When children with developmental coordination disorder use finger counting: behavioral and 3D motion analyses

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Introduction

In many cultures around the word, children use there fingers to deal with numbers (Bender & Beller, 2012). Since fingers are used as an external support, finger-counting (FC) is often described as an ideal tool for relieving the working memory (WM) load inherent to numerical tasks (de Chambrier et al., 2018). Children with poor WM have been shown to make more extensive use of FC which provides them with a physical representation of number while reducing the WM load of the task (Noël, 2005, 2009).

The use of the FC requires children to have good finger motor skills. While developmental coordination disorder (DCD) is characterized by persistent motor impairment associated with low WM (Wilson et al., 2012; Alloway & Archibald, 2009), no study has investigated functionality of FC in the children with DCD. However, their motor disorders could impede the use of FC, which could be particularly deleterious for them as they may benefit less from it to relieve their WM in tasks with high WM load.
The purpose of the study is to investigate the functionality of FC in children with DCD.

1. Do children with DCD take advantage of FC to relieve their WM in a task with high WM load?
2. Are their FC gestures functional (i.e., synchronized with number-word, fast, regular and automated)?

Method

Population

12 children with DCD (Mean age = 8.79±.56 years)
12 typically developing children (Mean Age = 8.67±.75 years)
Groups were matched on school-level and fluid reasoning habilities
Groups were age equivalent ($t(22)=.43$, $p=.67$)

Session 1: Home assessment

IQ (WISC-V; Weschler, 2014): Similarity, vocabulary, matrix reasoning and figures weights subtests.
Manual dexterity (MABC II; Henderson and al., 2007): Placing pegs, threading lace and drawing trail subtests.
Working memory (WM) : Backward letter span task.
Mastery of ordered sequences: Recitation of number sequence (numerical condition) and alphabet (non numerical condition) from first term or between two targeted terms.

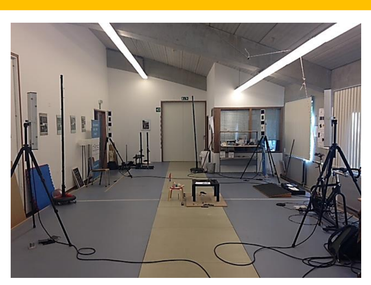
Session 2: biomechanical assessment in the motion laboratory

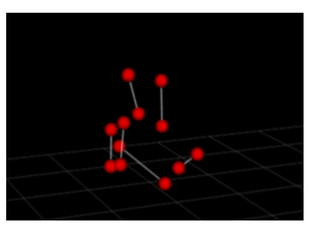
Tasks

Counting-like finger gesture (no WM load): Open the hand following the order of finger anatomical position (thumb, index, middle, ring and pinky finger).
Finger-counting (Low MW load): Count from 1 to 10 by combining the recitation of the verbal number sequence with coordinate finger gesture.
Nth–After (High WM load) : What is the n^{th} number/letter after *x*?

- Using Finger-Counting to count from *x+1* until *n*
- Two conditions: numerical and non numerical (alphabet)

3D motion analyses

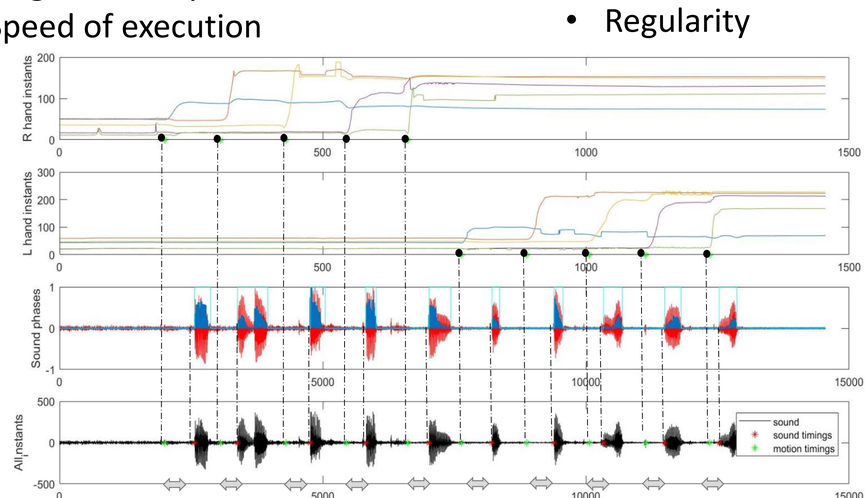




Output

Scores on the Nth-After task.
Four **functionality indexes** from Finger-Counting, Counting-like finger gesture and Nth-After tasks:

- Finger/voice synchronization index
- Speed of execution
- Interfinger transition speed
- Regularity



Results

General mixed model: behavioral measures

	Nth-After task scores		
Fixed effects	**Estimate**	**SE**	***t*(719)**
Intercept	1.83	.37	4.91***
Group	-1.32	.39	**-3.68*** **
Condition (numerical vs non numerical)	-.32	.19	-1.69
Group*Condition	.13	.17	.79

Note. Participants and items were considered as random effects. *$p \leq .05$,** $p \leq .01$, ***$p \leq .001$.

When working memory was added to the model, the group effect became nonsignificant SE= 1.26; $t(719)=1.27$, $p=.21$

General mixed model: biomechanical measures

Counting-like finger gesture

	Speed of execution		Interfinger transition		Regularity	
Fixed effects	**SE**	***t*(52)**	**SE**	***t*(52)**	**SE**	***t*(52)**
Intercept	.01	16.07***	.12	16.07***	.84	6.69***
Group	.01	-1.89	.11	-1.89	.84	-1.59

Note. Participants and items were considered as random effects .* $p \leq .05$,** $p \leq .01$, ***$p \leq .001$.

Finger-counting

	Synchronization		Speed of execution		Interfinger transition		Regularity	
Fixed effects	**SE**	***t*(52)**	**SE**	***t*(52)**	**SE**	***t*(52)**	**SE**	***t*(52)**
Intercept	.43	9.60***	.01	22.42***	.07	22.42***	.18	-8.81***
Group	.40	.10	.01	.40	.07	.69	.18	.21

Note. Participants and items were considered as random effects .* $p \leq .05$,** $p \leq .01$, ***$p \leq .001$.

Nth-After

	Synchronization		Speed of execution		Interfinger transition		Regularity	
Fixed effects	**SE**	***t*(237)**	**SE**	***t*(237)**	**SE**	***t*(237)**	**SE**	***t*(237)**
Intercept	.35	10.46***	.10	6.49***	.14	10.82***	.32	-5.56***
Group	.36	1.37	.06	-.76	.13	.72	.31	.79
Performance (success vs failure)	.24	.16	.05	.59	.09	-.81	.26	-.77
Group*performance	.25	.01	.04	-1.79	.09	.81	.28	.67

Note. Participants and items were considered as random effects. * $p \leq .05$,** $p \leq .01$, ***$p \leq .001$.

Conclusion

Compared to control group, children with DCD were **less accurate** in the N^{th}-After task

The difference would **not be due to FC movements**.

→ Children with DCD produce FC movements that are as synchronized, as fast, as regular and as automated as their peers.

There limitation in the FC task would be more likely to be rooted in their **limited WM resources** which limited their ability to maintain the task instruction in WM (start and stop markers).

References

Alloway, T. P., & Archibald, L. M. D. (2009). Working memory in children with developmental disorders. *Journal of Learning Disabilities*, *42*(4), 372–383.

Bender, A., & Beller, S. (2012). Nature and culture of finger counting: Diversity and representational effects of an embodied cognitive tool. *Cognition*, *124*(2), 156–182. https://doi.org/10.1016/j.cognition.2012.05.005

de Chambrier, A., Thevenot, C., & Barrouillet, P. (2018). Frequency of finger looking during finger counting is related to children ' s working memory capacities. *Journal of Cognitive Psychology*, *30*(5–6), 503–510. https://doi.org/10.1080/20445911.2018.1502190

Noël, M. (2005). Finger gnosia: a predictor of numerical abilities in children? *Child Neuropsychology : A Journal on Normal and Abnormal Development in Childhood and Adolescence*, *11*(5), 413–430. https://doi.org/10.1080/09297040590951550

Noël, M. P. (2009). Counting on working memory when learning to count and to add: A preschool study. *Developmental Psychology*, *45*(6), 1630–1643. https://doi.org/10.1037/a0016224

Wilson, P. H., Ruddock, S., Smits-Engelsman, B., Polatajko, H., & Blank, R. (2012). Understanding performance deficits in developmental coordination disorder: A meta-analysis of recent research. *Developmental Medicine and Child Neurology*, *55*(3), 217–228. https://doi.org/10.1111/j.1469-8749.2012.04436.x