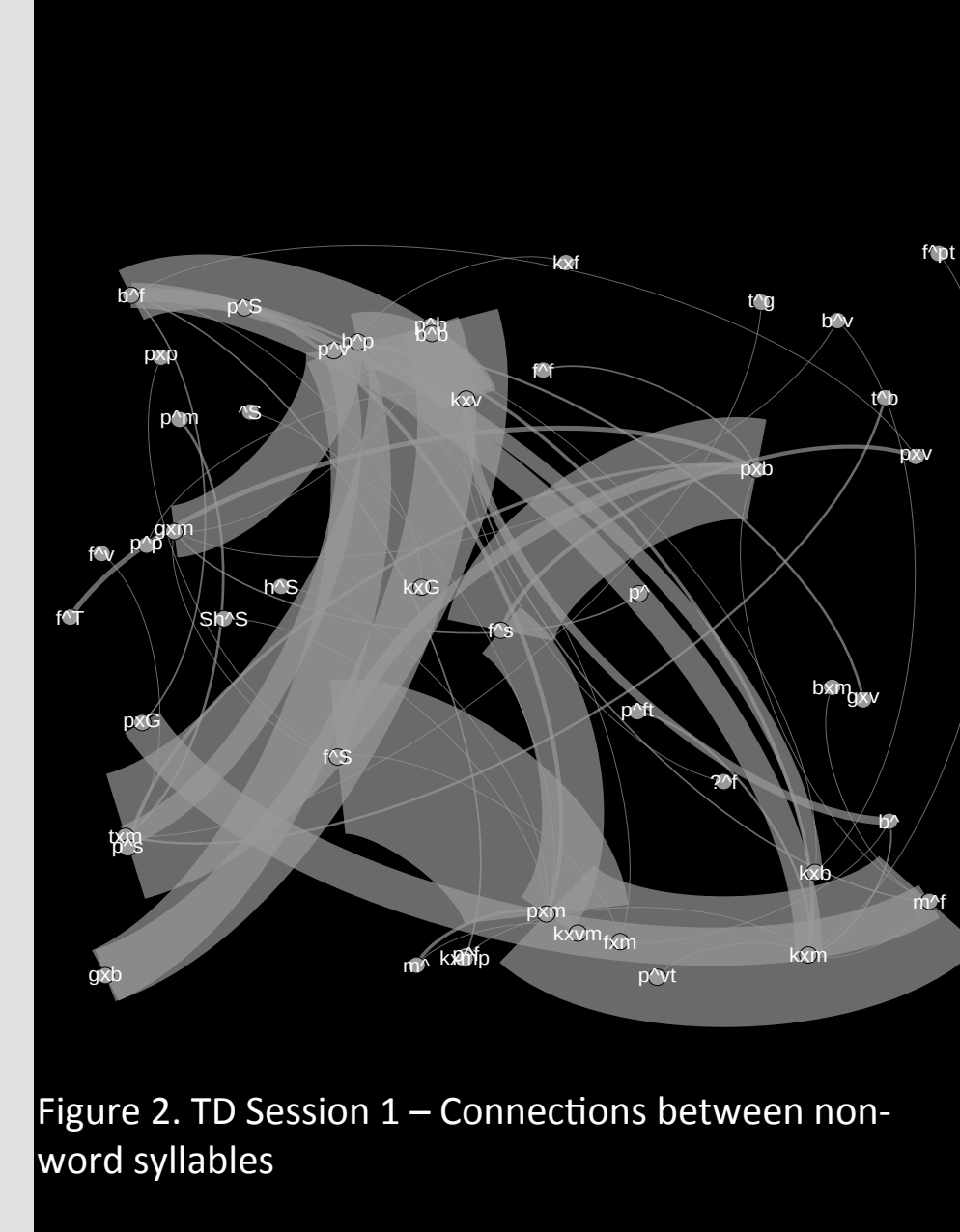
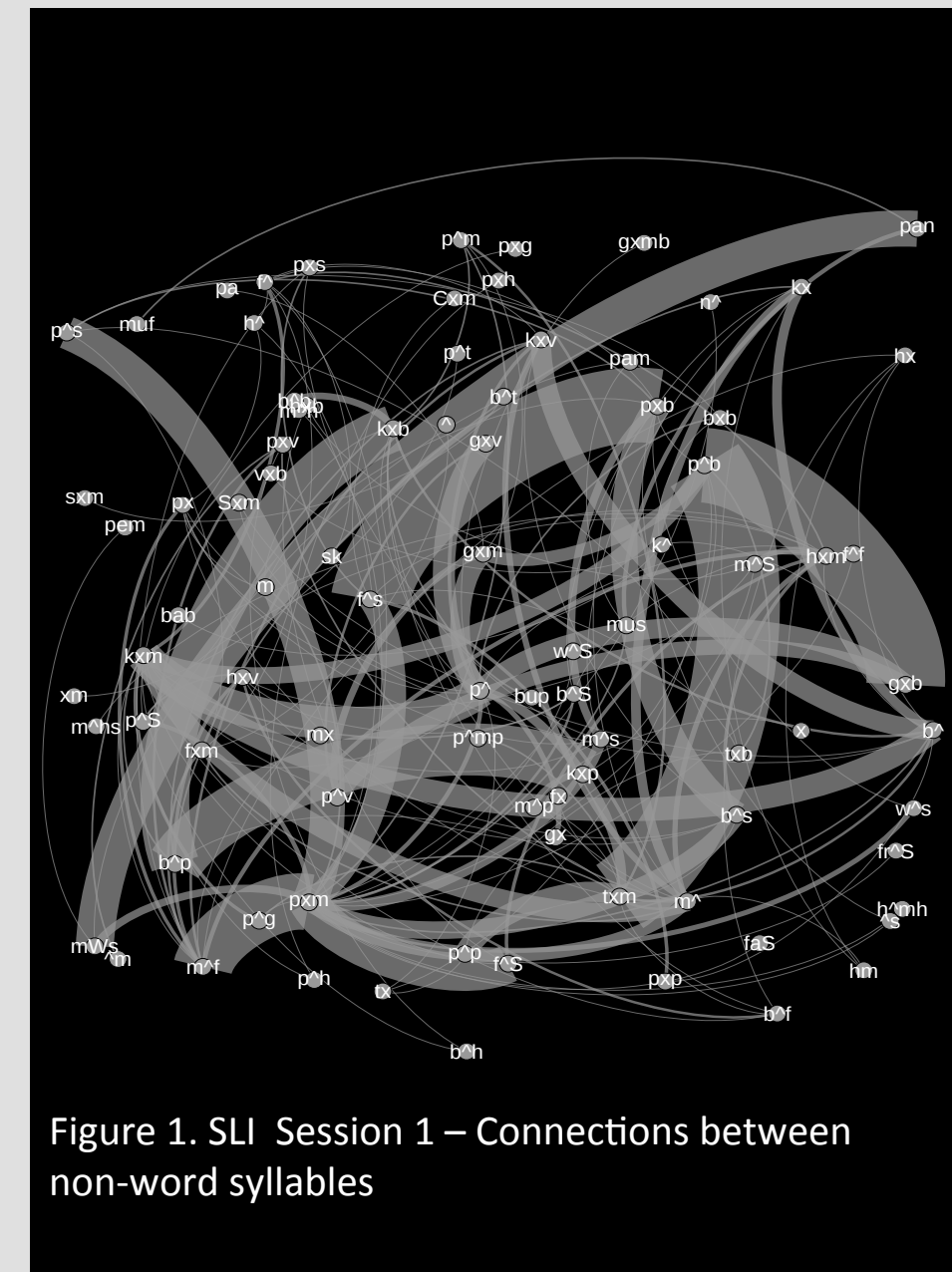




## Introduction

**Background:** Specific language impairment (SLI) is diagnosed on the basis of language ability. Morphosyntactic deficits are core components of SLI, although deficits in phonology are frequently observed, as well as impairments in fine, gross, and oral motor skill. However, the interactions between morphosyntactic, phonological, and motor deficits in children with SLI are still debated in the field. We hypothesize that these factors combined result in high levels of variability at the execution phase, which becomes a critical issue in the process of identification and intervention.

**Objective:** To determine whether and how two sources of variability, segmental and articulatory movement, interact in children with SLI. Currently, standard approaches to error analysis emphasize accuracy measures, which may not adequately characterize patterns of error and dynamic learning trajectories. Other alternatives to error analysis will be explored, as inspired by these network plots:



## Participants

Children (monolingual English speakers) with SLI (n = 12) and children who are typically developing (TD; n = 12), aged 4-6 years.

Children with SLI defined based on exclusionary criteria (Leonard, 2014):

- Normal hearing
- Performance in the normal range on the Columbia Mental Maturity Scale (CMMS)
- Impaired performance on Structured Photographic Expressive Language Test – Preschool 2 (87 or below; Greenslade, Plante, & Vance, 2009)

## Behavioral Data

Group	Age	Gender	CMMS	SPELT-P2/3	BB-ToP CI
SLI (n=12)	49-72 months (mean = 61.96)	5 female	103 (9)	77 (10)	72* (10)
TD (n=12)	48-67 months (mean = 59.92)	6 female	118 (8)	112 (11)	100 (9)

BB-ToP CI: Bankson-Bernthal Test of Phonology, Consonant Inventory Standard Score.  
\*Note: 10/12 (83%) of children with SLI demonstrate a phonological impairment with scores below 1 standard deviation below the mean.

### Fine/Gross Motor Assessment (Movement Assessment Battery for Children-2)

Group	MABC-2 Total	Manual Dexterity	Aiming & Catching	Balancing
SLI*	8 (3)	7 (3)	11 (3)	9 (4)
TD	11 (2)	10 (3)	11 (2)	12 (3)

\*Note: 6/11 (55%) of children with SLI demonstrate an overt motor impairment with scores below 1 standard deviation below the mean.

### Oral Motor Assessment (Robbins and Klee, 1987)

Group	Structural Score	Functional Score
SLI*	23 (1.5)	75 (4.6)
TD	24 (0)	109 (1.9)

\*Note: 2 children with SLI demonstrate structural deficits, and all 12 children with SLI demonstrate functional deficits. All children in the TD group were considered within normal ranges.

## Experimental Task – Extended Nonword Repetition

**Stimuli:**

p^vgəb	p^btəm	b^pkəv
m^fɹəpəm	f^ʃpəm	f^spəb

All were low neighborhood density & low phonotactic probability.



**Structure:** Non-word repetition and novel word learning over the course of 3 sessions occurring at least 24 hours apart

**Recording:** High quality audio recording and movement tracking using Northern Digital 3D Investigator.

## Results

### Segmental Accuracy – Percent Consonants Correct (Shriberg, et al, 1997)

Group	PCC Session 1	PCC Session 2	PCC Session 3	PCC Total
SLI	59.5	60.4	60.4	60.3
TD	81.8	85.1	86.5	84.3

# target consonants produced / total # of target consonants \* 100

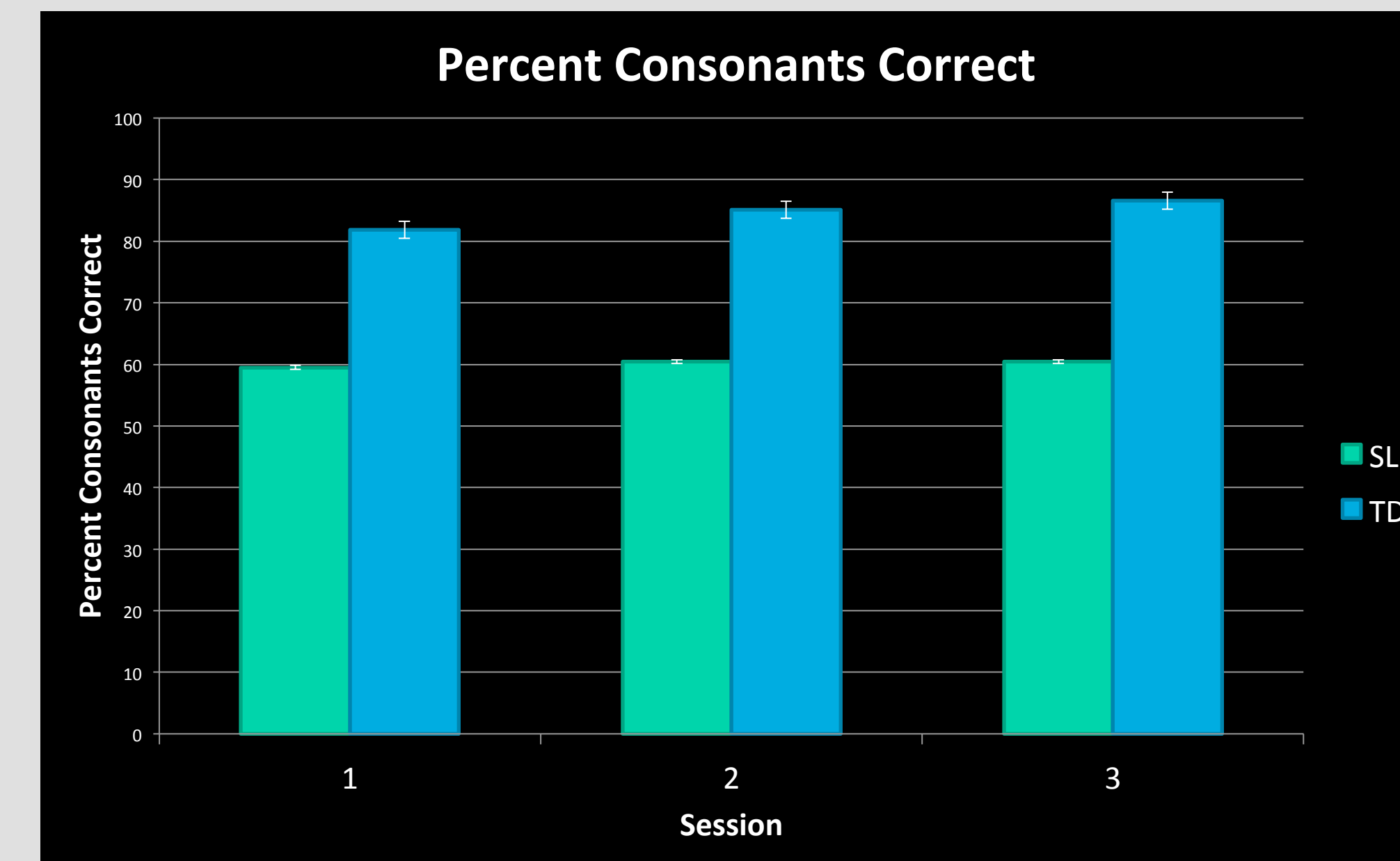


Figure 3. Significant group differences in accuracy across sessions (p<0.001). Session effect (p=0.02) with some learning over time.

### Segmental Variability – modified Inconsistency Severity Percentage (mISP; based on Iuzzini & Forrest, 2010)

Group	mISP Session 1	mISP Session 2	mISP Session 3	mISP Total
SLI	19.2	15.5	14.7	16.5
TD	14.5	12.9	11.9	13.1

# different phonemes by position across all targets / total # of target phonemes \* 100

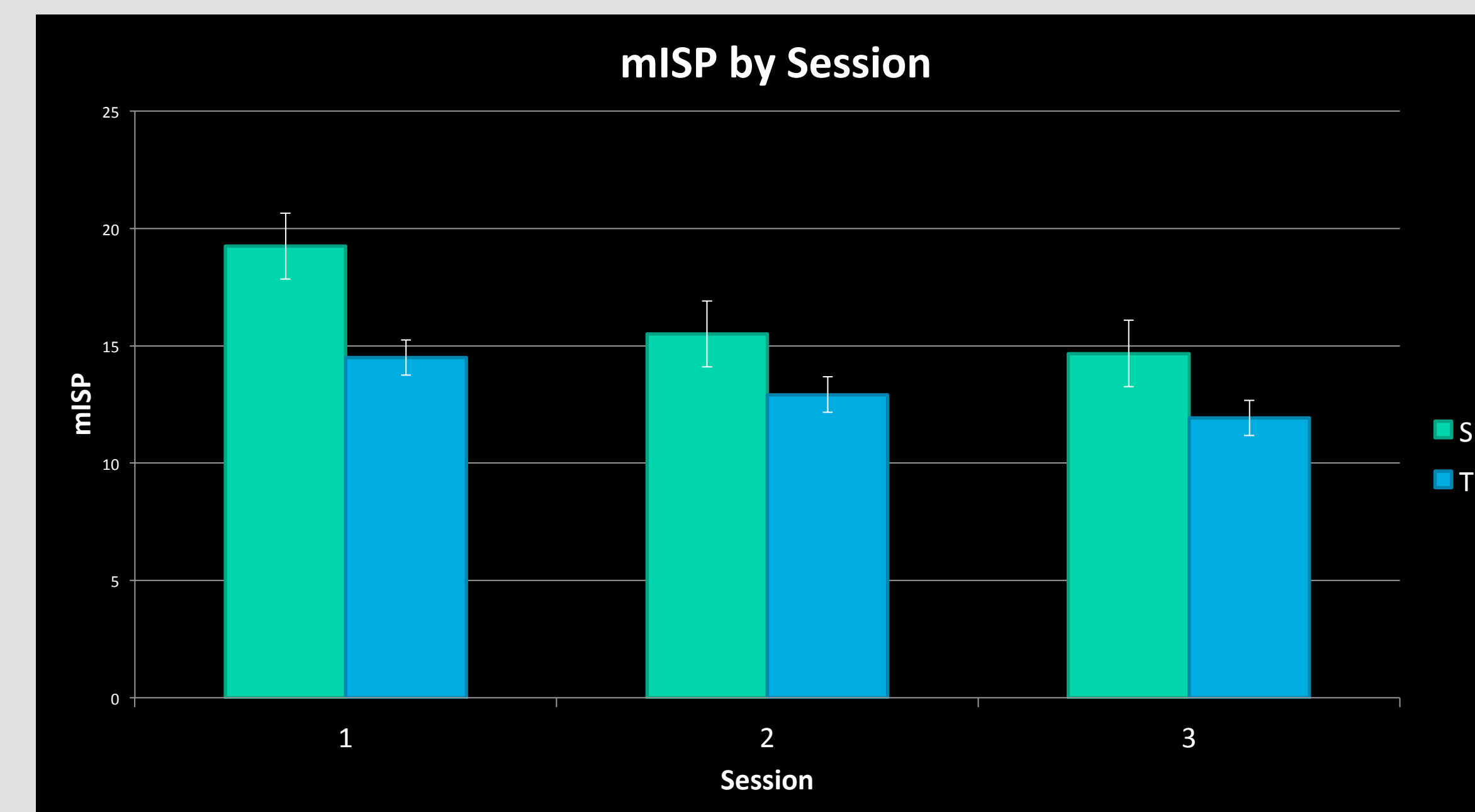


Figure 4. Significant group difference (p<0.001) in variability across sessions. Session\*group interaction (p=0.05), revealing narrowing of group differences by session 3.

### Kinematic Analysis – Spatiotemporal Index (STI)

Lip aperture (upper lip-lower lip)

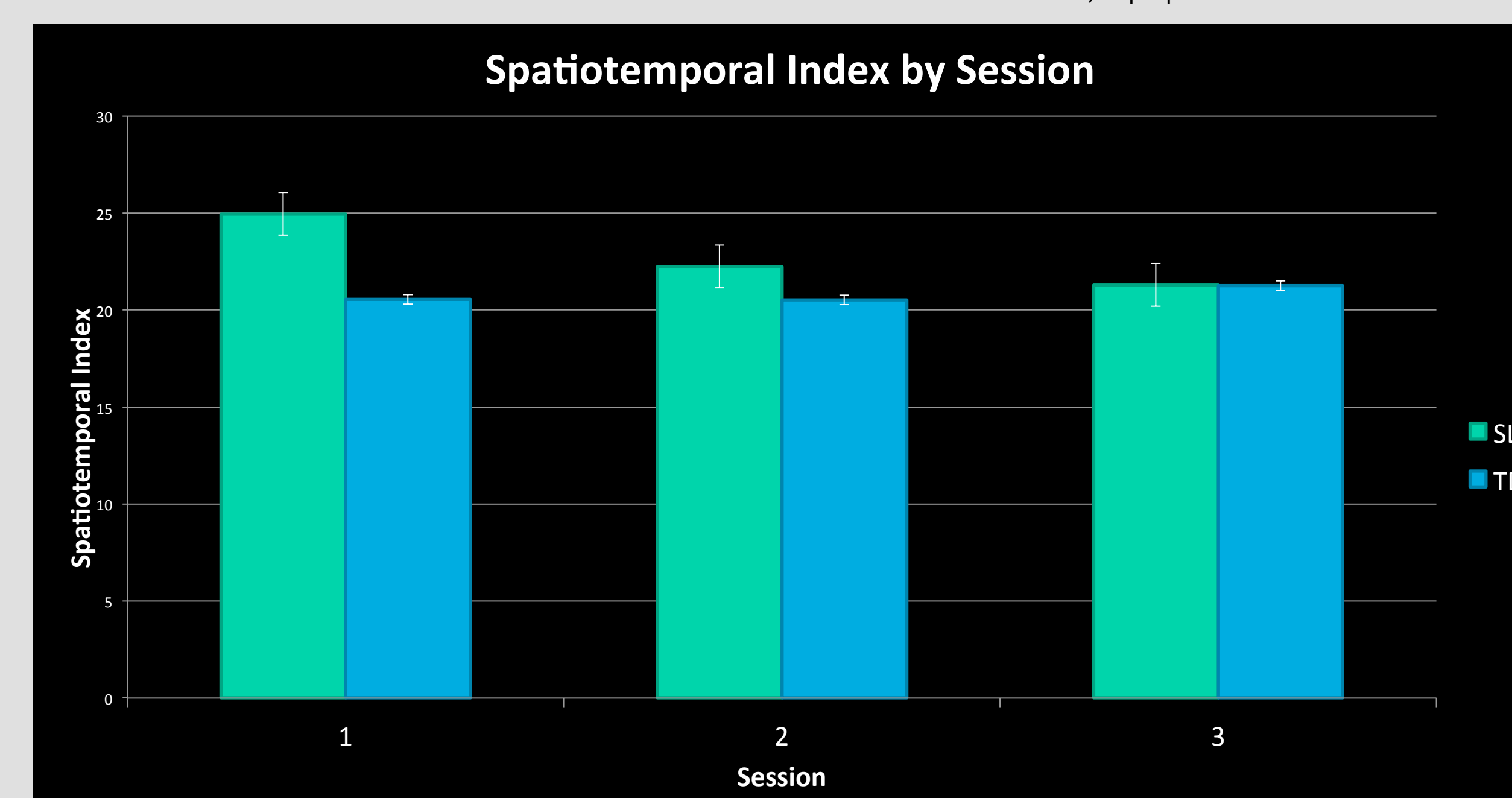
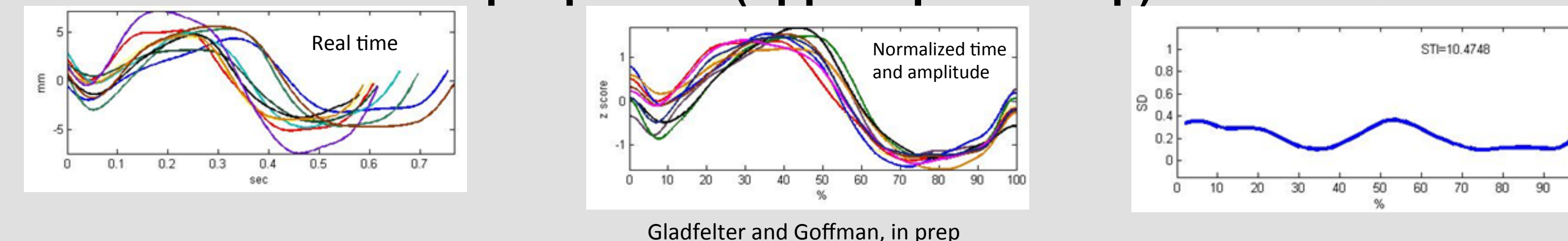
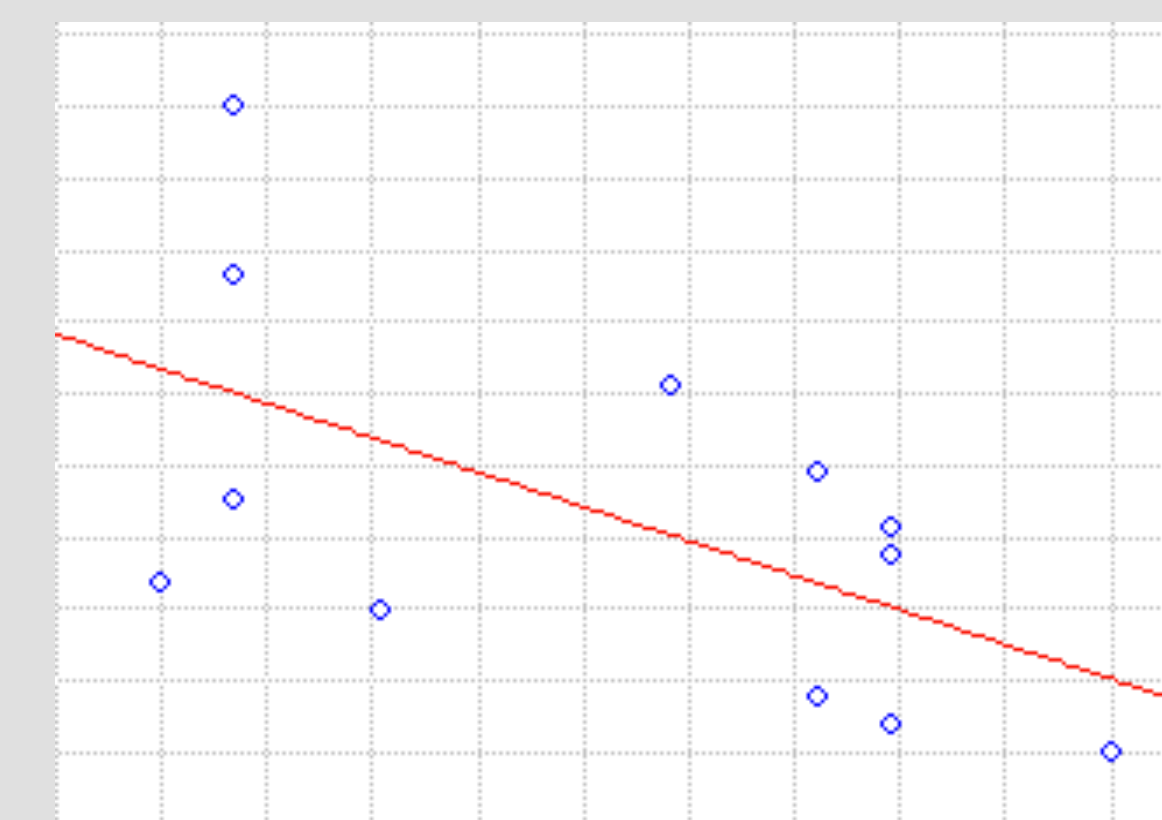


Figure 5. No overall group differences in kinematic variability (p=0.32), but session\*group interaction (p=0.008), revealing that groups converge by session 3.

### Correlation Analyses

Significant



Functional Oral Motor Score x mISP = -0.58

Not Significant

	PCC	STI	mISP
PCC			
STI	-0.03		
mISP	-0.15	0.19	

No significant correlations between kinematic variability, segmental variability, or segmental accuracy.

Interestingly, there was no significant correlation between fine/gross motor skill and oral motor skill (-0.17).

## Discussion

- As compared to typically developing same-aged peers, children with SLI demonstrate predicted deficits in accuracy, and segmental and articulatory variability. However, when exploring the interactions among these areas, children with SLI appear to demonstrate differential developmental trajectories within each domain, with no single system implicating the others.
- One interpretation is that the relationship between these variables may be attributed to higher-order processes that support linguistic and non-linguistic functions such as sequencing, timing and coordination (Vuolo, Goffman, & Zelaznik, in review).
- Given the different patterns of convergence when examining the time course for accuracy and variability, a new approach to analyzing the dynamics of phonological and motor skill is needed. Network science provides one such alternative, as it has the ability to capture and map patterns of variability in a dynamic and visually salient manner.

### Clinical Implications:

- Children with SLI may benefit from specialized treatment programs that tap into higher order processes that support the skills required for speech and language function.

### Future Directions:

- Further examine the relationship between oral motor skill and segmental variability.
- Develop network analyses to further characterize speech production in children with SLI.

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