# Testing the Validity of a new measure of rehearsal

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## BACKGROUND

- Rehearsal, the silent repetition of words, improves memory.

- Adults use rehearsal with little effort[1]. However, children consume attentional resources when rehearsing[2]. Also, inefficient rehearsal is likely related to memory deficits observed in children with atypical language development[3].

- Neither normal variation in rehearsal developmental nor how rehearsal becomes an attention-free process is understood because the conventional behavioral assessments of rehearsal:
  1. are more effective for group comparisons than for understanding individual variation, and
  2. require specific stimuli or impose unnatural task demands, making it difficult to assess rehearsal use across situations.

## PURPOSE

LONG-TERM GOAL: Identify individual children's memory weaknesses and create personalized interventions to encourage strategy use for improving memory.

PROBLEM: Current techniques for identifying the use of memory strategies are insufficient for application in children, especially young children and children with atypical language.

**CURRENT AIM**: Assess the validity and reliability of using surface electromyography (sEMG) as a measure of children's rehearsal strategies.

## PARTICIPANTS

**EXP 1:** 39 children in each of three age groups. Children must:
- Be 7.5, 8.5, or 9.5 years old
- Live in a home in which English is the primary language
- Be free of known developmental, cognitive, or neurological diagnoses
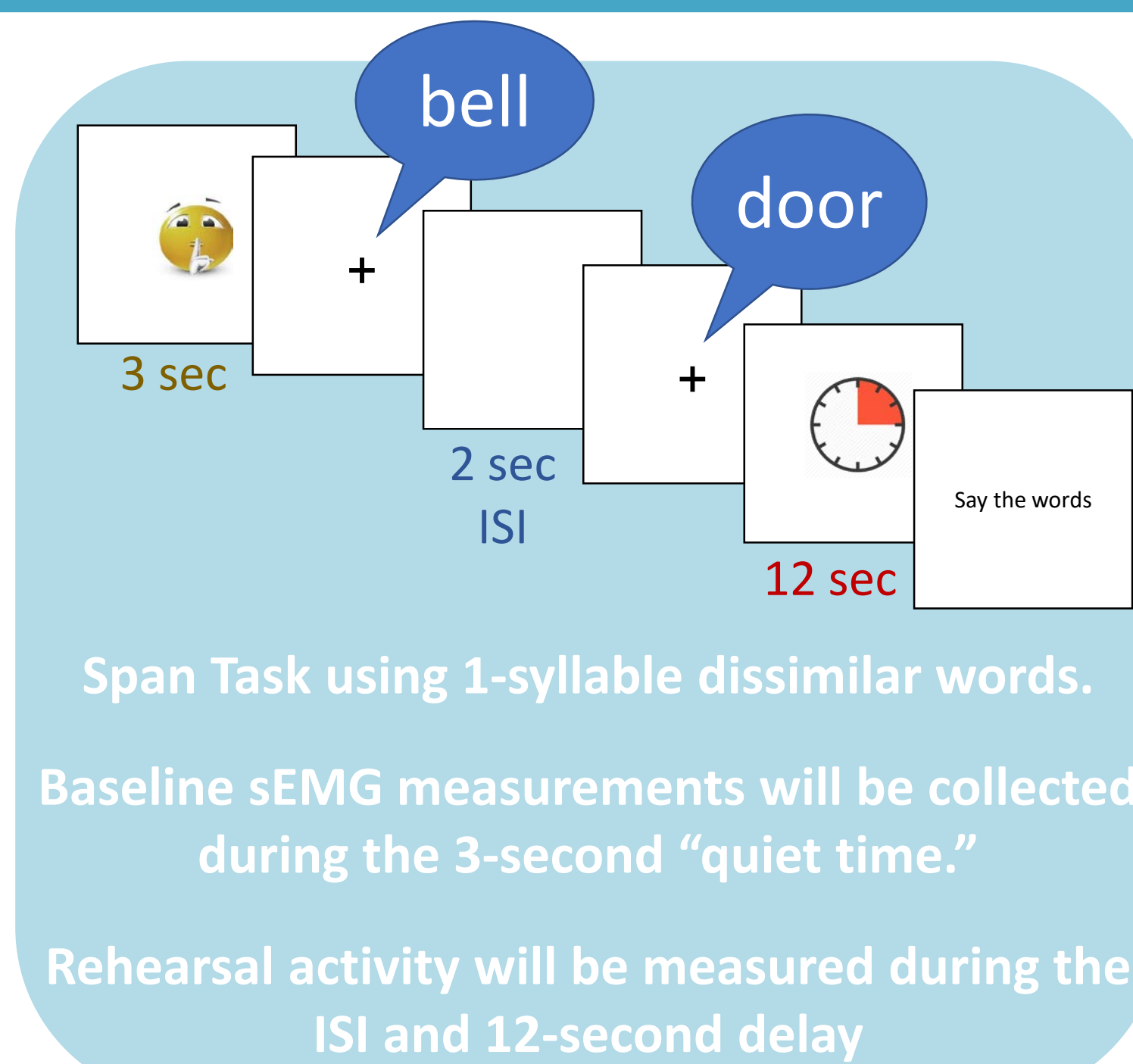- pass hearing and vision screenings.

**EXP 2:** Five children in each age group will return for reliability testing.

## PROCEEDURE

Six adaptive span tasks and an articulation rate measure, together, can be used to calculate rehearsal in the four conventional ways described earlier.

All lists start with 2 items and get progressively longer until participant errs out.

(1) auditory digit span
(2) 1-syllable / dissimilar words
(3) visual digit span in silence
(4) 3-syllable words
(5) visual digit span under articulatory suppression
(6) Similar words
(7) articulation rate of digits



Span Task using 1-syllable dissimilar words.

Baseline sEMG measurements will be collected during the 3-second "quiet time."

Rehearsal activity will be measured during the ISI and 12-second delay

## CONVENTIONAL BEHAVIORAL MEASURES

### ARTICULATION RATE

- Used as a proxy for rehearsal speed.
- Can be used across situations (e.g. calculated separately for different languages in bilingual participants)
- Group level articulation rate means are correlated with mean memory span[4].
- Correlations are not consistently observed within smaller age-ranges.

### PHONOLOGICAL SIMILARITY EFFECT

- Similar sounding words (e.g. *bat*, *bag*, *mat*, *man*) are harder to remember in order than different sounding words (e.g. *fork*, *bell*, *clock*, *door*).[5]

### WORD LENGTH EFFECT

- Short words (e.g. *fork*, *bell*, *clock*, *door*) are better remembered than long words (*ambulance*, *kangaroo*, *butterfly*, *umbrella*)[4].
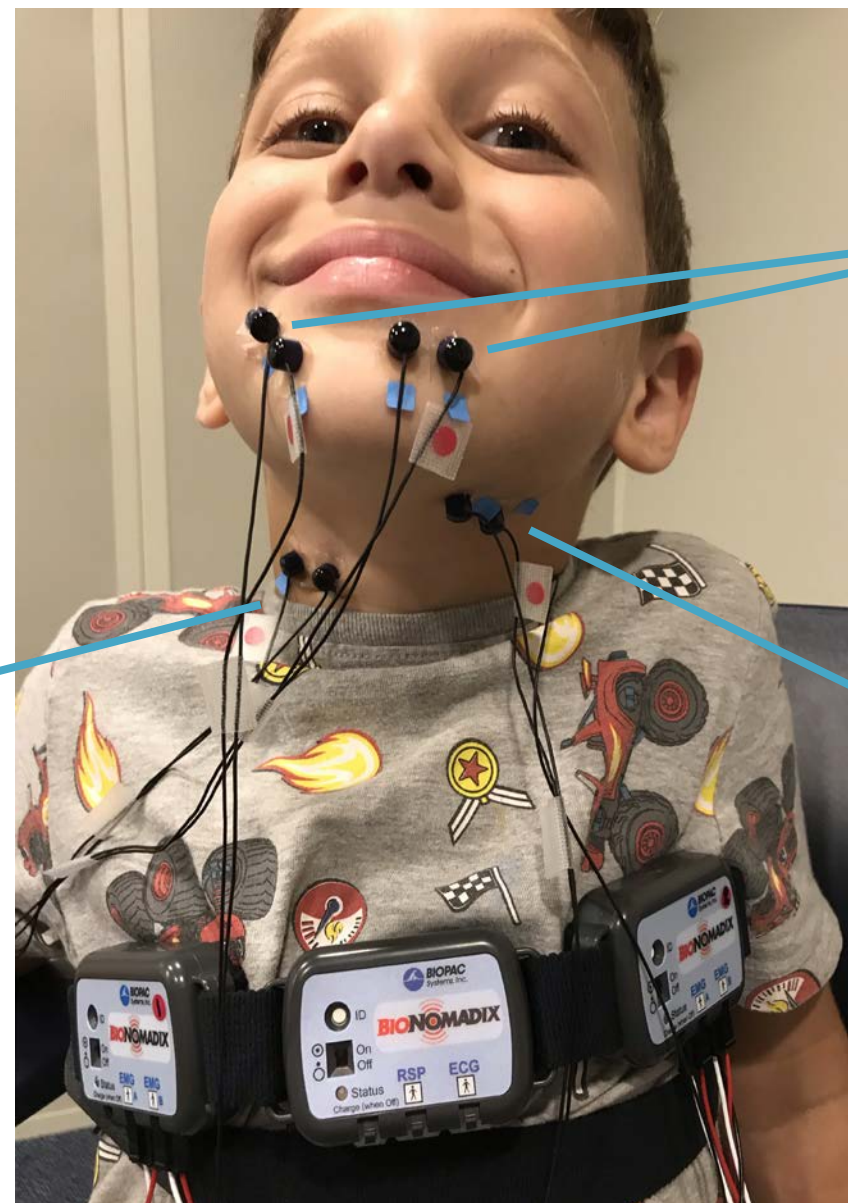
### ARTICULATORY SUPPRESSION

- Participant speaks (e.g. "ba, ba, ba") while trying to remember a list of visually presented items.
- Speech-production system (pre-motor cortex to articulators) unavailable for rehearsal.
- Eliminates rehearsal-related phenomena
  - Phonological Similarity Effect[6]
  - Word Length Effect[6]
  - Irrelevant Sound Effect[7]

## SURFACE ELECTROMYOGRAPHY

One goal is to determine the proper weighting of the four active electrode sites such that they can be averaged to provide a single estimate of the quantity of rehearsal.

For each site, sEMG signal will be analyzed as root-mean-squared percent increase over baseline (computed in 1500 ms windows).



**two sites around the mouth** activation of depressor anguli oris and depressor labii inferiori

**medial anterior neck surface** activation of the superficial neck "strap" muscles (sternohyoid and omohyoid) control vertical position of larynx

**submental space under chin** combined activation of the digastric, mylohyoid, geniohyoid Tongue movement

## STATISTI CAL APPROACH

**EXP 1:** Calculate the correlations between sEMG activity and the four conventional rehearsal measures:

- articulation rate with sEMG during auditory digit span.
- Word Length effect with sEMG during 1-syllable words
- Phonological Similarity Effect with sEMG during dissimilar words.
- Articulatory Suppression with sEMG during digits in silence

$$\text{WORD LENGTH EFFECT} = \frac{(1 \text{ syllable} - 3 \text{ syllable})}{1 \text{ syllable}}$$
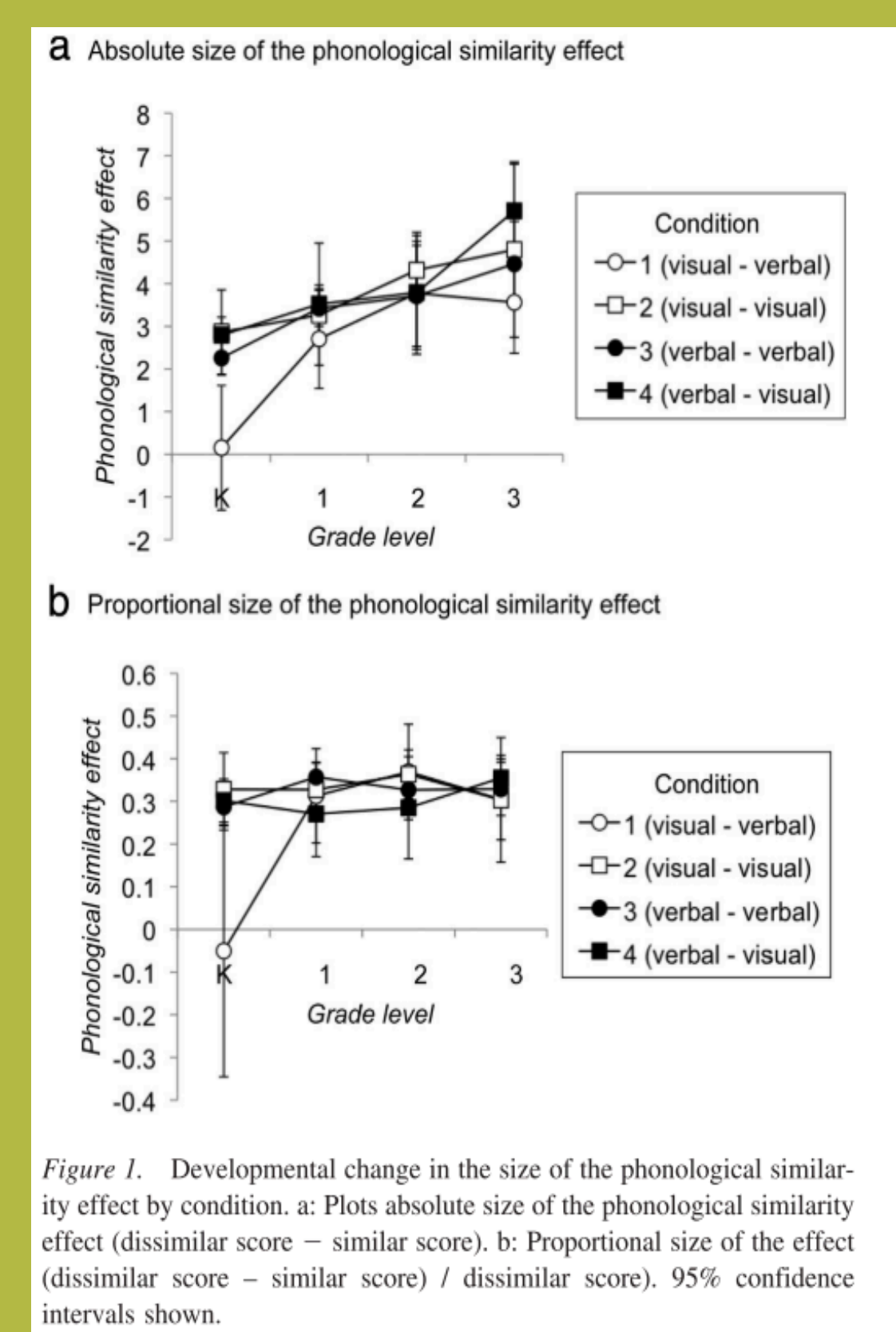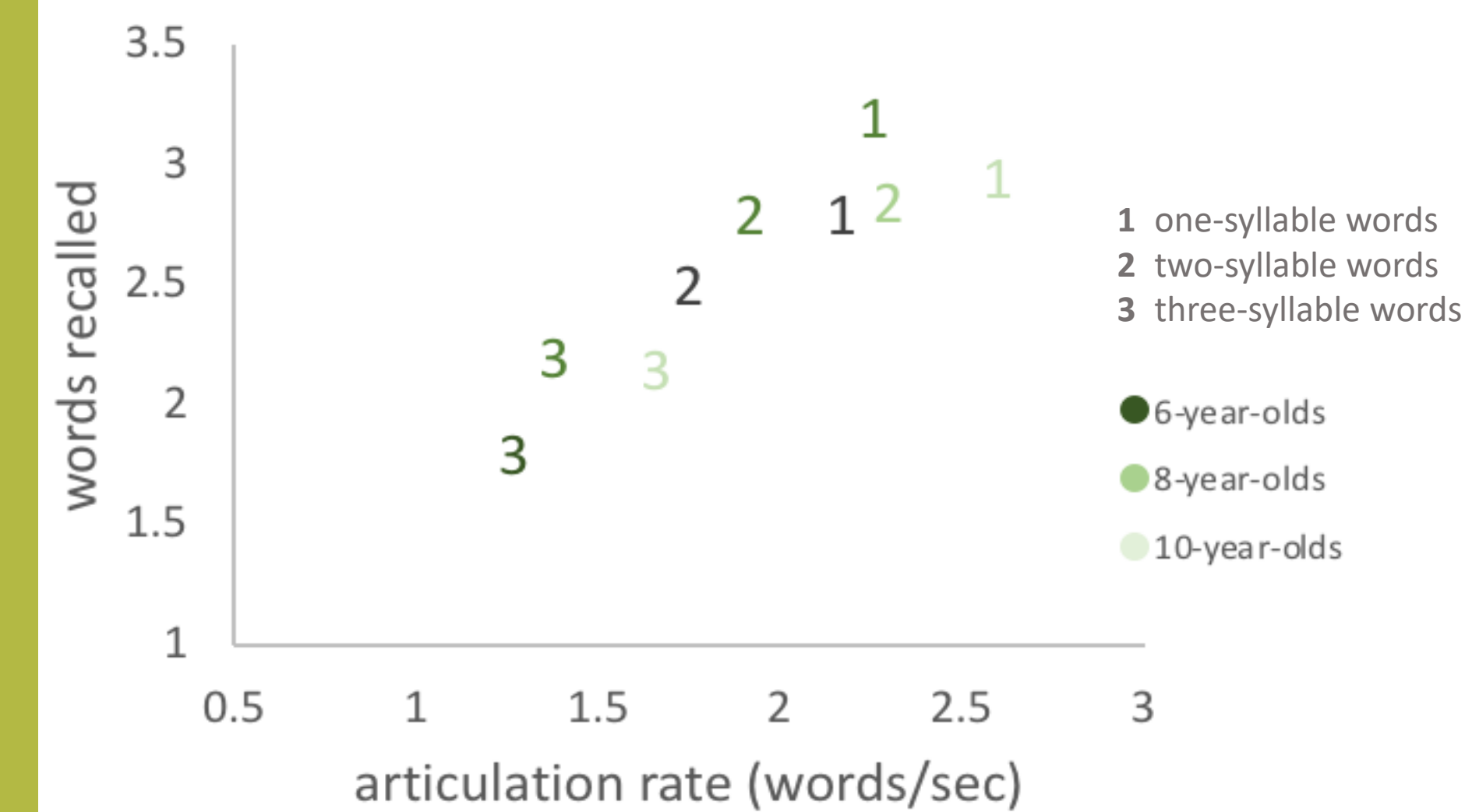
$$\text{PHONOLOGICAL SIMILARITY EFFECT} = \frac{(\text{dissimilar} - \text{similar})}{\text{dissimilar}}$$

$$\text{ARTICULATORY SUPPRESSION} = \frac{(\text{visual digits in silence} - \text{visual digits with AS})}{\text{visual digits in silence}}$$

**EXP 2:** Assess whether the proportionalized scoring procedure[5] is more reliable than simple subtraction by comparing scores at Time 1 and Time 2 using the concordance correlation coefficient.

Jarrold et al. (2008) report Phonological Similarity Effects beginning at Grade 1, *but only when using a proprotionalized scoring method.*

Data from Hitch et al. (1989) illustrate that – at the group level – articulation rate correlates with memory span. Additionally, fewer long words (3-syllable) are recalled than short words (1-syllable), a marker of the Word Length Effect





*Figure 1.* Developmental change in the size of the phonological similarity effect by condition. a: Plots absolute size of the phonological similarity effect (dissimilar score – similar score). b: Proportional size of the effect (dissimilar score – similar score) / dissimilar score). 95% confidence intervals shown.

## EXPECTED OUTCOMES

**EXPERIMENT 1:**

(1) sEMG activity will correlate with each of the four conventionally acquired rehearsal estimates

(2) Correlations will be weakest in the 7.5-year-old age group as younger participants are likely not consistent in their use of rehearsal across tasks

(3) Within all age groups, but particularly the 7.5 year-old, articulation rate should have the weakest correlation with the other measures. articulation rate is only a proxy for rehearsal speed if the participant actually rehearses. A child who does not rehearse should have a low proportionalized score on the other three tasks; yet there is no reason to presume that non-rehearsers would have the slowest articulation rates.

**EXPERIMENT 2:**

(1) Although reliability has never been quantified in the four conventional measures, the associated effects have been well replicated in the adult literature. Therefore, we would expect all of the measures to be reliable.

(2) We expect proportionalized scores to be at least as reliable as subtraction scores.

## NEXT STEPS

(1) Use sEMG to capture individual differences in children's rehearsal use.

(2) Investigate the role of attention in rehearsal develop by determining if children continue to rehearse when task complexity increases.

(3) Determine if the timing of children and adult's sEMG activity during silent retention mimics the characteristic timing patterns seen in adults recall during the use of more sophisticated memory strategies

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