18-month-olds compensate for a phonological alternation

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39th Boston University Conference on Language Development
November 7-9, 2014

Context-dependent variation

- In word recognition, listeners are sensitive to phonetic detail[1,2]
  - Sensitive to *degree* of mismatch between surface form and lexical representation[2]

- However, some phonetic variation must be ignored in the process of word learning.
  - **Context-dependent phonological variation**

e.g. [1] Swingley, 2009, [2] White & Morgan, 2008

Tapping in American English

- Word-final /t/s and /d/s can surface phonetically as a tap (or ***flap***), [ɾ]

- Most commonly occurs when the following word begins with an unstressed vowel e.g. *again* or *in*[3,4,5]
  - E.g. *bat again* → [*bæɾ#əgɛn*]

- Results in many-to-one mapping between legal surface forms and underlying lexical items - context-dependent, predictable

[3] Oshika, Zue, Weeks, Neu & Aurbach 1975, [4] Kahn, 1980, [5] Turk, 1992

Previous work on phonological variation

- Voicing assimilation in French:[6]
  - e.g. /bys **d**əvã/ → [byz **d**əvã] *bus devant*
  - 2 year-old French-learning toddlers successfully compensate for native voicing assimilation in a **preferential looking task *with training***
  - Also sensitive to context in which this process occurs

- But: 12 month-olds already successfully map surface [ɾ] to underlying /d/ in a **segmentation** study: *padding* → *pad*[7]

- Perhaps this ability is in place at an earlier age than 2 years?

[6] Skoruppa , Mani, Plunkett, Cabrol & Peperkamp, 2013b, [7] Sundara, Kim, White & Chong (under revision)

Experiment Overview

- **Do 18-month-old toddlers recognize familiar words produced with a surface tap in a word recognition task?**

- Intermodal Preferential Looking Experiment[8]
- Implemented using eye-tracking – SR Eyelink 1000 (Arm-mount)

- Experiment 1: Adults
- Experiment 2: 18-month-old toddlers

[8] Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987

Why 18 month-olds?

- Toddlers at 18-months of age can detect mispronunciations in coda position[1]

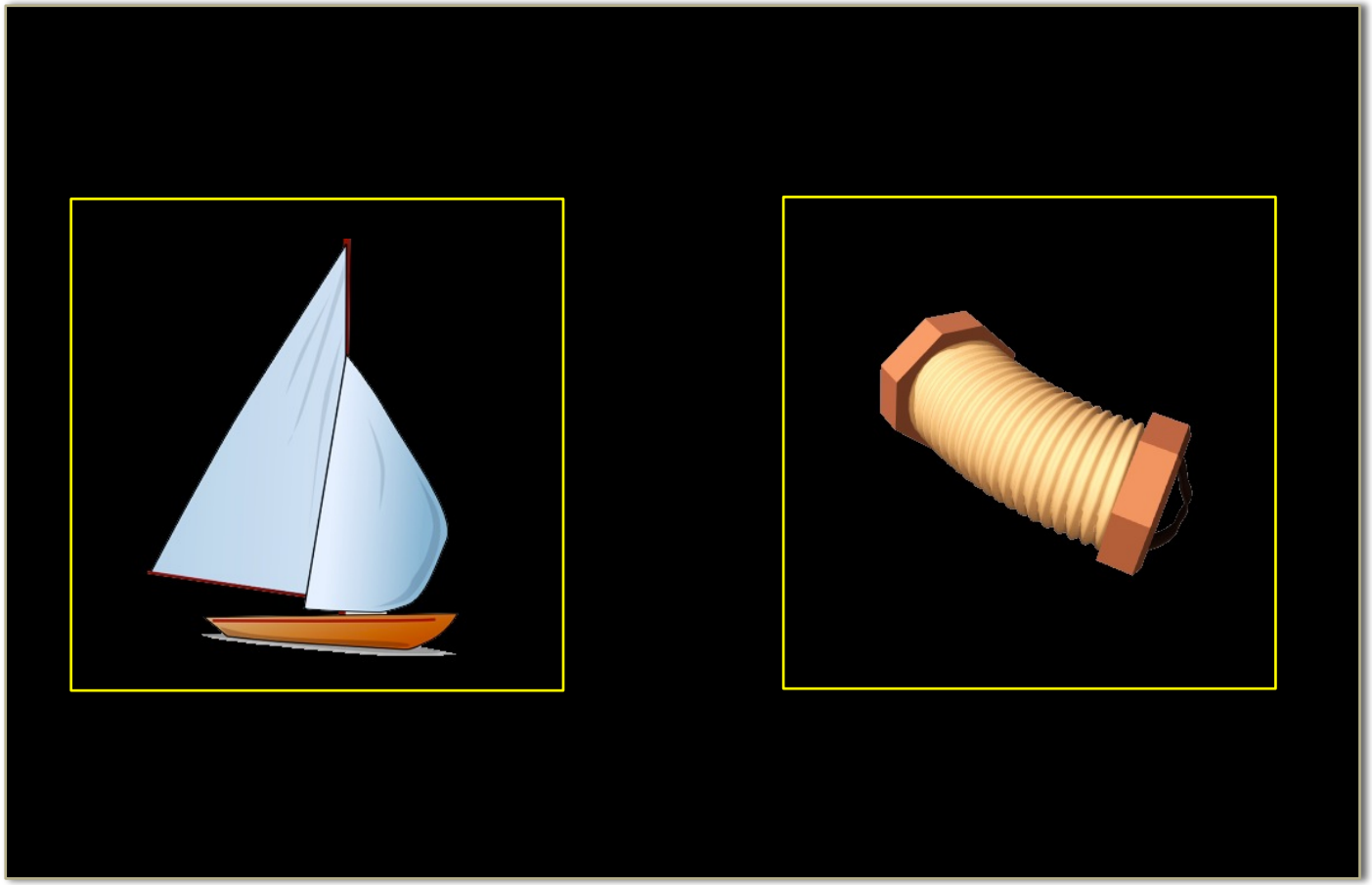
- Toddlers at this age are also sensitive to the degree of mismatch between mispronunciations and target lexical representations:
  - In onsets[2]
  - In codas[10]

∴ 18 month-olds are sensitive to phonetic detail in coda position during word recognition

[1] Swingley, 2009, [2] White & Morgan, 2008, [10] Ren & Morgan, 2011

Visual set-up

(following White & Morgan, 2008)



Stop

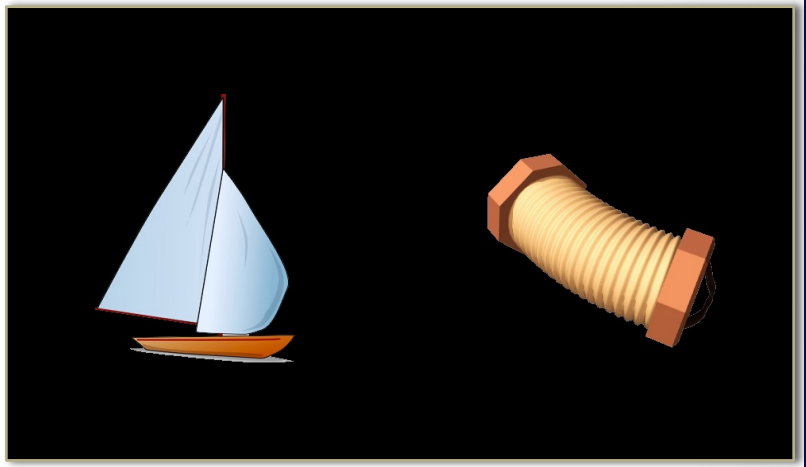
Mispron.

Novel

Tap

General procedure

- Baseline Phase (4s)
  - Pair of images shown
  - No audio stimulus
  - Establish baseline preferences



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Re-centered

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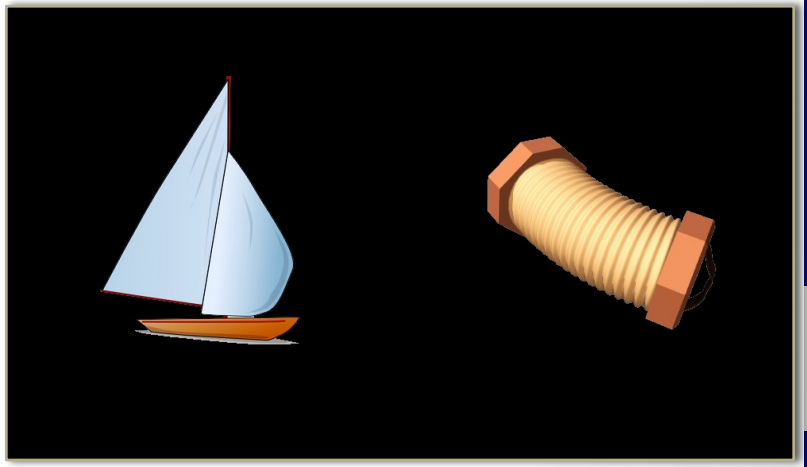
- Test Phase
  - Same pair of images
  - Same location
  - Simultaneous presentation of audio



Target words

- Target words:
  - 6 /t/-final words: *bat, cat, foot, plate, hat, boat*
  - 6 /d/-final words: *bed, slide, food, cloud, bread, bird*
  - All picture-able words known by 18 month-old toddlers
- 4 Non-words: *lif, neem,*[10] *bize, dape*[11]

- No target word is repeated twice in stop and tap condition: only 3 target words in each condition.

- Only half of the target words appeared in MP condition in each expt. group

- Words are embedded sentence-medially – an environment that makes processing difficult[12]

[10] Stager & Werker, 1997, [11] Albright & Hayes, 2003, [12] Plunkett, 2005

Audio stimuli

- Recorded by phonetically-trained female native speaker of American English – IDS

- Recorded in two sentence frames:
  1. *Look for the X Sam lost!* (Expt. 1) or *Look for the X now!* (Expt. 2)
     - Context that favors stop production (= Stop condition)
  2. *Look for the X again!*
     - Context that favors tap production (= Tap condition)

- Stop and tap variants only presented in the frame that supports the alternation

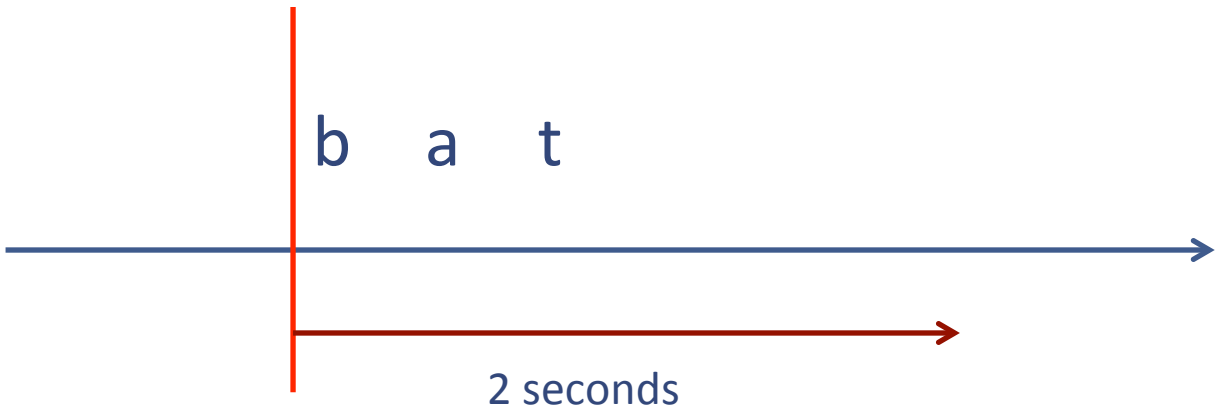
- Mispronunciations (MP) and novel items were produced in both frames

Experiment 1: Adults

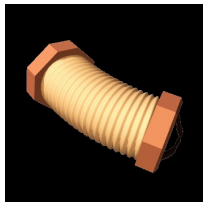
- 32 subjects (recruited from UCLA Psych Subject Pool)
- Native speakers of American English
- Trials were excluded if baseline fixation proportions < 10% or > 90%
  - Subjects excluded if more than half of their trials were not useable (n = 3)

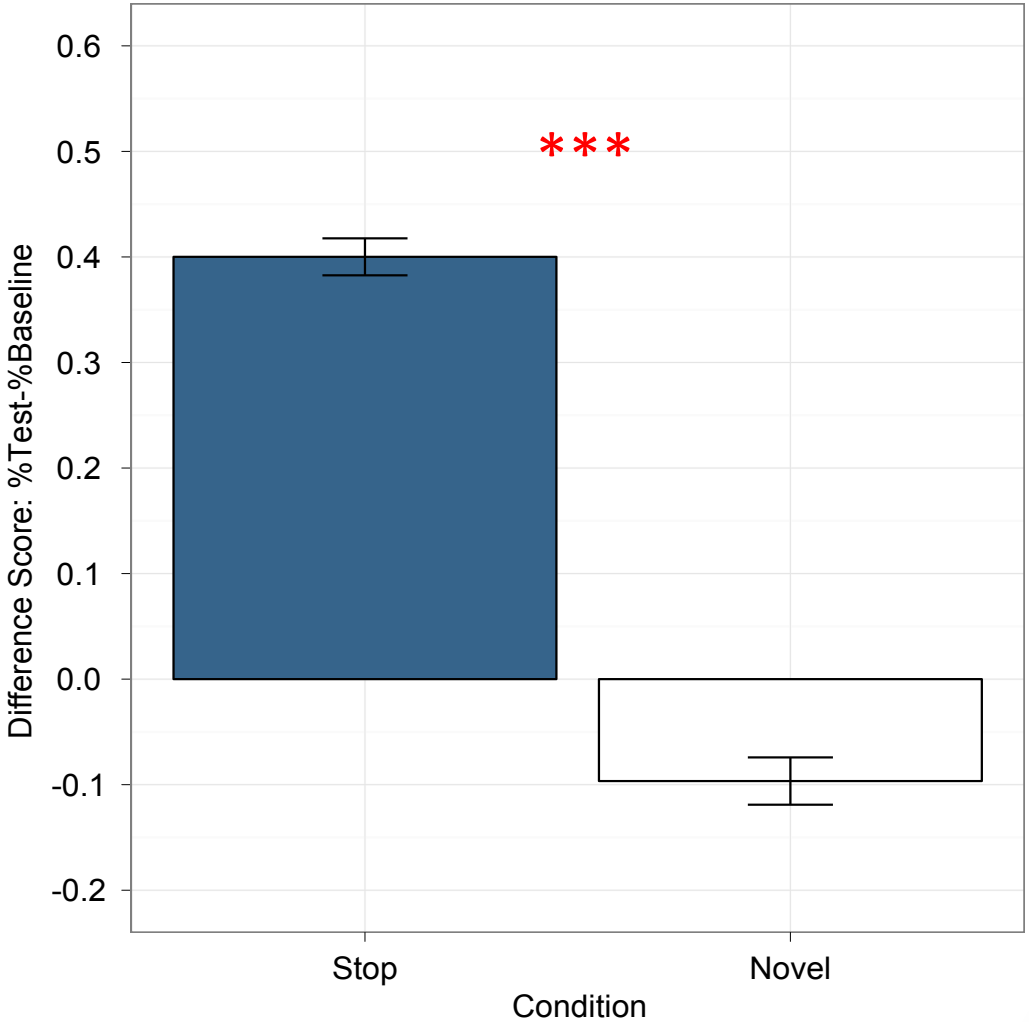
Analysis I: Stop vs. Novel

- **Difference score: <u>%Test - %Baseline</u>**
- **Baseline:** Measured proportion of looks to target in 4 s phase
- **Stop vs. Novel:** Measured proportion of looks to target in a 2 second window from the **<u>start</u>** of the target word



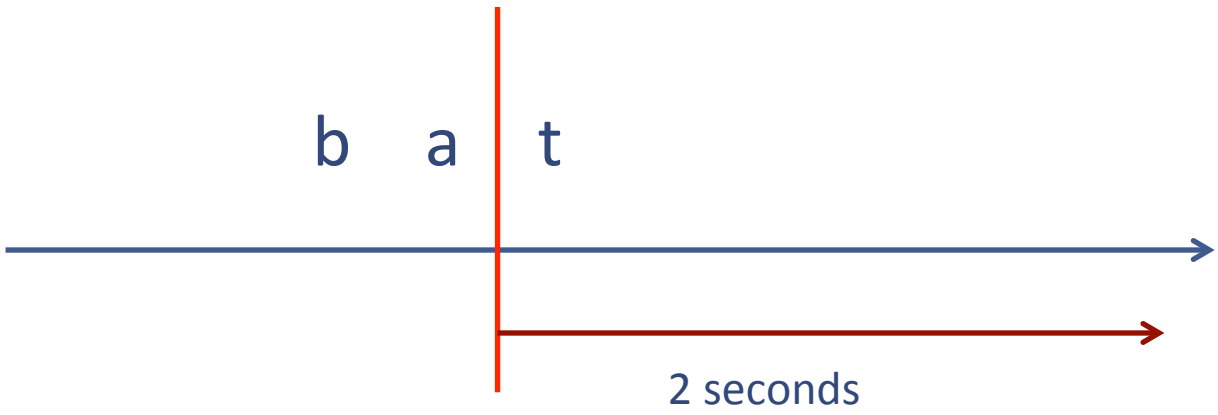
Exp. 1: Results – Stop vs. Novel



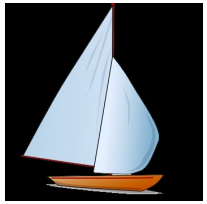


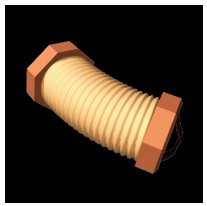
Analysis II: Stop vs. Tap vs. MP

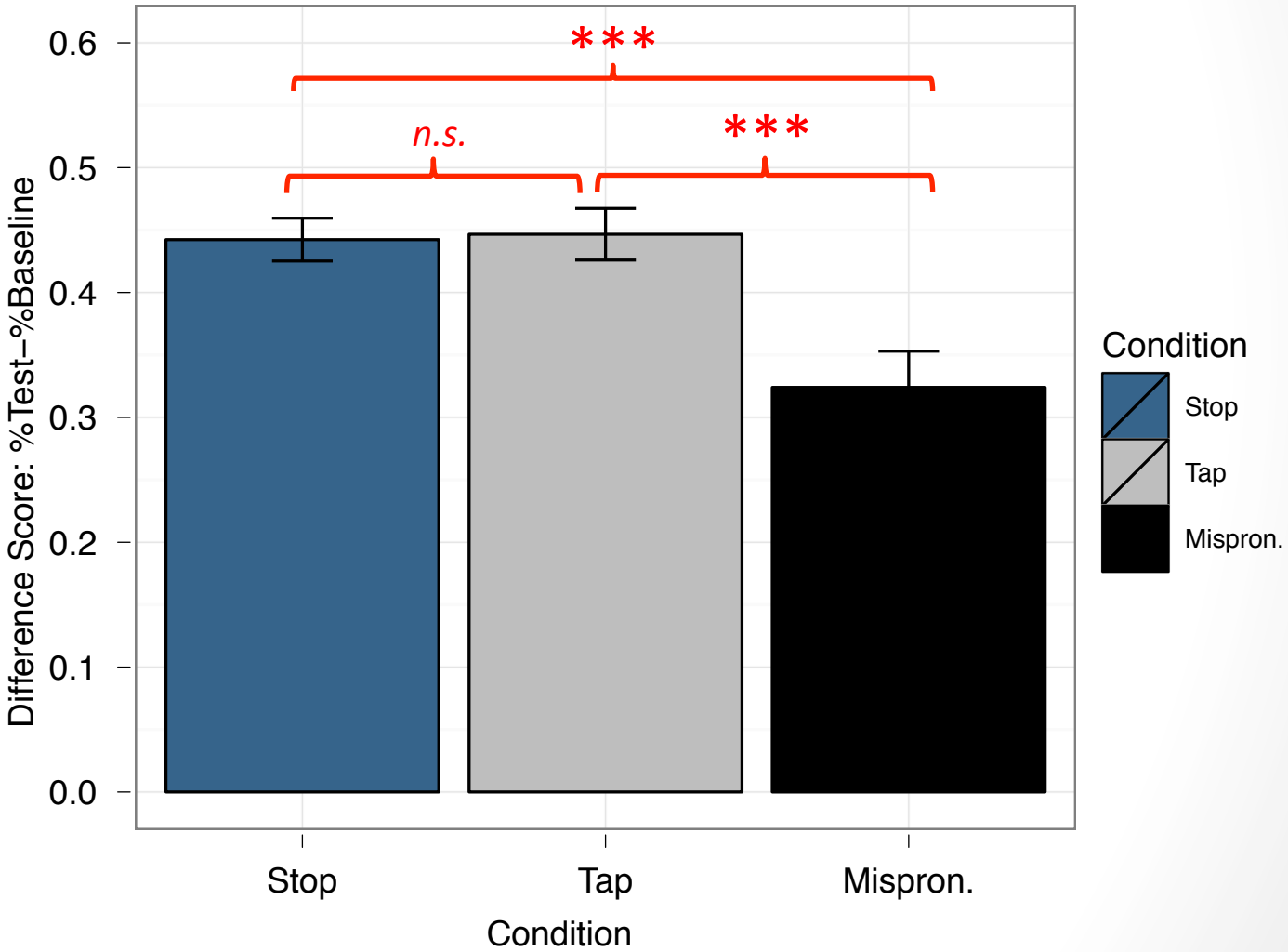
- **Stop vs. Tap vs. MP:** Measured proportion of looks to target in a 2 second window from the **coda** of the target word



Exp. 1: Results – Stop, Tap and MP







Interim summary

- Adults recognize words equally well with stop and tap variants
- Adults accept mispronunciations as labels for target objects,
  - Not to the same degree as for stop and tap variants
- Gives us a baseline from which to compare the 18-month-olds

Experiment 2: 18 mo. Toddlers

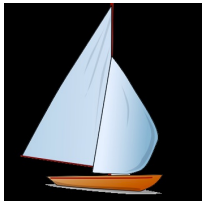
- 38 English-learning toddlers (mean age: 18.2; range: 17.6: 20.2)
- Only included trials in which words were familiar to the child
  - Post-hoc questionnaire
- Trials were excluded if baseline fixation proportions < 10% or > 90%
  - Subjects excluded if more than half of their trials were not useable (n = 8)

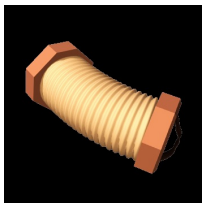
Predictions from adult data

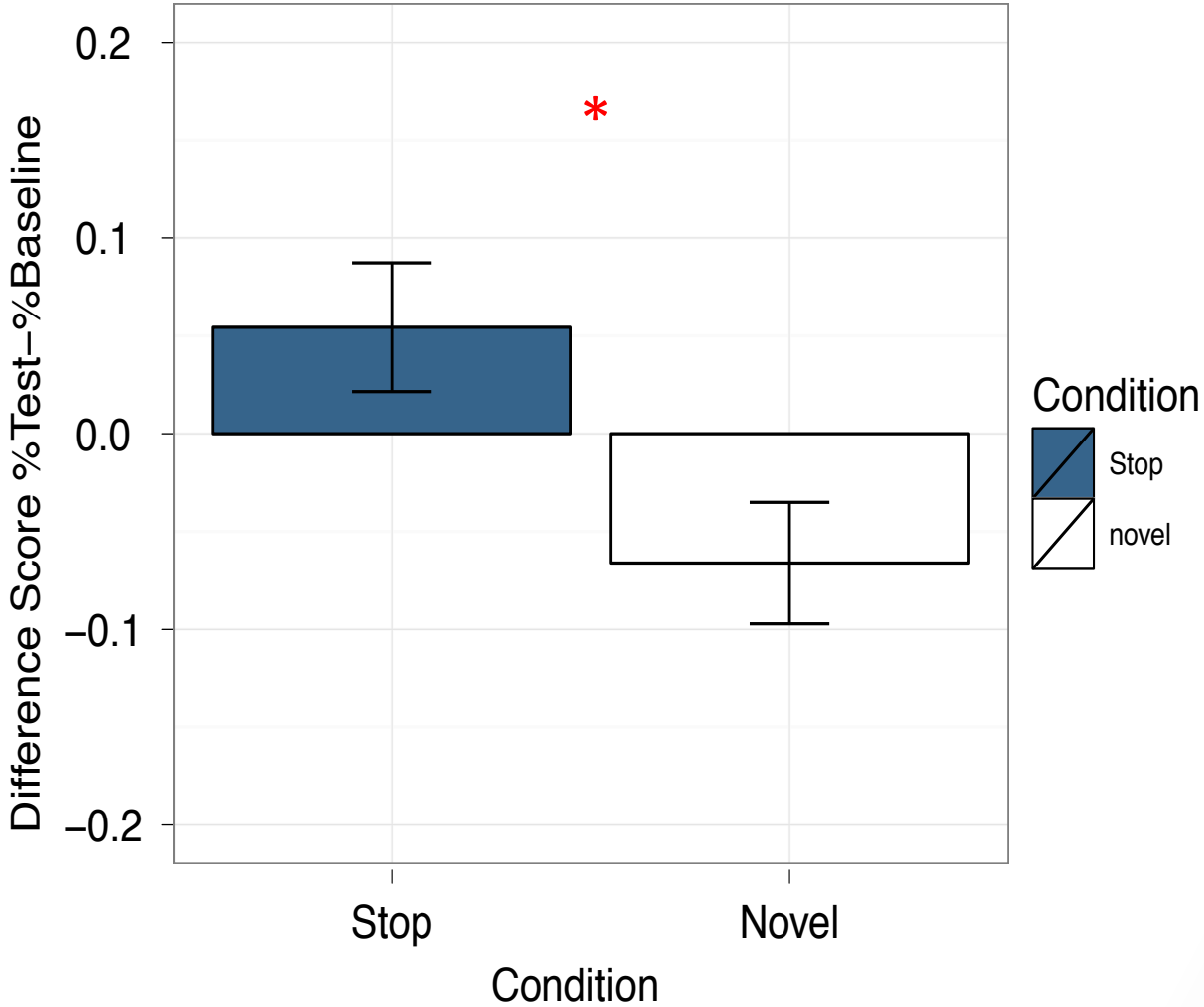
- Stop vs. Novel:
  - Look ***more*** to the target in **Stop condition** than **Novel condition**

- Stop vs. Tap vs. MP
  - Look ***more*** to the target in **Stop condition** than in **MP condition**
  - Look ***more*** to the target in **Tap condition** than in **MP condition**
  - Look ***equally*** to target in both **Stop** and **Tap conditions**

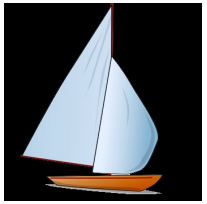
Exp. 2: Results – Stop vs. Novel

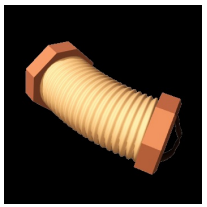


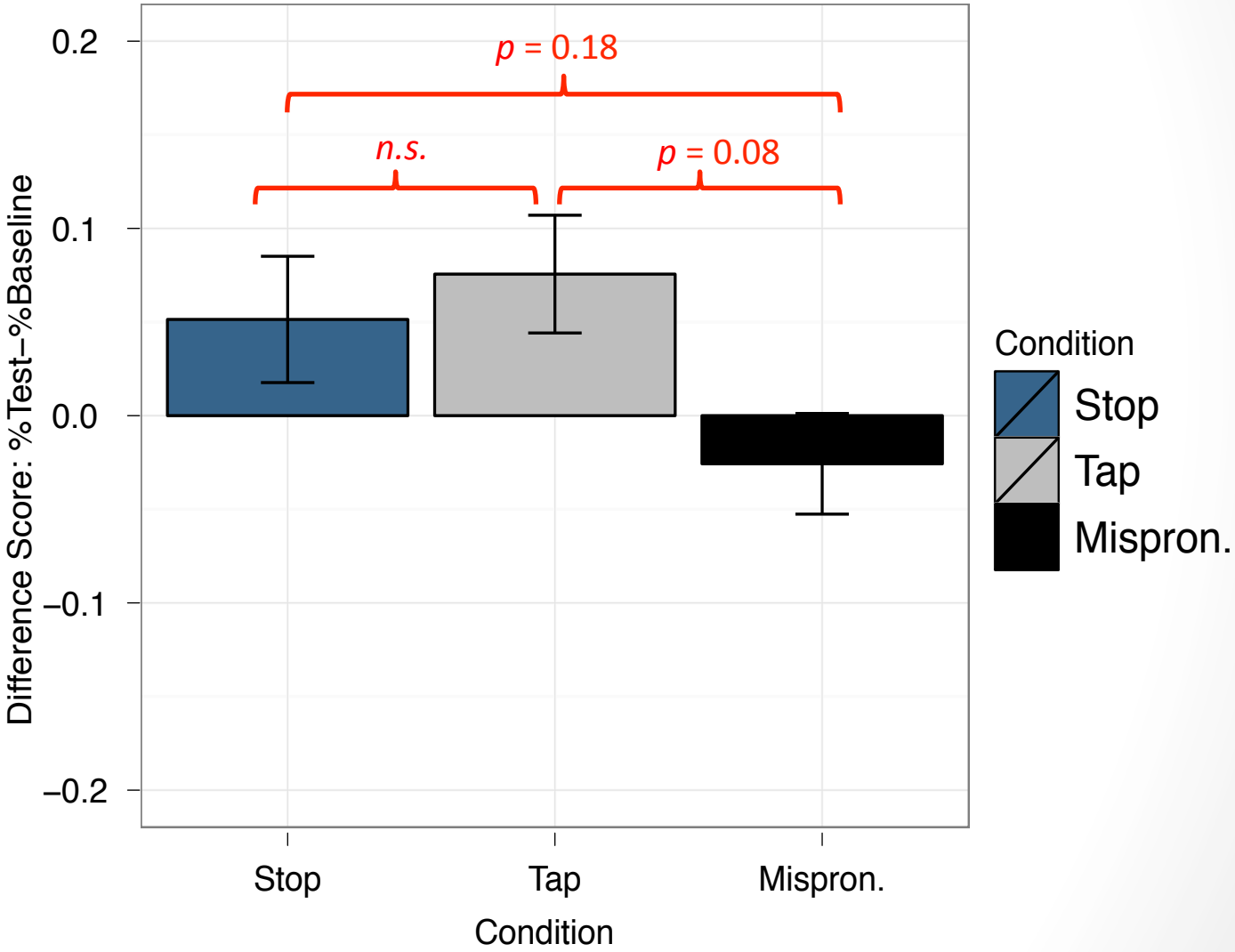




Exp. 2: Results – Stop, Tap and MP



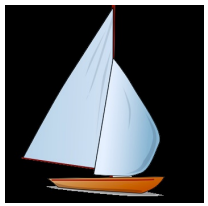


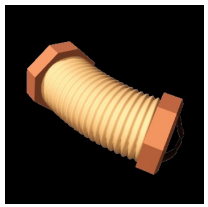


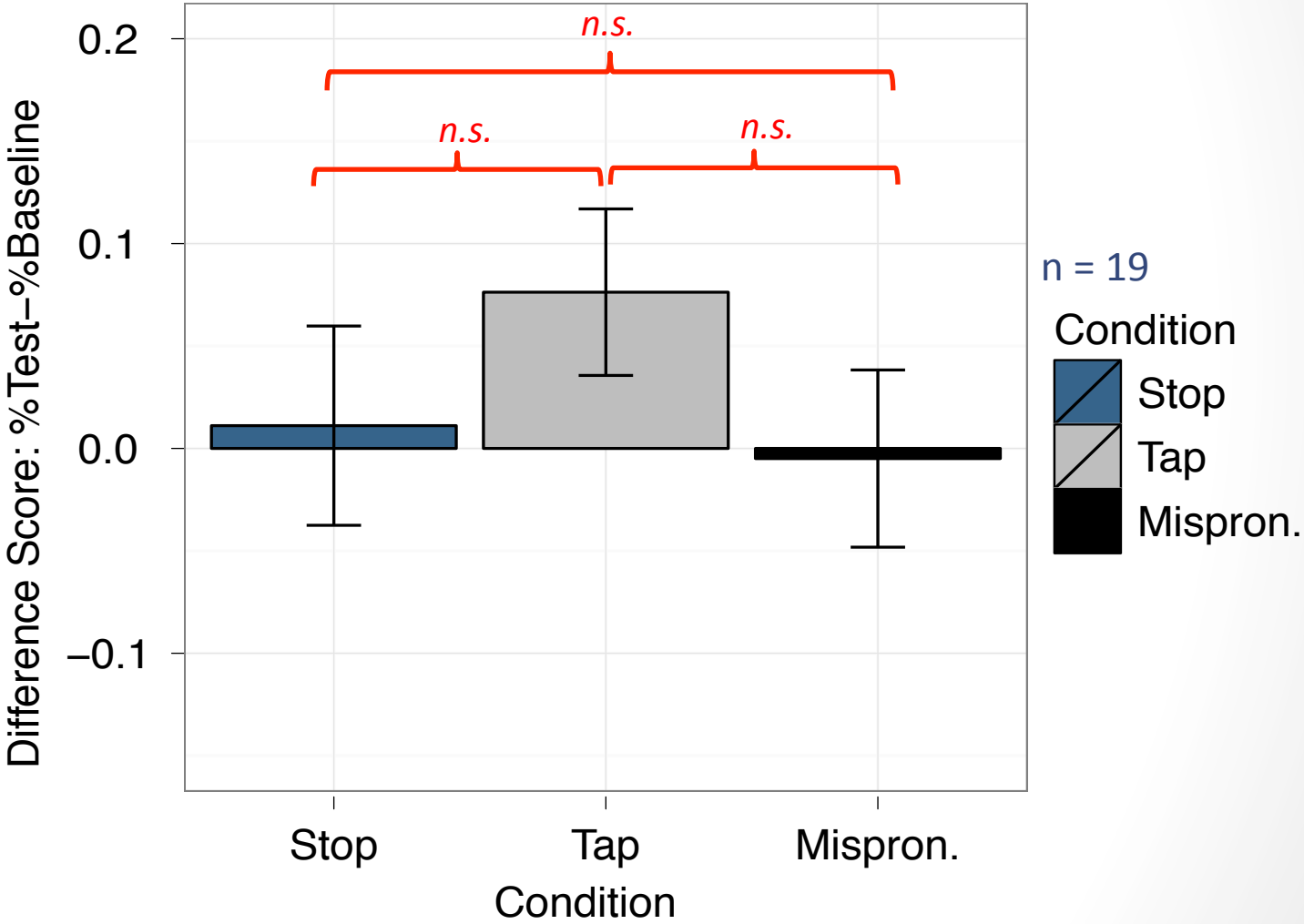
Effects of vocabulary?

- Why poor performance on stop trials (correct pronunciation)?
- This may be due to the sentence medial, pre-consonantal context
  - Cues to the segment might be obscured (e.g. weaker stop burst)
- Is the poor performance on stop trials attributable to a subset of the participants?
- **Median split of production raw scores (CDI)**

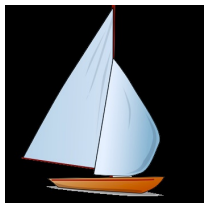
Exp. 2: Results – low CDI (Raw)

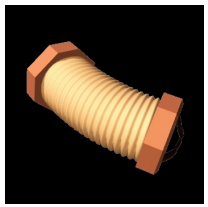


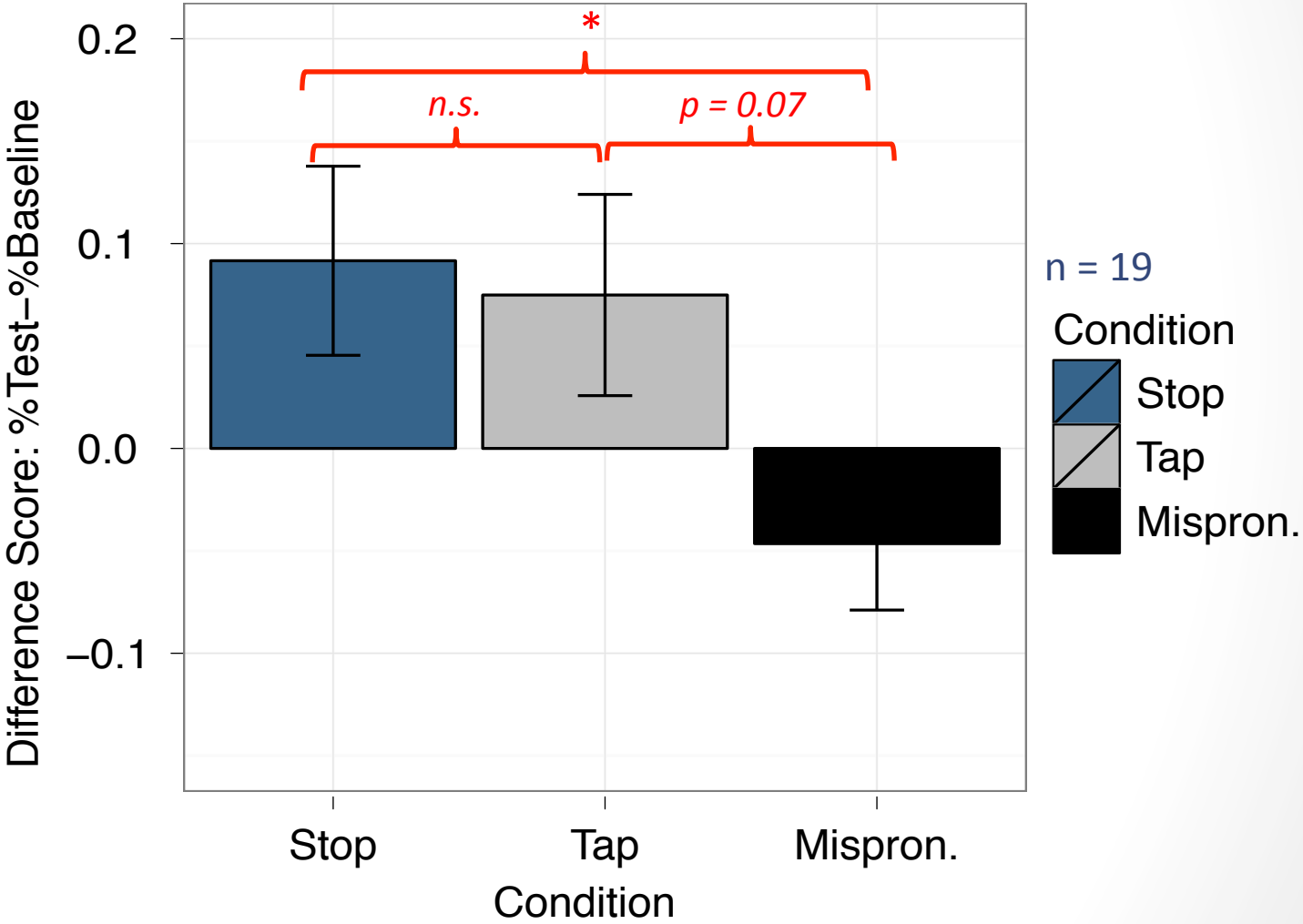




Exp. 2: Results – high CDI (Raw)







Exp. 2 Discussion

- Suggestive pattern: Tap > MP; Stop > MP
  - But only with toddlers with a high production score
- Tap = stop
  - 18 month-old toddlers are able to compensate online for tap variants
- Earlier than has been shown for voicing assimilation in French (Skoruppa et al., 2013a; Skoruppa et al., 2013b)
- 18 month-olds successfully detect mispronunciations in sentence-medial position (without training)

Conclusions

- Adults treat stop and tap variants for words equivalently.

- Strongly suggestive evidence that 18 month-olds have learned to compensate for tap variants of both /t/ and /d/ words as well.
  - Treat both stop and tap variants equivalently
  - Caveat: Only with toddlers with higher raw production CDI scores

- Future work:
  - How important is phonological context?
  - Is it item-specific? Can they generalize to novel words?
  - Continue testing

Acknowledgements

- Funding:
  - NSF BCS-0951639 and UCLA COR Faculty Research Grants awarded to MS
- Families who participated in the experiments
- Lab managers
  - Robyn Orfitelli (now at U. Sheffield, UK)
  - Anya Mancillas
- Undergraduate research assistants at the UCLA Language Acquisition Lab
- Helpful comments from members of the UCLA Phonetics Lab, particularly Bruce Hayes, Pat Keating, Kie Zuraw and Yun Jung Kim
- Henry Tehrani and Bryan Nguyen for technical assistance

Thank you!

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CDI Frequencies

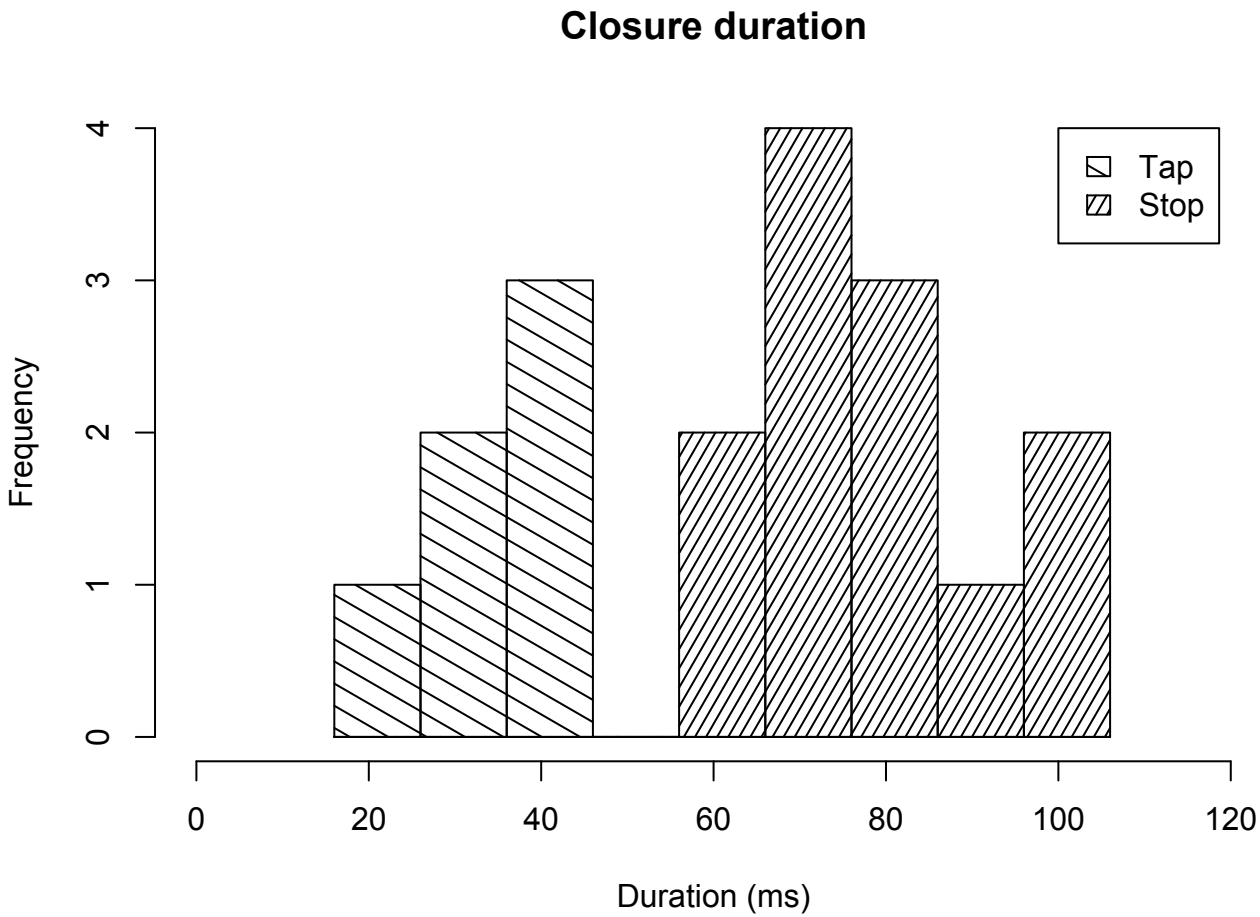
Target word		CDI comprehension freq. 16 months (%)	CDI production freq. 18 months (%)
		[t]-words	
1	hat	53.7	61.1
2	cat	51.2	76.4
3	boat	50	N/A
4	foot	41.2	50
5	bat	17.5	N/A
6	plate	13.8	33.3
		[d]-words	
1	bird	67.5	79.2
2	bed	28.8	68.1
3	bread	25	48.6
4	food	16.3	47.2
5	cloud	12.5	N/A
6	slide	12.5	48.6

Comprehension frequency of target [t]- and [d]-words for 16-month-olds and production frequency for 18-month-olds.

Mispronunciations

/t/-words				/d/-words			
Correct Pron.		Mispronunciation		Correct Pron.		Mispronunciation	
cat	[kæt]	*cak*	[kæk]	slide	[slaɪd]	*slige*	[slaɪg]
bat	[bæt]	*bap*	[bæp]	bed	[bɛd]	*beb*	[bɛb]
foot	[fʊt]	*foop*	[fʊp]	bread	[bɹɛd]	*breag*	[bɹɛg]
plate	[plet]	*plake*	[plek]	food	[fud]	*foog*	[fug]
hat	[hæt]	*hap*	[hæp]	cloud	[klaʊd]	*cloub*	[klaʊb]
boat	[boʊt]	*boak*	[boʊk]	bird	[bɝd]	*birb*	[bɝb]

Closure duration



Vowel duration

	Tap	Stop			Tap	Stop
bat	214	223		bed	128	203
boat	179	237		bird	229	389
cat	162	176		bread	192	311
foot	96	126		cloud	271	373
hat	137	202		food	158	297
plate	179	225		slide	225	274
Mean	***161***	***198***		***Mean***	***200***	***308***