

## Supplemental Material S1. Detailed information regarding stimuli.

### Link to Project on Open Science Framework (Data and Scripts Available)

<https://osf.io/f5sbg/>

### Sentence Stimuli and Paired Distractor Objects

\*Italicized lines are filler trials

Item	Sentence	Cohort	Unrelated	Unrelated
1a	The friend plays the big piano.	peanut	trophy	tractor
1b	The friend has the big piano.	peanut	trophy	tractor
1c	<i>The friend has the big peanut.</i>	<i>piano</i>	<i>trophy</i>	<i>tractor</i>
2a	The child wins the big trophy.	tractor	piano	peanut
2b	The child sees the big trophy.	tractor	piano	peanut
2c	<i>The child sees the big tractor.</i>	<i>trophy</i>	<i>piano</i>	<i>peanut</i>
3a	The dad reads the green book.	bush	kite	couch
3b	The dad finds the green book.	bush	kite	couch
3c	<i>The dad finds the green bush.</i>	<i>book</i>	<i>kite</i>	<i>couch</i>
4a	The boy flies the green kite.	couch	book	bush
4b	The boy likes the green kite.	couch	book	bush
4c	<i>The boy likes the green couch.</i>	<i>kite</i>	<i>book</i>	<i>bush</i>
5a	The brother toasts the old bread.	brush	horn	horse
5b	The brother shares the old bread.	brush	horn	horse
5c	<i>The brother shares the old brush.</i>	<i>bread</i>	<i>horn</i>	<i>horse</i>
6a	The mother blows the old horn.	horse	bread	brush
6b	The mother sees the old horn.	horse	bread	brush
6c	<i>The mother sees the old horse.</i>	<i>horn</i>	<i>bread</i>	<i>brush</i>
7a	The woman eats the little sandwich.	Santa	football	footprint
7b	The woman finds the little sandwich.	Santa	football	footprint
7c	<i>The woman finds the little Santa.</i>	<i>sandwich</i>	<i>football</i>	<i>footprint</i>
8a	The girl throws the little football.	footprint	sandwich	Santa
8b	The girl gets the little football.	footprint	sandwich	Santa
8c	<i>The girl gets the little footprint.</i>	<i>football</i>	<i>sandwich</i>	<i>Santa</i>
9a	The brother draws the small picture.	pickle	cookies	costume
9b	The brother gets the small picture.	pickle	cookies	costume
9c	<i>The brother gets the small pickle.</i>	<i>picture</i>	<i>cookies</i>	<i>costume</i>
10a	The girl bakes the small cookies.	costume	picture	pickle
10b	The girl shares the small cookies.	costume	picture	pickle
10c	<i>The girl shares the small costume.</i>	<i>cookies</i>	<i>picture</i>	<i>pickle</i>
11a	The sister pours the good juice.	jewel	tree	truck
11b	The sister sees the good juice.	jewel	tree	truck

11c	<i>The sister sees the good jewel.</i>	<i>juice</i>	<i>tree</i>	<i>truck</i>
12a	The child climbs the good tree.	truck	juice	jewel
12b	The child likes the good tree.	truck	juice	jewel
12c	<i>The child likes the good truck.</i>	<i>tree</i>	<i>juice</i>	<i>jewel</i>
13a	The grandma pets the gray cat.	can	bike	bag
13b	The grandma buys the gray cat.	can	bike	bag
13c	<i>The grandma buys the gray can.</i>	<i>cat</i>	<i>bike</i>	<i>bag</i>
14a	The friend rides the gray bike.	bag	cat	can
14b	The friend drops the gray bike.	bag	cat	can
14c	<i>The friend drops the gray bag.</i>	<i>bike</i>	<i>cat</i>	<i>can</i>
15a	The grandpa drives the white car.	cart	dog	doll
15b	The grandpa has the white car.	cart	dog	doll
15c	<i>The grandpa has the white cart.</i>	<i>car</i>	<i>dog</i>	<i>doll</i>
16a	The man feeds the white dog.	doll	car	cart
16b	The man buys the white dog.	doll	car	cart
16c	<i>The man buys the white doll.</i>	<i>dog</i>	<i>car</i>	<i>cart</i>
17a	The sister kicks the nice ball.	box	milk	mail
17b	The sister finds the nice ball.	box	milk	mail
17c	<i>The sister finds the nice box.</i>	<i>ball</i>	<i>milk</i>	<i>mail</i>
18a	The boy drinks the nice milk.	mail	ball	box
18b	The boy hides the nice milk.	mail	ball	box
18c	<i>The boy hides the nice mail.</i>	<i>milk</i>	<i>ball</i>	<i>box</i>

## Norming of Sentence Stimuli

The extent to which a semantically informative verb predicts the target noun was measured with a cloze task administered via an online survey to adults in Amazon Mechanical Turk. Each sentence stimulus (e.g., *The girl plays the big piano*) was made into a cloze task question by replacing the final noun with a blank for the participant to write in (e.g., *The girl plays the \_\_\_\_*). The adjective was also removed to prevent the semantics of the adjective from influencing the responder’s choice of noun. A minimum of 500 participants completed each sentence. First, 12 sentence stimuli were chosen based on proportion of responses for that item, with a proportion of .1 as the criteria (i.e., at least 10% of respondents filled in the blank with the target noun). An additional 5 sentences were selected as stimuli with proportions less than .1, which were decided to be sufficiently predictable given the nature of the verb and more frequent responses. For example, a large portion of the responses for “*wins the \_\_\_\_*” were *game*, *lottery*, and *prize*, but these words are not clearly imageable. The chosen target noun, *trophy*, which had a .03 proportion of responses, is easily imageable. One of the sentences, “*The brother toasts the old bread*,” was not normed because it was added after the completion of the cloze task experiment.

We also investigated whether the combination of adjective-target strings (e.g., *green book*) differed in frequency from adjective-cohort strings (*green bush*) using string frequency values from The Corpus of Contemporary American English (COCA) (Davies, 2008–). The adjective-cohort strings were more frequent than the adjective-target strings [ $t(33) = 2.40, p < .05$ ]. While this difference does not introduce bias into our investigation of the effect of condition, it is

possible that this significant difference could potentially lead to more cohort fixations in general. This would mean that in all conditions and groups we could be seeing more cohort fixations than we would see if the frequency of adjective-target and adjective-cohort strings were matched. When log frequency of adjective-cohort strings were added to an item-level analyses of cohort fixations, the significant effects of Condition remained for both the age-matched comparison [ $\beta = -.06$ ,  $SE = .02$ ,  $t(48) = -3.33$ ,  $p < .01$ ] and vocabulary-matched comparison [ $\beta = -.06$ ,  $SE = .02$ ,  $t(48) = -3.38$ ,  $p < .01$ ], and there were no significant effects or interactions with the string frequency measure [ $ps > .05$ ]. These results suggest that adjective-cohort string frequency does not have a significant effect on cohort fixations for children in this study. It is also possible that we may not have the power to detect such an effect in this sample size.

Davies, M. (2008–). *The Corpus of Contemporary American English (COCA): One billion words, 1990–2019*. <https://www.english-corpora.org/coca/>

### Norming of Visual Stimuli

All images were normed on 3- to 5-year-old children in four preschool classrooms at the University of Maryland Center for Young Children. Each child met with an experimenter individually and was shown a card containing four images in a recognition task. The child was asked to point to the picture of the word the experimenter said. Each picture was seen by at least 18 children and was recognized with at least 85% accuracy.

If the adjective in the sentence described the color of the target image (e.g., *the green kite*), the distractor objects shared the same attribute (*green book*, *green bush*, *green couch*). In the case of other preceding adjectives, such as *old* or *big*, the picture stimuli were designed so that none of the referents better represented the adjective compared to the others (e.g., none of the objects looked particularly old).

### R code for model of response accuracy

```
Accuracy ~ 1 + Condition * Group + (1 | Participant)
```

### Fixed effects for response accuracy in age-matched comparison

	Estimate	SE	z value	p value	Sig.
(Intercept)	4.4628	.3979	11.2152	.0000	***
Condition	0.8637	.4921	1.7553	.0792	+
Group	0.7021	.5478	1.2817	.2000	
Condition: group	−0.2982	.7991	−0.3731	.7091	

+ $p < .10$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

### Fixed effects for response accuracy in vocabulary-matched comparison

	Estimate	SE	z value	p value	Sig.
(Intercept)	4.5010	.4025	11.1831	.0000	***
Condition	0.8645	.4923	1.7561	.0791	+
Group	0.2243	.5266	0.4259	.6702	
Condition: group	0.3576	.8251	0.4334	.6647	

+ $p < .10$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

### R code for model of individual differences in children with CIs

```
Proportion of Target Fixations ~ 1 + Condition * PPVT-4
Standard Score + Age of Implantation + Age of Implantation:
Condition + Chronological Age + Chronological Age:
Condition + (1 | Participant)
```

### R code for models of target fixations

```
Proportion of Target Fixations ~ 1 + Condition * Group *
PPVT-4 GSV + (1 | Participant)
```

### R code for models of cohort fixations

```
Proportion of Cohort Fixations ~ 1 + Condition * Group *
PPVT-4 GSV + (1 | Participant)
```

### Fixed effects for target fixations in individual differences analysis

	Estimate	SE	df	t value	p value	Sig.
(Intercept)	0.3533	0.0203	27.3082	17.4390	.0000	***
Condition	0.1383	0.0162	20.0000	8.5561	.0000	***
Norm-referenced receptive vocabulary	0.0440	0.0208	27.3082	2.1118	.0347	*
Chronological Age	-0.0046	0.0168	27.3082	-0.2748	.7835	
Age of implantation	0.0103	0.0195	27.3082	0.5278	.5977	
Condition: norm-referenced receptive vocabulary	0.0125	0.0166	20.0000	0.7532	.4514	
Condition: chronological age	0.0191	0.0134	20.0000	1.4266	.1537	
Condition: age of implantation	-0.0224	0.0156	20.0000	-1.4387	.1502	

+ $p < .10$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

**Fixed effects for target fixations in age-matched comparison**

	<b>Estimate</b>	<b>SE</b>	<b>df</b>	<b>t value</b>	<b>p value</b>	<b>Sig.</b>
(Intercept)	0.3372	.0186	60.2209	18.1310	.0000	***
Condition	0.1444	.0149	44.0000	9.6963	.0000	***
Group	0.0728	.0269	60.2209	2.7019	.0069	**
Receptive vocabulary	0.0240	.0167	60.2209	1.4324	.1520	
Condition: group	0.0510	.0216	44.0000	2.3640	.0181	*
Condition: receptive vocabulary	0.0295	.0134	44.0000	2.2000	.0278	*
Group: receptive vocabulary	−0.0222	.0277	60.2209	−0.8002	.4236	
Condition: group: receptive vocabulary	−0.0519	.0222	44.0000	−2.3348	.0196	*

+ $p < .10$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

**Fixed effects for cohort fixations in age-matched comparison**

	<b>Estimate</b>	<b>SE</b>	<b>df</b>	<b>t value</b>	<b>p value</b>	<b>Sig.</b>
(Intercept)	0.1374	.0075	75.1368	18.3187	.0000	***
Condition	−0.0716	.0081	44.0000	−8.8205	.0000	***
Group	−0.0158	.0109	75.1368	−1.4510	.1468	
Receptive vocabulary	−0.0002	.0068	75.1368	−0.0328	.9738	
Condition: group	−0.0162	.0118	44.0000	−1.3738	.1695	
Condition: receptive vocabulary	−0.0180	.0073	44.0000	−2.4646	.0137	*
Group: receptive vocabulary	−0.0120	.0112	75.1368	−1.0752	.2823	
Condition: group: receptive vocabulary	0.0219	.0121	44.0000	1.8067	.0708	+

+ $p < .10$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

**Fixed effects for target fixations in vocabulary-matched comparison**

	<b>Estimate</b>	<b>SE</b>	<b>df</b>	<b>t value</b>	<b>p value</b>	<b>Sig.</b>
(Intercept)	0.3263	.0166	57.2170	19.6769	.0000	***
Condition	0.1311	.0121	44.0000	10.8256	.0000	***
Group	0.0344	.0235	57.2170	1.4676	.1422	
Receptive vocabulary	0.0229	.0158	57.2170	1.4535	.1461	
Condition: group	0.0357	.0171	44.0000	2.0871	.0369	*
Condition: receptive vocabulary	0.0282	.0115	44.0000	2.4492	.0143	*
Group: receptive vocabulary	−0.0357	.0237	57.2170	−1.5084	.1314	
Condition: group: receptive vocabulary	−0.0432	.0173	44.0000	−2.4996	.0124	*

+ $p < .10$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

**Fixed effects for cohort fixations in vocabulary-matched comparison**

	<b>Estimate</b>	<b>SE</b>	<b>df</b>	<b>t value</b>	<b>p value</b>	<b>Sig.</b>
(Intercept)	0.1375	.0072	75.8927	18.9804	.0000	***
Condition	−0.0635	.0079	44.0000	−7.9948	.0000	***
Group	−0.0101	.0102	75.8927	−0.9874	.3235	
Receptive vocabulary	−0.0002	.0069	75.8927	−0.0307	.9755	
Condition: group	−0.0174	.0112	44.0000	−1.5491	.1214	
Condition: receptive vocabulary	−0.0173	.0076	44.0000	−2.2812	.0225	*
Group: receptive vocabulary	−0.0284	.0104	75.8927	−2.7347	.0062	**
Condition: group: receptive vocabulary	0.0430	.0114	44.0000	3.7802	.0002	***

+ $p < .10$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

## Item-level models

An item analysis was carried out to determine whether inclusion of the log frequency of the target word explained any of the observed significant Condition or Group effects or Condition by Group interactions in the participant-level analysis. Each of the four models in the participant-level analyses were also run as an item-level model. Each dataset was constructed in the same manner as for the participant-level models, with the exception that eye gaze within the time window of interest was aggregated by item rather than by participant. This calculation averaged across trials and participants, so that each item had proportion calculations for each group (CI and NH) in each condition (Informative and Neutral). As in the participant-level analyses, both models of target and cohort fixations had the dependent variable of eye gaze regressed on the effect of Condition (coded as 0 for neutral and 1 for informative), the effect of Group (coded as 0 for CI and 1 for NH), and the interaction between Condition and Group. All item-level models included a random intercept for item. The log frequency of target word (centered and scaled) was also in the item-level models, including all interactions with Group and Condition.

## Age-matched comparison

### Target Fixations.

For item-level analysis of target fixations in the age-matched comparison, there was a significant main effect of Condition [ $\beta = .13$ ,  $SE = .02$ ,  $t(48) = 8.22$ ,  $p < .001$ ]. The proportion of looking to the target referent was significantly greater in the informative condition relative to the neutral. There was also a significant effect of Group [ $\beta = .08$ ,  $SE = .02$ ,  $t(48) = 5.29$ ,  $p < .001$ ], indicating that the group with NH were more accurate at looking to the target in the neutral condition in comparison to the group with CIs. The interaction between Condition and Group was significant [ $\beta = .05$ ,  $SE = .02$ ,  $t(48) = 2.39$ ,  $p < .05$ ]. The group with NH demonstrated more looking to the target in the informative condition relative to the neutral, and while children with CIs also showed this effect of condition they did so to a lesser extent. This item-level model reveals that the significant Condition and Group effects and Condition by Group interaction found in the participant-level model remain when accounting for item-level variability in target word frequency.

### Cohort Fixations.

The item-level analysis of cohort fixations in the age-matched comparison showed a significant effect of Condition [ $\beta = -.06$ ,  $SE = .01$ ,  $t(48) = -6.36$ ,  $p < .001$ ], meaning the cohort referent was looked at less in the informative condition relative to the neutral. There was also a significant effect of Group [ $\beta = -.02$ ,  $SE = .01$ ,  $t(48) = -2.11$ ,  $p < .05$ ], with the Group with NH demonstrating more looks to the target than the group with CIs in the neutral condition. This item-level model demonstrates that the significant effect of Condition shown in the participant-level model of cohort fixations is also significant when the item-level variable of target word frequency is included in the model. This item-level analysis also yielded a significant effect of Group that was not observed in the participant-level model. Since this effect is not significant in the participant-level analysis, it can be concluded that this item-level effect is not consistent or reliable across individuals within the groups. In addition, neither model for the age-matched comparison yielded significant effects or interactions with log frequency of target.

### ***Vocabulary-matched comparison***

#### **Target Fixations.**

For item-level analysis of target fixations in the vocabulary-matched comparison, there was a significant main effect of Condition [ $\beta = .13$ ,  $SE = .02$ ,  $t(48) = 7.99$ ,  $p < .001$ ]. Children showed more significantly more looking to the target referent in the informative condition relative to the neutral. There was also a significant effect of Group [ $\beta = .04$ ,  $SE = .02$ ,  $t(48) = 2.14$ ,  $p < .05$ ]. The group with NH demonstrated more target fixations than the group with CIs in the neutral condition. This item-level model shows that the significant effect of Condition shown in the participant-level model of cohort fixations is also significant when the item-level variable of target word frequency is included. However, this item-level analysis did not find a significant Condition by Group interaction [ $p > .05$ ], which was found to be significant in the participant-level model. This result suggests that this Condition by Group interaction in the participant-level model is not reliably found across all of the item sets in the experiment. For this reason, this interaction in the vocabulary-matched comparison should be interpreted with caution as we may not have the statistical power to generalize this result to spoken language beyond our experimental stimuli. This item-level analysis also found a significant effect of Group that was not seen in the participant-level model. This contradiction between participant-level and item-level models suggests that this item-level effect of Group is not reliable across individuals within the groups.

#### **Cohort Fixations.**

The item-level analysis of cohort fixations in the vocabulary-matched comparison yielded a significant effect of Condition [ $\beta = -.06$ ,  $SE = .01$ ,  $t(48) = -6.36$ ,  $p < .001$ ], showing that there were less cohort fixations in the informative condition relative to the neutral. This item-level model demonstrates that the significant effect of Condition seen in the participant-level model of cohort fixations is also significant when the item-level variable of target word frequency is included in the model. As in the age-matched comparison, neither model for the vocabulary-matched comparison resulted in any significant effects or interactions with log frequency of target.

#### **R code for item-level models of target fixations**

```
Proportion of Target Fixations ~ 1 + Condition * Group *  
Log Frequency of Target + (1 | Item Set)
```

#### **R code for item-level models of cohort fixations**

```
Proportion of Cohort Fixations ~ 1 + Condition * Group *  
Log Frequency of Target + (1 | Item Set)
```



**Fixed effects for item-level model of target fixations in age-matched comparison**

	<b>Estimate</b>	<b>SE</b>	<b>df</b>	<b>t value</b>	<b>p value</b>	<b>Sig.</b>
(Intercept)	0.3256	.0156	38.3508	20.9092	.0000	***
Condition	0.1315	.0160	48.0000	8.2195	.0000	***
Group	0.0847	.0160	48.0000	5.2937	.0000	***
Log frequency of target	0.0097	.0157	38.3508	0.6216	.5342	
Condition: group	0.0541	.0226	48.0000	2.3927	.0167	*
Condition: log frequency of target	−0.0059	.0161	48.0000	−0.3691	.7120	
Group: log frequency of target	−0.0099	.0161	48.0000	−0.6142	.5391	
Condition: group: log frequency of target	0.0095	.0228	48.0000	0.4148	.6783	

+ $p < .10$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

**Fixed effects for item-level model of cohort fixations in age-matched comparison**

	<b>Estimate</b>	<b>SE</b>	<b>df</b>	<b>t value</b>	<b>p value</b>	<b>Sig.</b>
(Intercept)	0.1380	.0095	40.6613	14.4975	.0000	***
Condition	−0.0642	.0101	48.0000	−6.3604	.0000	***
Group	−0.0213	.0101	48.0000	−2.1097	.0349	*
Log frequency of target	−0.0091	.0096	40.6613	−0.9449	.3447	
Condition: group	−0.0224	.0143	48.0000	−1.5676	.1170	
Condition: log frequency of target	0.0079	.0102	48.0000	0.7788	.4361	
Group: log frequency of target	0.0114	.0102	48.0000	1.1252	.2605	
Condition: group: log frequency of target	−0.0110	.0144	48.0000	−0.7661	.4436	

+ $p < .10$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

**Fixed effects for item-level model of target fixations in vocabulary-matched comparison**

	<b>Estimate</b>	<b>SE</b>	<b>df</b>	<b>t value</b>	<b>p value</b>	<b>Sig.</b>
(Intercept)	0.3256	.0151	42.9675	21.5997	.0000	***
Condition	0.1315	.0165	48.0000	7.9903	.0000	***
Group	0.0352	.0165	48.0000	2.1376	.0325	*
Log frequency of target	0.0097	.0152	42.9675	0.6422	.5208	
Condition: group	0.0346	.0233	48.0000	1.4866	.1371	
Condition: log frequency of target	-0.0059	.0166	48.0000	-0.3588	.7197	
Group: log frequency of target	-0.0138	.0166	48.0000	-0.8338	.4044	
Condition: group: log frequency of target	0.0016	.0234	48.0000	0.0679	.9459	

+ $p < .10$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

**Fixed effects for item-level model of cohort fixations in vocabulary-matched comparison**

	<b>Estimate</b>	<b>SE</b>	<b>df</b>	<b>t value</b>	<b>p value</b>	<b>Sig.</b>
(Intercept)	0.1380	.0090	44.7122	15.2621	.0000	***
Condition	-0.0642	.0101	48.0000	-6.3742	.0000	***
Group	-0.0103	.0101	48.0000	-1.0195	.3080	
Log frequency of target	-0.0091	.0091	44.7122	-0.9948	.3198	
Condition: group	-0.0169	.0142	48.0000	-1.1837	.2365	
Condition: log frequency of target	0.0079	.0101	48.0000	0.7805	.4351	
Group: log frequency of target	0.0030	.0101	48.0000	0.3001	.7641	
Condition: group: log frequency of target	0.0025	.0143	48.0000	0.1721	.8634	

+ $p < .10$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .