Increases in speed and accuracy of children's online word recognition measured via a large-scale, open database of developmental eye-tracking data

Real-time word recognition is key to infants' developing lexical skills. A commonly used method to measure the time course of word recognition is the "looking-while-listening" (LWL) paradigm (1). In this paradigm, researchers present infants with two images and a prompt sentence (e.g., *Look at the dog!*), tracking eye movements to measure how quickly and accurately infants fixate the target image in real time. Across the first years of life, the speed and accuracy with which infants recognize words undergo rapid developmental change (2). Facility in online word recognition plays a crucial role in language development, enabling infants to learn efficiently from input (3), thereby supporting later language outcomes (4).

Measuring developmental change in online word recognition has often proven challenging, however, due to the difficulty of choosing appropriate items across age groups (5). Items that are well-suited for measuring variation in younger infants are often too easy for older infants, while presenting different age groups with non-overlapping item sets can obscure developmental change. Modeling changes in word recognition ability would ideally involve measuring lexical processing efficiency across a wide range of test items to estimate item-independent growth in word recognition skill.

Peekbank (http://peekbank.stanford.edu) aims to overcome these challenges by creating a large-scale, open database of LWL datasets aggregating data across a variety of test items. Peekbank's overarching goal is to inform theoretical questions in lexical development by compiling data from many studies, modeled on past efforts to build domain-specific repositories (6). Peekbank (a) collects eye-tracking datasets on children's word recognition, (b) introduces a data format for standardizing eye-tracking data, and (c) provides an interface for accessing and analyzing the database (the peekbankr R package). Fifteen datasets (N=1,320) are currently in Peekbank (Table 1).

In an initial analysis, we used linear mixed-effects models to estimate the time course of word recognition via growth curves (7). We modeled developmental change while accounting for non-independence between items and variation across datasets. The model predicted children's proportion target looking (empirical logit-transformed) from time (up to 4th order polynomial functions) and age (quadratic), and their interactions. The random effects structure included by-item, by-participant, and by-dataset random intercepts. Empirical word recognition curves are not interpretable when simply averaging across all items and datasets (Fig. 1A). Developmental change also appears irregular: e.g., 12-24-month-olds appear very similar to 24-36-month-olds. Once item non-independence is taken into account in the growth curve model (Fig 1B), however, we observe continuous increases in both speed and accuracy across age groups. This pattern provides evidence for gradual, item-independent changes in online word processing skill across development, findings that are difficult to obtain with individual datasets.

This result illustrates the benefits of aggregating existing datasets in the service of large-scale developmental modeling. In addition to testing theoretical questions, the database will also serve to investigate methodological questions and develop data-driven best-practices in measuring word recognition (e.g., how selecting different time windows of analysis impacts measure reliability). Future work will expand the database to provide a broader view of children's early lexical development.

Word Count: 498 words

Dataset Name	Citation	N	Mean Age (mos.)	Age Range (mos.)	Method	Language
attword	Yurovsky & Frank, 2017	288	25.5	13 - 59	eye-tracking	English
canine	unpublished	36	23.8	21 - 27	manual coding	English
coartic	Mahr et al., 2015	29	20.8	18 - 24	eye-tracking	English
cowpig	Perry et al., 2017	45	20.5	19 - 22	manual coding	English
ft_pt	Adams et al., 2018	69	17.1	13 - 20	manual coding	English
mispron	Swingley & Aslin, 2002	50	15.1	14 - 16	manual coding	English
mix	Byers-Heinlein et al., 2017	48	20.1	19 - 21	eye-tracking	English, French
reflook_socword	Yurovsky et al., 2013	435	33.6	12 - 70	eye-tracking	English
reflook_v4	unpublished	45	34.2	11 - 60	eye-tracking	English
remix	Potter et al., 2019	44	22.6	18 - 29	manual coding	Spanish, English
salientme	Pomper & Saffran, 2019	44	40.1	38 - 43	manual coding	English
switchingCues	Pomper & Saffran, 2016	60	44.3	41 - 47	manual coding	English
tablet	Frank et al., 2016	69	35.5	12 - 60	eye-tracking	English
tseltal	Casillas et al., 2017	23	31.3	9 - 48	manual coding	Tseltal
yoursmy	Garrison et al., 2020	35	14.5	12 - 18	eye-tracking	English

Table 1. Overview of the current Peekbank datasets. See OSF repository for further information and references for each dataset (https://osf.io/pr6wu/?view_only=07a3887eb7a24643bdc1b2612f2729de).

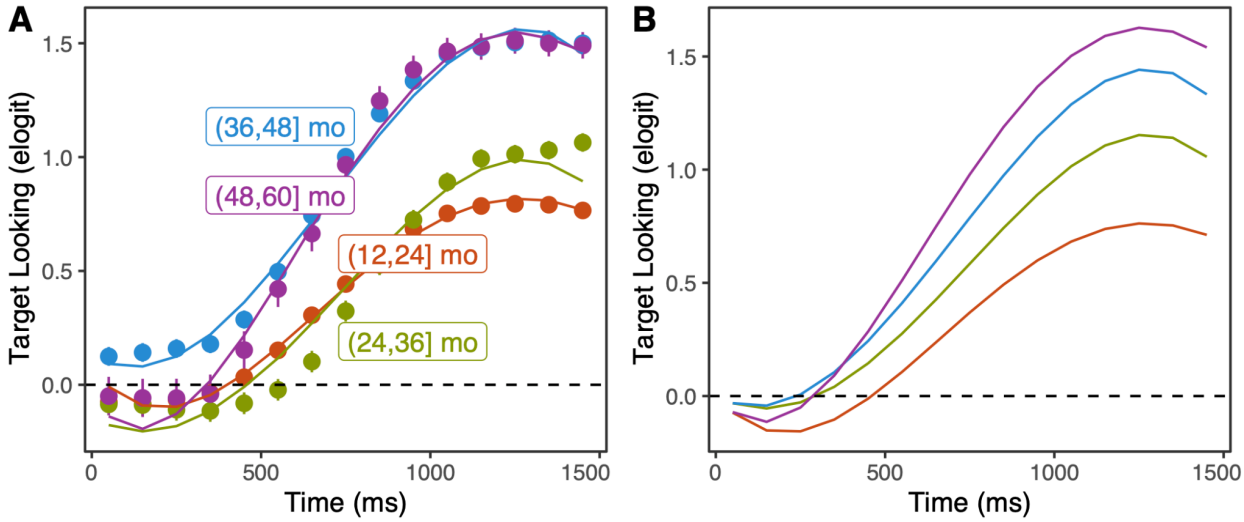

Figure 1. Growth curve models of proportion target looking after target word onset at each age range (in months). Accuracy is reflected in the average height of the curve; speed is reflected in latency of increased looking from target word onset. (A) Mean empirical word recognition fit. (B) Population-level estimates under a linear mixed-effects model with by-{item, participant,dataset} random intercepts show more interpretable developmental change.

References.

1. Fernald, A., Zangl, R., Portillo, A. L., & Marchman, V. A. (2008). Looking while listening: Using eye movements to monitor spoken language comprehension by infants and young children. In I. A. Sekerina, E. M. Fernandez, & H. Clahsen (Eds.), *Developmental psycholinguistics: On-line methods in children's language processing* (pp. 97–135). Amsterdam: John Benjamins.
2. Fernald, A., Pinto, J. P., Swingley, D., Weinberg, A., & McRoberts, G. W. (1998). Rapid gains in speed of verbal processing by infants in the 2nd year. *Psychological Science, 9*(3), 228–231.
3. Fernald, A., & Marchman, V. A. (2012). Individual differences in lexical processing at 18 months predict vocabulary growth in typically developing and late-talking toddlers. *Child Development, 83*, 203–22.
4. Marchman, V. A., & Fernald, A. (2008). Speed of word recognition and vocabulary knowledge in infancy predict cognitive and language outcomes in later childhood. *Developmental Science, 11*(3), F9–16.
5. Peter, M. S., Durrant, S., Jessop, A., Bidgood, A., Pine, J. M., & Rowland, C. F. (2019). Does speed of processing or vocabulary size predict later language growth in toddlers? *Cog Psychology, 115*, 101238.
6. Frank, M. C., Braginsky, M., Yurovsky, D., & Marchman, V. A. (2017). Wordbank: An open repository for developmental vocabulary data. *Journal of Child Language, 44*(3), 677–694.
7. Mirman, D. (2014). *Growth curve analysis and visualization using R*. Boca Raton: CRC Press.