers.
- Mayer, M. (1969). *Frog, where are you?*. New York: Dial Books for Young Readers.
- Nippold, M. A., Mansfield, T. C., Billow, J. L., & Tomblin, J. B. (2008). Expository discourse in adolescents with language impairments: Examining syntactic development. American Journal of Speech-Language Pathology, 17(4), 356.
- Raven J.C. (1995). *Coloured Progressive Matrices Sets A, Ab, B. Manual Sections 1 & 2.* Oxford Psychologists Press; Oxford, UK: 1995.
- Riches, N. G. 2012. Sentence repetition in children with specific language impairment: an investigation of underlying mechanisms. *International Journal of Language & Communication Disorders*, *47*(5), 499–510.
- Segalowitz, N.S. & Segalowitz, S. J. (1993). Skilled performance, practice, and the differentiation of speed-up from automatization effects: Evidence from second language word recognition. *Applied Psycholingusitics, 14*, 369-385.
- Wiig, E. H., Semel, E. & Secord, W. A. (2013). *Clinical Evaluation of Language Fundamentals–5th edn. (CELF-5)*. Bloomington, MN: NCS Pearson.

CONTACT INFORMATION

a.r.blake@bham.ac.uk
@ashleyrblake
https://www.ashley-blake.com