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ARTICLE

Children's disambiguation of novel words varies by the number and position of phonological contrasts

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Abstract
Young children often make pragmatic assumptions when learning new words. For example, they assume that a speaker who uses different words intends to refer to different things – the so-called principle of contrast. We used a standard disambiguation task to explore whether children's assumptions about contrast depend on how much words differ. Three- to 6-year-olds heard pairs of words that differed in terms of the number, position, and types of phonological contrasts. Results indicate that children were less likely to disambiguate words differing by one phoneme than words differing by two or more phonemes, particularly when those one-phoneme differences were located at the beginning or end of the words (as in fim/vim). Overall, the findings suggest that children's pragmatic assumptions about two contrasting words depend not only on if words differ, but also on how they differ.

Keywords: disambiguation; contrast; children; word learning; pragmatics

Introduction

The challenge of learning any new word comes in deciding what that word means. Because a new word could have any number of possible meanings (Quine, 1960), deciding which meaning is the most likely can be harder than one might initially guess. To meet this challenge, even young children must find a way to consider less than the full set of possible meanings. In the experiment presented here, we explore children's use of the pragmatic principle of contrast to limit the set of meanings considered for a new word. According to this principle, children understand that "different words mean different things" (Clark, 1987) and assume that a speaker who uses different words intends to refer to different things. This assumption can help limit the number of candidate meanings children might otherwise consider for the word by allowing them to eliminate any referent for which they already have a word.

In our experiment, 3- to 6-year-olds were presented with pairs of novel words that varied in the number and position of phonological differences between the words. In some cases, the words were very similar, differing in only one phoneme (e.g., *deen/geen* or *fim/vim*). In other cases, the words were very dissimilar, differing on all three phonemes (e.g., *waf/kud*). Word pairs were always presented in the context of a disambiguation task where children saw two objects, one of which was labeled with a word and one of which was left unlabeled. Children then were asked to identify the referent of a second word. Our overall question was whether the amount and/or position of phonological differences between the two words would affect the likelihood that children would observe the pragmatics of contrast and assign the second word to the unlabeled object.

Previous studies routinely find that children do just that: when presented with two objects, one known and one novel, and asked for the referent of a novel word, children show a strong tendency to select the novel, unlabeled object. This tendency is known as the disambiguation effect (Markman & Wachtel, 1988; Merriman, Bowman, & MacWhinney, 1989). This effect emerges in infancy (Graham, Poulin-Dubois, & Baker, 1998; Halberda, 2003; Markman, Wasow, & Hansen, 2003; Mervis & Bertrand, 1994) and increases gradually during the first few years of language development (Bion, Borovsky, & Fernald, 2013) (see also Clark, 1990; Markman, 1991; Markman & Wachtel, 1988; Merriman et a., 1989). Knowledge and size of the child's vocabulary as well as their overall language experience help drive these increases (Byers-Heinlein & Werker, 2009; Graham et al., 1998; Grassmann, Schulze, & Tomasello, 2015; Kalashnikova, Mattock, & Monaghan, 2016).

Despite a strong tendency to disambiguate novel words, children do not always do it. For example, young children sometimes prioritize other cues, like a speaker's gestures and gaze, and instead select the known object in response to a novel word (Grassmann & Tomasello, 2010). Other times they disregard such cues and select the novel object (Jaswal & Hansen, 2006). Likewise, depending on age and modality (Scofield, Hernandez-Reif, & Keith, 2009), children sometimes expect speakers to communicate about the novel object (4-year-olds but not 3-year-olds, Henning & Merriman, 2019) and other times they expect them to communicate about the known object (4-year-olds but not 3-year-olds, Scofield, Merriman, & Wall, 2018; Wall, Merriman, & Scofield, 2015; Wall & Merriman, 2020).

There is also evidence that the degree of phonological similarity between words can affect the likelihood that a child disambiguates. When novel words are greater in similarity to familiar words, young children show a weaker disambiguation effect (Merriman & Schuster, 1991). Young children also show greater sensitivity to larger phonological differences between familiar and novel words when differences occur at the beginning of the word (e.g., shoe/foo) (White & Morgan, 2008). For three-to-five-year-olds, phonological feature differences also resulted in varying novelty responses for atypically pronounced words, compared to familiar words (e.g., fesh/fish) (Creel, 2012). One important antecedent to the disambiguation of any two words occurs when children successfully discriminate between those words, as Merriman and Marazita (1995) note in step 5 of their model of disambiguation.

Although discrimination is necessary for disambiguation, it may not be sufficient. For example, 3- to 5-year-olds detect phonological deviations when presented with accented pronunciations of familiar words as in apple/epple. However, their tendency is to assume that the alternate pronunciation is referring to the familiar rather than a novel object (Creel, 2012; see Swingley, 2016 and Swingley & Aslin, 2007 for evidence in 2-year-olds), perhaps signaling a willingness to accept a range of pronunciations for a given word

(Krueger & Storkel, 2020; Krueger, Storkel, & Minai, 2018). This kind of flexibility would allow children to pivot to other potentially informative cues when interpreting a speaker's intent, something that could benefit word learning when interacting with foreign or accented speakers or with a speaker prone to mispronunciations (like a child peer) (Creel, 2012).

However, a willingness to accept alternate pronunciations could also undermine word learning. For each case where a child correctly interprets a mispronunciation, there could be a corresponding case where they incorrectly interpret an accurate pronunciation (Swingley, 2016). Moreover, the assumption that phonological contrasts do not reflect important underlying differences between the words would contradict one of the most prominent and well-supported explanations for the disambiguation effect: the pragmatic principle of contrast (see Diesendruck & Markson, 2001). According to contrast, language learners assume that any two contrasting forms (such as two different words) correspond to contrasting meanings in the world (Clark, 1987, 1990). From a pragmatic standpoint, a speaker who uses different words does so intentionally to denote different referents. This readiness to infer a speaker's referential intent is at the heart of the pragmatic explanation for the disambiguation effect (Clark, 1990; Diesendruck, 2005; Diesendruck & Markson, 2001; Scofield & Behrend, 2007).

The Current Experiment

When completing the disambiguation task, children usually observe the pragmatics of contrast and select the novel object as the referent of the novel word. But they will sometimes ignore the pragmatics of contrast and select the known object as the referent of the novel word. The contradictory nature of this evidence raises questions about the factors that lead children down one path or the other. Past research suggests that the degree of similarity between words and position of phonological differences within the words could each play a role. In the current experiment, we systematically manipulate these factors. 3- to 6-year-olds were presented with pairs of novel words. Each word contained three phonemes in a consonant-vowel-consonant sequence, as in *fim*. The words in each pair contrasted by 0, 1, 2, or 3 phonemes. Words also contrasted in terms of the position of phonemic differences. For example, one phoneme differences could be located on the first phoneme (i.e., the initial consonant or onset), on the middle phoneme (i.e., the vowel, or nucleus), or on the last phoneme (i.e., the final consonant, or coda). See Table 1 for examples of position differences for one phoneme trials as well as for two and three phoneme trials. Finally, word pairs contrasted in terms of the number of differing phonological features occurring on each phoneme. Word pairs were presented in a disambiguation task where children had to identify the referent of a novel word and, separately, in an auditory discrimination task where children simply had to decide whether the words differed.

Method

Participants

Eighty-five 3- to 6-year-olds (42 females, 43 males; age: 57 mos.; 71 White, 12 Black, two other) were recruited to participate in this experiment through preschools located in a

Table 1. Sample Novel Word Pairs with Number, Position, and Features of Contrasting Phonemes

Number of phoneme contrasts	Phoneme contrast position(s)	Sample word pairs	IC*	V*	FC*	Contrasting phonological features
0	None	Fim				None
		Fim				None
1	IC	Deen	**/d/**			**/d/** - voiced, alveolar, stop
		Geen	**/g/**			**/g/** - voiced, velar, stop
1	V	Rabe		**/eɪ/**		**/eɪ/** - tense, mid, front
		Reeb		**/iː/**		/iː/- tense, high, front
1	FC	Koot			**/t/**	**/t/** - voiceless, alveolar, stop
		Kood			**/d/**	**/d/** - voiced, alveolar, stop
2	IC, V	Fich	**/f/**	**/ɪ/**		**/f/** - voiceless, labiodental, fricative
						/I/ - lax, high, front
		Vooch	**/v/**	**/uː/**		**/v/** - voiced, labiodental, fricative
						/uː/ - tense, high, back
2	V, FC	Nase		**/eɪ/**	**/s/**	**/eɪ/** - tense, mid, front
						/s/ - alveolar, voiceless, fricative
		Nath		**/æ/**	**/θ/**	**/æ/**- tense, low, front
						/θ/- interdental, voiceless, fricative
2	IC, FC	Vip	**/v/**		**/p/**	**/v/** - voiced, labiodental, fricative
						/p/ - voiceless, bilabial, stop
		Zib	**/z/**		**/b/**	**/z/** - voiced, alveolar, fricative
						/b/ - voiced, bilabial, stop

Table 1. *(Continued)*

Number of phoneme contrasts	Phoneme contrast position(s)	Sample word pairs	IC*	V*	FC*	Contrasting phonological features
3	IC, V, FC	Shoon	/ʃ/	/**ʊ**/	/**n**/	/ʃ/ - voiceless, palatal, fricative
						/**ʊ**/- tense, high, back
						/n/ - voiced, alveolar, nasal
		Feez	/f/	/iː/	/z/	/**f**/ - voiceless, labiodental, fricative
						/**i**ː/- tense, high, front
						/**z**/ - voiced, alveolar, fricative

**Bold* signifies contrasting phoneme. IC: Initial Consonant, V: Vowel, FC: Final mid-sized university town in the southeastern United States. Over the course of the study, we developed two different versions of the discrimination task. In the original version, children were asked to judge whether the words they heard were “the same” or “different”. However, successfully communicating these instructions to children (especially those below five years of age) in a way that they understood proved exceedingly difficult. We therefore created a simplified version of the task (as described later), which proved much easier for children to understand, and we discarded all data prior to the simplified version.

Materials

Novel words

One hundred and ten unique novel words were created for use in this experiment. All novel words were monosyllabic, comprising three English phonemes, and frequently followed a standard consonant-vowel-consonant (CVC) sequence. Some novel words contained more orthographic consonants or vowels but phonetically all were CVC. Pairs of novel words were constructed from either two of the same novel word (same pairs; $n = 54$) or two different novel words (different pairs; $n = 60$) for use in this experiment. To ensure that a given word was presented only once per task, the word appeared in either a same trial or a different trial, but not both.

In different word pairs, novel words differed from each other in number of contrasting phonemes (one, two, three), position of contrasting phonemes (initial consonant, vowel, final consonant), and number of contrasting phonological features (one, two, three). Contrasting consonants differed in at least one of the following three phonological features: place of articulation, manner of articulation, and voicing. Contrasting vowels differed in at least one of the following three phonological features: tension, horizontal place of articulation, and vertical place of articulation. See Table 1 for examples of novel word pairs and phonological characteristics (please see Appendix A for all word pairs used and response proportions of the disambiguation task.)

Novel objects

Novel object images used in this experiment were selected from objects with low familiarity scores and low name-ability scores from the Novel Object Unusual Name (NOUN) database (Horst & Hout, 2014, 2016). Additional object images were selected from Internet searches of household objects (kitchen and tools) likely to be unfamiliar and unnameable to young children. All object images were overlaid on a white background, appeared to be small enough to fit in a hand, and were presented in color. During experimental task paradigm development, novel objects were randomly pre-paired with novel words, such that the same novel object was always presented with the same novel word during experimental testing. No novel objects were duplicated across a participant’s task.

Technology and software

Experimental task paradigms were developed and administered using SuperLab 5 (Cedrus Corporation, 2012). Audio recordings of an adult male saying novel words and framing phrases were captured for use in experimental tasks. Words and sentence frames were recorded in a soundproof booth. After recording, novel words were spliced into framing phrases (*"This is a"* and *"Point to the"*) to create full audio clips using Audacity® 2.3.0 (http://audacityteam.org/). Experimental tasks were presented using a small, lightweight, tablet-style computer with touchscreen responsiveness (Microsoft Surface Pro 6). During experimental sessions, participants wore a pair of noise-limiting headphones (BT2200 by Puro Sound Labs) plugged into the computer. Prior to experimental task administration, audio levels were set at a default of 75 decibels and were increased if participants indicated that they could not hear test audio sufficiently. Experimental tasks were initiated when participants reported that they were able to hear test audio sufficiently.

Procedure

Parents of participants completed consent forms approved by the host university's Institutional Review Board, which they returned to participants' preschools. The experimenter met with assenting participants individually in a quiet room outside of their normal preschool classroom and invited them to participate in a game. Participants were positioned in front of the computer and fitted with headphones. A laminated set of handprints was used to help participants start from the same position during experimental tasks. Once participants were comfortable, the experimenter initiated one of the two experimental tasks described below. The experimenter took notes during tasks as a back-up for participant responses. At the end of experimental sessions, participants received a sticker as a reward for participation. The presentation order of the two tasks was counterbalanced. No effect for task order was found.

Disambiguation task

At the onset of the disambiguation task, participants completed a brief set of four warm-up trials (two same and two different) designed to orient them to the disambiguation task and ensure that they could follow task procedures. In these trials, participants saw a familiar object (e.g., a ball) appear on the computer screen and heard a pre-recorded male voice label the object with a familiar name (e.g., *"This is a ball"*). A second familiar object then appeared on screen alongside the first (e.g., a shoe), and participants were asked to identify one of the objects. In "same" trials, participants were prompted to identify the original object (e.g., *"Point to the ball"*). The "point to" instructions were accompanied by the experimenter demonstrating how to properly touch one of the two images on the screen. Children's choices were coded according to which object they touched. In "different" trials, participants were prompted to identify the novel object (e.g., *"Point to the shoe"*; see Figure 1). If a child was unsuccessful on two of the four warm-up trials, researchers provided one more set of four warm-up trials. If a child failed to correctly identify two of the four trials in the second attempt, the session was ended by the experimenter and no data were collected. All children successfully completed the warm-up trials, but due to lack of interest, two children failed to complete the disambiguation task (a 4-year-old and a 6-year-old), and their data were excluded from the study.

After successfully completing all warm-up trials, participants proceeded to experimental trials. Experimental trials were structured identically to warm-up trials except that they included novel words. Participants completed a total of 28 experimental trials, 14 of which were "same" trials and 14 of which were "different" trials.

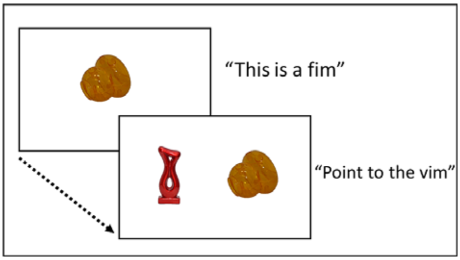

Figure 1. Schematic of a "Different" Trial in the Disambiguation Task

Auditory discrimination task

At the onset of the auditory discrimination task, participants completed a brief set of warm-up trials designed to orient them to the task. In these trials, participants saw two images side-by-side on the computer screen. Each image featured a cartoon drawing of a male speaker from the shoulders up, as depicted in Figure 2. The task was described as a "copycat" game where the first speaker (on the left) had to say a word and the second speaker (on the right) had to repeat it. Participants were instructed to judge whether the two speakers said the same word. To begin the task, children first saw the first speaker open his mouth and (in a pre-recorded male voice) say a familiar word (e.g., "ball"). Children then saw the second speaker open his mouth and (in the same a pre-recorded male voice) say a familiar word that was either the same (e.g., "ball") or different (e.g., "shoe") from the first word. Children indicated their judgment by touching a green button (yes, they said the same word) or a red button (no, they said the same word) on the screen. The button placement was randomized to the right or left side of the screen, as was the speaker placement. As in the disambiguation task, participants were excluded if they failed two of the four warm-up trials on the two consecutive warm up sets. One child (four-year-old) failed the warm-up trials and three children (two three-year-olds and one four-year-old) did not complete the task due to lack of interest. Their data were excluded from the study. The auditory discrimination task was included as a secondary task, used for insight into trials on which children failed to disambiguate.

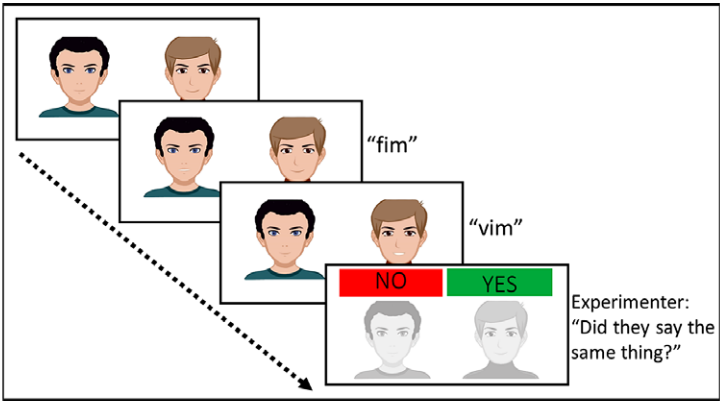

Figure 2. Schematic of a "Different" Trial in the Auditory Discrimination Task

After successfully completing warm-up trials, participants proceeded to the experimental trials. The experimental trials were structured identically to warm-up trials except that they included novel rather than familiar words. As in the disambiguation task, participants completed a total of 28 experimental trials, 14 of which were "same" trials and 14 of which were "different" trials.

Results

Analyses

All data from the disambiguation task were analyzed using mixed effect models, which permit analysis of non-aggregated trial level data without assumptions of linearity, normality, or homoscedasticity. These data were analyzed using logit mixed effects models, which model the log odds (or logit) of a correct response on each trial (1 = correct; 0 = incorrect). In these models, number of phoneme or feature differences were included as fixed effects, and participants and word pairs were included as random effects. These models were fit using the lme4 package (Bates, Mächler, Bolker, & Walker, 2015) in the R statistical programming language.

In what follows, we report the results of analyses of the number of phoneme differences and, for single phoneme changes, the position of differences, number of feature differences in those positions, and types of feature differences. For these analyses, only comparisons reaching or trending towards significance are reported; all other comparisons failed to reach significance. All models used to obtain these results are specified in Appendix B. As a supplementary analysis, we conducted one-sample *t* tests on the discrimination of word pairs incorrectly disambiguated. Our goal here was to gain insight into whether failed disambiguation might result from children not hearing the differences between words (and thus not discriminating them) or from children hearing but then ignoring the differences between words. For these analyses, only comparisons failing to reach significance (indicating at-chance accuracy) are reported; all other conditions reached significance (indicating above-chance accuracy).

Number of differing phonemes

We first examined whether disambiguation accuracy might vary based on the number of differing phonemes between words. We observed a main effect for same words compared to words differing in one, two, or three phonemes (see Table 2). Tukey-adjusted post-hoc tests revealed that disambiguation was less accurate for words that differed by one phoneme ($M = 0.67$, $SD = 0.47$) compared to those that differed by two ($M = 0.79$; $SD = 0.41$) or three phonemes ($M = 0.83$; $SD = 0.38$) or to words that were the same ($M = 0.80$, $SD = 0.40$; see Table 3 and Figure 3). This indicates that children are less likely to disambiguate words that differ by a single phoneme.

Position of differing phonemes

We next examined whether disambiguation accuracy for words that differed by a single phoneme might vary based on the position of that difference (i.e., the initial consonant, vowel, or final consonant). We observed main effects for the initial as well as the final consonants (see Table 4). Compared to trials that featured the same words, Tukey-adjusted post-hoc tests show that disambiguation was marginally less accurate for words

Table 2. Fixed Effect Estimates (Top) and Variance Estimates (Bottom) for Multi-Level Logit Model of 3-6 Yr.-Olds' Disambiguation Task Performance by Number of Differing Phonemes and Age (Observations = 2378, Log Likelihood = −1190.0)

Fixed effect	Coefficient	*SE*	Wald *z*	*p*
Intercept	1.63	0.16	10.28	<.001***
0 vs. 1, 2, or 3 differing phonemes	−0.80	0.20	−4.07	<.001***
0 or 1 vs. 2 or 3 differing phonemes	−0.07	0.18	−0.37	.71
0, 1, or 2 vs. 3 differing phonemes	0.19	0.23	0.82	.42
Random effect	s^2			
Participant	0.83			
Item	0.52			
Item x 0 vs. 1, 2, or 3 differing phonemes	0.79			
Item x 0 or 1 vs. 2 or 3 differing phonemes	0.57			
Item x 0, 1, or 2 vs. 3 differing phonemes	0.52			

Table 3. Tukey HSD-Corrected Post-Hoc Tests for Multi-Level Logit Model of 3-6 Yr.-Olds' Disambiguation Task Performance by Number of Differing Phonemes

Comparison	Estimate	*SE*	*z*–ratio	*p*
1 vs. 0 differing phonemes	−0.80	0.20	−4.07	< .001***
1 vs. 2 differing phonemes	−0.74	0.17	−4.43	< .001***
1 vs. 3 differing phonemes	−0.99	0.23	−4.33	< .001***

differing on the initial consonant and significantly less accurate for words differing on the final consonant (see Table 5 and Figure 4).[1] In fact, disambiguation rates for words that differed on the final consonant were at chance ($M = 0.56$, $SD = 0.16$; $t = 1.52$, $p = .13$). This indicates that children are less likely to disambiguate words that differ on the first or the last phoneme.

Number of differing phonological features

We next examined whether disambiguation accuracy varied by the number of differing phonological features between words. Given the prior analysis, we focused only on those words that differed in their initial or final consonants. Regarding initial consonants, we observed a main effect for words differing in no features vs. one, two, or three features. Tukey-adjusted post-hoc tests revealed that disambiguation was less accurate for words in

[1]We note that each participant received only 2 trials with a single phonological difference in each position, which limits the possible accuracy values for trials of this type, whereas they received 18 trials with no phonological differences in each position, which provides much more possibilities for trials of this type.

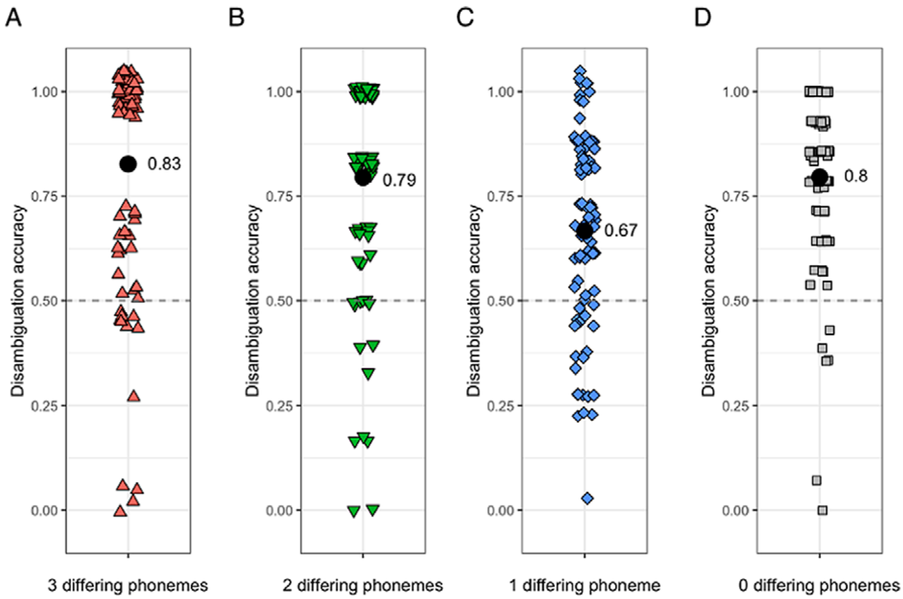

Figure 3. Disambiguation Task Performance of 3-6 Yr.-Olds for Word Pairs with (A) Three Differing Phonemes (different = accurate); (B) Two Differing Phonemes (different = accurate); (C) One Differing Phoneme (different = accurate); (D) No Differing Phonemes (same = accurate). Data Points Jittered Horizontally and Vertically; Means Indicated by Black Dots and Values; Dashed Lines Represent Chance.

Table 4. Fixed Effect Estimates (Top) and Variance Estimates (Bottom) for Multi-Level Logit Model of 3-6 Yr.-Olds' Disambiguation Task Performance for Same Word Pairs and Word Pairs with One Differing Phoneme by Position of Phoneme Difference (Observations = 1681, Log Likelihood = −871.2)

Fixed effect	Coefficient	*SE*	Wald *z*	*p*
Intercept	−0.64	0.51	−1.27	.20
Initial consonant, same vs. different	0.77	0.26	2.96	< .003**
Vowel, same vs. different	0.23	0.24	0.97	.33
Final consonant, same vs. different	1.23	0.28	4.46	< .001***
Random effect	s^2			
Participant	0.74			
Item	1.84			
Item x initial consonant, same vs. different	0.82			
Item x vowel, same vs. different	0.58			
Item x final consonant, same vs. different	1.06			

Table 5. Tukey HSD-Corrected Post-Hoc Tests for Multi-Level Logit Model of 3-6 Yr.-Olds' Disambiguation Task Performance for Same Word Pairs and Word Pairs with One Differing Phoneme by Position of Phoneme Difference

Comparison	Estimate	*SE*	*z*−ratio	*p*
Same vs. different initial consonant	−0.77	0.26	−2.96	.06†
Same vs. different vowel	−0.23	0.24	−0.97	.98
Same vs. different final consonant	−1.24	0.28	−4.46	< .001***
Different initial consonant vs. different vowel	0.54	0.29	1.85	.59
Different initial consonant vs. different final consonant	−0.47	0.28	−1.69	.69
Different vowel vs. different final consonant	−1.00	0.28	−3.61	.008**

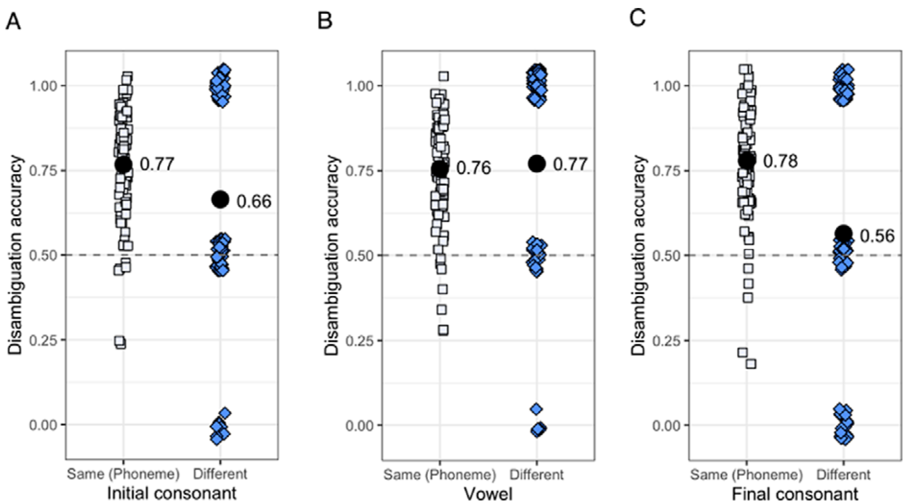

Figure 4. Disambiguation Task Performance of 3-6 Yr.-Olds for Word Pairs the Same or Differing in (A) Initial Consonant; (B) Vowel; and (C) Final Consonant. Data Points Jittered Horizontally and Vertically; Means Indicated by Black Dots and Values; Dashed Lines Represent Chance.

which initial consonants differed in one phonological feature compared to no feature differences (i.e., in which initial consonants were the same). Moreover, disambiguation accuracy was at chance for words in which initial consonants differed in one phonological feature ($M = 0.58$, $SD = 0.50$; $t = 1.42$, $p = .16$). Regarding final consonants, we observed a main effect for words differing in no features vs. one, two, or three features. In addition, we observed a main effect for words in which final consonants differed in zero or one features compared to those differing in two or three features. Tukey-adjusted post-hoc tests revealed that disambiguation was less accurate for words in which final consonants differed in one phonological feature compared to those in which final consonants were the same and words in which final consonants differed in two or three phonological features compared to words in which final consonants were the same (see Tables 6 and 7

Table 6. Fixed Effect Estimates (Top) and Variance Estimates (Bottom) for Multi-Level Logit Model of 3-6 Yr.-Olds' Disambiguation Task Performance for Same Word Pairs and Word Pairs with One Differing Phoneme by Number and Position of Feature Differences (Observations = 1681, Log Likelihood = −875.4)

Fixed effect	Coefficient	*SE*	Wald *z*	*p*
Intercept	1.31	0.11	11.75	< .001***
Initial consonant, 0 vs. 1, 2, or 3 feature differences	−1.18	0.25	−4.80	< .001***
Initial consonant, 0 or 1 vs. 2 or 3 feature differences	0.34	0.29	1.16	.25
Final consonant, 0 vs. 1, 2, or 3 feature differences	−1.13	0.25	−4.59	< .001***
Final consonant, 0 or 1 vs. 2 or 3 feature differences	−0.77	0.26	−2.91	.004**
Random effect	s^2			
Participant	0.70			
Item	0.25			

Table 7. Tukey HSD-Corrected Post-Hoc Tests for Multi-Level Logit Model of 3-6 Yr.-Olds' Disambiguation Task Performance for Same Word Pairs and Word Pairs with One Differing Phoneme by Number and Position of Feature Differences

Comparison	Estimate	*SE*	*z*-ratio	*p*
Same vs. initial consonant, 1 feature difference	1.18	0.25	4.80	< .001***
Same vs. final consonant, 1 feature difference	1.13	0.25	4.59	.001**
Same vs. final consonant, 2 or 3 feature differences	1.33	0.25	5.43	< .001***

and Figure 5)[2]. Disambiguation accuracy was at chance for words in which final consonants differed in one feature ($M = 0.59$, $SD = 0.50$; $t = 1.64$, $p = .10$) as well as words in which final consonants differed in two or three features ($M = 0.54$, $SD = 0.50$; $t = 0.76$, $p = .45$). In all, these patterns indicate that children are less likely to disambiguate words that differ in a single phonological feature on the initial consonant or any number of feature differences on the final consonant.

Types of differing features

We next examined whether disambiguation accuracy might vary by the specific types of phonological features that differ between words. As before, we focused only on those words that differed on the initial or final consonants. For initial consonants, we observed a main effect of voicing (see Table 8). Tukey-adjusted post-hoc tests revealed that disambiguation was less accurate for word pairs in which initial consonants differed only in voicing ($M = 0.65$, $SD = 0.48$) compared to those that were the same in voicing ($M = 0.77$,

[2]We note that each participant received only 1 trial with 1 or 2 or 3 feature differences in the initial and final positions, which limits the possible accuracy values for trials of this type, whereas they received 18 trials with no phonological differences in each position, which provides much more possibilities for trials of this type.

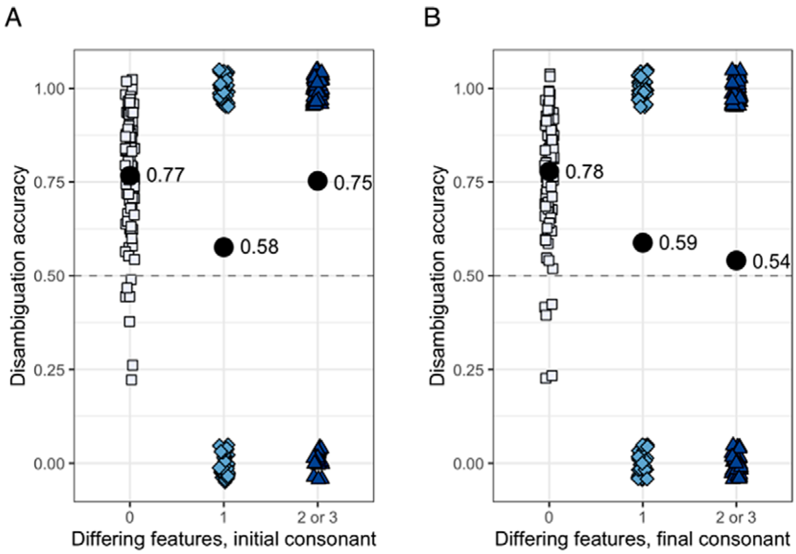

Figure 5. Disambiguation Task Performance of 3-6 Yr.-Olds for Word Pairs with Zero (same = accurate) and One (different = accurate) or Two or Three (different = accurate) Differing Features in (A) Initial Consonants and (B) Final Consonants. Data Points Jittered Horizontally and Vertically; Means Indicated by Black Dots and Values; Dashed Lines Represent Chance.

Table 8. Fixed Effect Estimates (Top) and Variance Estimates (Bottom) for Multi-Level Logit Model of 3-6 Yr.-Olds' Disambiguation Task Performance for Same Word Pairs and Word Pairs Differing in Initial Consonants by Feature Differences (Observations = 1681, Log Likelihood = −896.6)

Fixed effect	Coefficient	*SE*	Wald *z*	*p*
Intercept	0.79	0.06	12.68	< .001***
Place	−0.15	0.33	−0.46	.64
Voicing	−0.86	0.19	−4.62	.001***
Manner	−0.23	0.33	−0.70	.48
Place x voicing	0.63	0.48	1.31	.19
Place x manner	0.69	0.48	1.45	.15
Random effect	s^2			
Participant	0.40			
Item	0.13			

SD = 0.42) or that differed in place, voicing, and manner (*M* = 0.78, *SD* = 0.42; see Table 9). For final consonants, we observed main effects of place and voicing and a place by voicing interaction (see Table 10). Tukey-corrected post-hoc tests revealed that disambiguation was less accurate for words in which final consonants differed only in voicing (*M* = 0.49, *SD* = 0.50) compared to those that were the same in voicing (*M* = 0.78,

Table 9. Tukey HSD-Corrected Post-Hoc Tests for Multi-Level Logit Model of 3-6 Yr.-Olds' Disambiguation Task Performance for Same Word Pairs and Word Pairs Differing in Initial Consonants by Feature Differences

Comparison	Estimate	*SE*	*z*-ratio	*p*
Same vs. voicing	0.86	0.19	4.62	< .001***
Voicing vs. place, voicing, manner	−0.94	0.26	−3.60	.008***

Table 10. Fixed Effect Estimates (Top) and Variance Estimates (Bottom) for Multi-Level Logit Model of 3-6 Yr.-Olds' Disambiguation Task Performance for Same Word Pairs and Word Pairs Differing in Final Consonants by Feature Differences (Observations = 1681, Log Likelihood = −878.5)

Fixed effect	Coefficient	*SE*	Wald *z*	*p*
Intercept	0.84	0.06	13.30	< .001***
Place	−0.88	0.32	−2.77	.006**
Voicing	−1.31	0.25	−5.25	< .001***
Manner	0.24	0.26	0.92	.36
Place x voicing	1.23	0.50	2.46	.01*
Random effect	s^2			
Participant	0.40			
Item	0.12			

Table 11. Tukey HSD-Corrected Post-Hoc Tests for Multi-Level Logit Model of 3-6 Yr.-Olds' Disambiguation Task Performance for Same Word Pairs and Word Pairs Differing in Final Consonants by Feature Differences

Comparison	Estimate	*SE*	*z*-ratio	*p*
Same vs. voicing	1.32	0.25	5.25	< .001***
Same vs. place, voicing, manner	0.73	0.15	4.98	< .001***
Voicing vs. manner	−1.56	0.36	4.31	< .001***

$SD = 0.42$) and those that differed only in manner ($M = 0.84$, $SD = 0.37$; see Table 11). Moreover, disambiguation was at chance for words in which the final consonant differed only in place ($M = 0.55$, $SD = 0.48$; $t = 0.90$, $p = .37$) and voicing ($M = 0.49$, $SD = 0.50$; $t = 0.12$, $p = .91$) and trended towards chance for word pairs in which the final consonant differed only in manner ($M = 0.59$, $SD = 0.45$; $t = 1.92$, $p = .06$).

Auditory discrimination

Finally, we examined auditory discrimination for word pairs that children failed to disambiguate reliably. Here we compared discrimination rates to chance. For words that differed by voicing on the initial consonant ($M = 0.63$, $SD = 0.46$; $t = 1.54$, $p = .14$) or on the final consonant ($M = 0.63$, $SD = 0.45$; $t = 1.66$, $p = .11$), discrimination rates did not differ from chance. By contrast, auditory discrimination rates were above chance for words that differed by place on the final consonant ($M = 0.72$, $SD = 0.38$; $t = 2.90$, $p = .008$).

Discussion

In this experiment, we asked whether 3- to 6-year-olds' disambiguation of novel words would vary based on the number, position, or type of phonological differences between words. The results revealed that it did – when two words were more phonologically similar, children's disambiguation performance was less accurate. Specifically, disambiguation of words that differed by one phoneme was less accurate than disambiguation of words that differed by two or more phonemes. Further, among word pairs that differed by one phoneme, disambiguation was least accurate for differences located at the initial (e.g., fim/vim) or final (e.g., val/vaz) consonant position. Feature-level analysis further suggested that position differences relying on voicing and place resulted in the lowest rates of disambiguation. Taken together, these findings indicate that 3- to 6-year-olds were less likely to disambiguate words that sounded more similar than words that sounded more different and suggest that what children assume about contrasting words may depend on how much those words differ.

Overall, our results are consistent with previous work, but they also extend it in important ways. As in previous studies, we found that the amount of difference between two words can affect whether children disambiguate a novel word. Overall, children appear to be sensitive to graded similarity between words (Creel, 2012; Gerken, Murphy, & Aslin, 1995; Havy, Bertoncini, & Nazzi, 2011; Merriman & Schuster, 1991; White & Morgan, 2008). As the number of sound and feature differences increases, particularly early in a word, so does the likelihood that the second word is interpreted as referring to the second object (e.g., Jarvis, Merriman, Barnett, Hanba & Van Haitsma, 2004). In our experiment, two and three phoneme differences produced significantly higher rates of disambiguation for 3- to 6-year-olds than did single phoneme differences. One additional note, though: not all single phoneme differences in our experiment resulted in lower levels of disambiguation. We found that word pairs featuring changes to the medial (vowel) position did not lead to lower disambiguation rates as compared to word pairs that differed by two or three phonemes. Instead, children reliably used vowel differences to trigger the disambiguation process (see also White & Aslin, 2011 for findings with toddlers; but see Havy et al., 2011 for contradictory results). Given that vowels play a critical role in studies on accent variation, we might have expected children to demonstrate higher overall tolerance for changes in vowel sounds as compared to changes in consonants. Although children accept changes to vowels under some situations, they did not here. Therefore, children might show a flexible interpretation of vowels that allows them to avoid confusing similar words in some contexts, yet also accept variable pronunciations of the same word in other contexts (White & Aslin, 2011).

Our experiment also extends this prior work in a couple ways. First, many studies have focused on contrasting a known, familiar word (*apple*) with an altered pronunciation of that same word (*epple*) (e.g., Creel, 2012; Merriman & Schuster, 1991; Swingley, 2016; though see Havy et al., 2011). These studies tend to show that even toddlers will interpret the altered pronunciation as referring to the known or familiar object. However, because children are familiar with the known words, it is not clear whether their tolerance for the altered pronunciation is based on a prior history of having heard these words pronounced in a variety of ways or on an inference about what the speaker in a given situation is intending to communicate. In our experiment, we focused exclusively on novel words. By doing so, we clarify that when children accept an altered pronunciation of a word, it is not simply because they have done so previously. Second, many prior studies have emphasized subtle contrasts between words (Creel, 2012). In these studies, children often hear words that differ only in one segment (e.g., onset sound) and perhaps even in just a single phonological feature (e.g., White & Morgan, 2008). In our experiment, we systematically varied the amount of contrast, from words that differed in a single feature of a single phoneme to words that differed in three features of all three phonemes. As a result, we were able to assess whether the number, position, or even type of differences could shift children's focus to the novel referent.

For children 3 years of age and older, the most robust effect on disambiguation in our study came from the amount or number of phonological differences between words. In fact, disambiguation rates were consistently high when word pairs differed by at least two contrasting phonemes. When words differed by only one phoneme, rates were often lower. However, we found that other factors – for example, the position of phonological differences between two words – also can affect whether children disambiguate a novel word. This is consistent with previous studies. For example, Merriman and Schuster (1991) found that 2- and 4-year-olds were more likely to select a familiar (rather than novel) object when a novel label differed in onset sound(s) but shared a syllabic ending (rime) with the familiar word (e.g., *japple/apple*). Further, Creel (2012) has shown that when atypical word pronunciations (like those from accented speakers) differ in onset sounds, they are more often interpreted by 3- to 5-year-olds as references to a known rather than a novel referent. This was true despite children detecting those differences. There is additional evidence that younger children also show a high sensitivity to phonological differences when they occur early in a word. White and Morgan (2008) found that 19-month-olds more often interpreted novel words that differed from familiar words in one phonological feature (e.g., *shoe/foo*) as mispronunciations of the known label rather than as labels for novel objects. In our experiment, 3- to 6-year-olds were also less likely to disambiguate words that differed only in initial or onset sounds (e.g., *fim/vim*).

Interestingly, however, in addition to initial or onset differences, we also observed lower disambiguation rates on final or coda sounds (e.g., *val/vaz*). Perhaps this is not surprising given that children make more errors when producing codas in their own speech (e.g., Bernhardt & Stemberger, 1998; Stoel-Gammon & Dunn, 1985). Codas are processed last in the word sequence, often after initial hypotheses about the meaning of a word have already begun, and children tend to have more trouble identifying mispronunciations when they occur at the end of the word (Cole, 1981; Creel, 2012), perhaps due to higher rates of devoicing on final sounds. In fact, children in our experiment did not reliably discriminate words that differed only in voicing on the final phoneme, suggesting that the lower disambiguation rates could be a product of poorer discrimination. For many other phoneme position differences (e.g., words that differed on both the vowel and final consonant, words that differed on both the initial and final consonants, etc.), we did not find a negative effect on disambiguation.

Taken as a whole, the findings from our experiment suggest that not all contrasts are treated equally, and that the likelihood of disambiguation can vary based on how two words differ. Our results do show that factors like the number, position, and type of phonological differences between words can affect disambiguation. But they do not point to a simple explanation for why certain combinations of these factors undermine disambiguation while others do not. We can explore a couple of possible reasons though. One possibility is that contrast operates more like a correlate than a cause of disambiguation. Children assume that a speaker who uses different words is likely referring to different things. When two words are highly dissimilar, as they often are, this assumption may appear fairly automatic and accurate. The speaker's intent is uncomplicated and the second word can be reliably interpreted as referring to a novel thing. But, when two words are highly similar, because they have fewer differences, because the differences are located on certain positions, or because some sound features more closely resemble each other, children may be less certain about the speaker's intent and hesitate to quickly conclude that the second word was meant for a novel thing. They may instead consider that some differences between words could be unintentional, as in the case of mispronunciations, that the differences represent acceptable variations in normal pronunciation, such as in the case of slurred speech or an accent, or that more information is needed.

This line of reasoning could be interpreted as contradicting the principle of contrast – it suggests children may not automatically assume that two contrasting forms correspond to contrasting meanings in the world (Clark, 1987, 1988). However, it is worth noting that contrast is just one of the many pragmatic or contextual cues that children might consider when trying to determine the target of a speaker's intentions (Grassmann, Stracke, & Tomasello, 2009; Grassmann & Tomasello, 2010; Markman, 1990; Smith, Jones, & Landau, 1996; Tomasello & Akhtar, 1995). The value of each cue, including contrast, might change depending on the context and what other cues are present (Jaswal, 2004). This would allow children to apply the pragmatics of contrast flexibly, supporting their disambiguation of contrasting words in some instances but not others, depending on the information most relevant to understanding a speaker's intentions (Krueger & Storkel, 2020). For highly dissimilar words, contrast might be the most relevant and thus the most valuable cue. However, as word contrast decreases children may attend more closely, and assign more value, to the contextual cues most likely to indicate a speaker's intentions. In the end, at least from a pragmatic standpoint, it is this intention-reading piece that is the most critical (Grassmann, 2014).

Another possible reason for lower rates of disambiguation for some contrasts but not others is that the disambiguation task itself is cognitively demanding. Unlike a more traditional word learning task, the disambiguation task requires children to attend to multiple words and objects, detect differences between the words and objects, map multiple words to multiple objects, and to do all this simultaneously. The task creates multiple pressure points on a child's attentional, memory, language, and decision-making systems (Merriman & Marazita, 1995) and in doing so consumes considerable cognitive resources. Of course, this would be true for any instance of disambiguation, so task difficulty alone would not explain why disambiguation rates might differ across word pairs. However, cognitive resources are also needed to process phonological differences. During a cognitively complex task like disambiguation, fewer resources would be available to the child for processing these differences. Indeed, Werker and colleagues have shown that task difficulty is greater when mapping novel labels to novel objects than when mapping known object-labels (Fennell & Werker, 2003; Stager & Werker, 1997; Werker, Fennell, Corcoran, & Stager, 2002), especially for tasks involving minimally contrastive syllables (Pater, Stager, & Werker, 2004). Lower rates of disambiguation might then occur because the additional resources needed to process subtle phonological changes between words are not available, or are less available, when solving the disambiguation task.

Both possibilities imply that disambiguation rates might fluctuate in step with changes in word similarity. Our data provide mixed support for this. We do find that words with single phoneme differences generate lower disambiguation rates than words with multiple phoneme differences showing that decreasing the contrast between words lowers disambiguation. But we do not find that disambiguation rates decline with every decrease in contrast – for example, two phoneme differences do not yield lower rates than three phoneme differences.

A final possible reason for lower disambiguation rates is that children simply did not hear the differences between certain words pairs. If the presentation of contrasting words activates assumptions about a speaker's intent, then we would not expect those assumptions to be active in cases where children did not think the words contrasted. There is some evidence that this may have occurred in our experiment. For example, children did not reliably disambiguate words that differed only in voicing. Correspondingly, when these same word pairs were presented in an auditory discrimination task, children did not reliably discriminate them at above-chance rates. This leaves open the possibility that children did not disambiguate because they did not perceive these as different words. However, we did find that children were able to discriminate words that differed by place on the final consonant even though they did not reliably disambiguate them. These findings suggest that children may find it difficult to detect differences in words whose initial and final consonants differ by voicing and that this can negatively affect their ability to reliably disambiguate such words. However, for words that differ in place on the final consonant, disambiguation performance is not the result of an inability to reliably detect differences between the words.

In summary, the current research examined how differences between words might affect 3- to 6-year-olds' use of the principle of contrast within a disambiguation task. The results suggest that the number, position, and types of phonological differences could all affect the likelihood that children would assign a novel word to a novel object. In general, as the differences between words decreased the likelihood of disambiguation also decreased. Together, these findings support the possibility that young children's pragmatic assumptions about two contrasting words depend not only on if the words differ, but also on how they differ.

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Appendix A

Table A1. List of Words Used for Same Trials in the Disambiguation Task for 3- to 6-year-olds, Number of Occurrences in the Sample, and Proportion of Novel Objects Chosen

Words A-P	*Phonemes*	*Proportion (Novel)*	*N*	*Words R-Z*	*Phonemes*	*Proportion (Novel)*	*N*
bafe	beɪf	0.24	17	rabe	rɛɪb	0.35	17
besh	bɛʃ	0.35	17	reth	rɛθ	0.20	30
booj	buːʒ	0.35	17	rop	rɒp	0.14	21
buv	bʌv	0.24	17	seeb	siːb	0.12	17
dar	dɑːr	0.24	17	seev	siːv	0.18	17
dat	dæt	0.24	21	shoon	ʃuːn	0.14	21
deen	diːn	0.33	21	tef	tɛf	0.17	30
diz	dɪz	0.29	21	thid	θɪd	0.14	21
fep	fɛp	0.18	17	thole	θoʊl	0.18	17
fich	fɪʧ	0.29	34	tush	tʌʃ	0.27	30
fim	fɪm	0.24	17	tuv	tʌv	0.13	30
gafe	gɛɪf	0.03	30	val	væl	0.38	16
gathe	gɛɪθ	0.19	21	vip	vɪp	0.19	16
gode	goʊd	0.35	17	vome	voʊm	0.25	51*
jope	dʒoʊp	0.27	30	waf	wɒf	0.12	17
jup	dʒʌp	0.24	21	wek	wɛk	0.18	17
koof	kuːf	0.05	21	wesh	wɛʃ	0.10	30
koot	kuːt	0.18	17	wik	wɪk	0.29	21
koov	kuːv	0.41	17	yat	jæt	0.24	17
lum	lʌm	0.07	30	yol	yɒl	0.13	30
miz	mɪz	0.27	30	yote	yoʊt	0.19	21
moob	muːb	0.12	17	yun	yʌn	0.24	17
nase	nɛɪs	0.13	30	zeb	zɛb	0.13	30
neep	niːp	0.12	17	zeet	ziːt	0.12	17
nes	nɛs	0.19	21	zob	zɒb	0.18	17
noke	noʊk	0.18	17	zuv	zʌv	0.30	30
pob	pɒb	0.14	21				

*51 occurrences of vome (voʊm) due to an additional same trial set

Table A2. List of Words Used for Different Trials in the Disambiguation Task for 3- to 6-year-old Featuring One Phoneme Differences, Number of Occurrences in the Sample, and Proportion of Novel Objects Chosen

Position	*Word 1*	*Word 2*	*Word 1 Phonemes*	*Word 2 Phonemes*	*Proportion (Novel)*	*N*
Initial	buv	puv	bʌv	pʌv	0.62	21
	dar	har	dɑːr	hɑːr	0.67	21
	deen	geen	diːn	giːn	0.71	17
	fep	wep	fɛp	wɛp	0.73	30
	fim	vim	fɪm	vɪm	0.40	30
	sup	jup	sʌp	dʒʌp	0.77	17
	tef	sef	tɛf	sɛf	0.71	17
	yol	kol	jɒl	kɑːl	0.88	17
Vowel	jope	joop	dʒoʊp	dʒuːp	0.53	17
	nook	nake	nʊk	neɪk	0.82	17
	rabe	reeb	rɛɪb	riːb	0.67	21
	seeb	sib	siːb	sɪb	0.80	30
	wik	wook	wɪk	wʊk	0.76	17
	vome	vim	voʊm	vɪm	0.82	17
	yat	yute	jæt	juːt	0.86	21
	zeet	zot	ziːt	zɒt	0.83	30
Final	koot	kood	kuːt	kuːd	0.33	30
	lum	luw	lʌm	lʌw	0.88	17
	nes	neth	nɛs	nɛθ	0.47	17
	reth	rej	rɛθ	rɛdʒ	0.53	17
	val	vaz	væl	væz	0.81	21
	wek	wev	wɛk	wɛv	0.53	30
	yote	yove	joʊt	joʊv	0.41	17
	yun	yuch	jʌn	jʌʧ	0.67	21

Table A3. List of Words Used for Different Trials in the Disambiguation Task for 3- to 6-year-olds Featuring Two Phoneme Differences, Number of Occurrences in the Sample, and Proportion of Novel Objects Chosen

Position	*Word 1*	*Word 2*	*Word 1 Phonemes*	*Word 2 Phonemes*	*Proportion (Novel)*	*N*
Initial + Vowel	fich	vooch	fɪʧ	vʊʧ	0.81	21
	koof	geefe	kuːf	giːf	0.77	17
	moob	cheb	muːb	ʧɛb	0.90	21
	neep	dape	niːp	deɪp	0.83	30
	shoz	taz	ʃɒz	tæz	0.90	30
	thid	lod	θɪd	lɒd	0.82	17
	wesh	jash	wɛʃ	dʒæʃ	0.82	17
	zuv	bav	zʌv	bæv	0.77	17
Initial + Final	besh	peth	bɛʃ	pɛθ	0.80	30
	dat	gak	dæt	gæk	0.77	17
	gafe	thane	gɛɪf	θeɪn	0.65	17
	koov	joop	kuːv	dʒuːp	0.73	30
	miz	wid	mɪz	wɪd	0.71	17
	noke	chome	noʊk	ʧoʊm	0.81	21
	rop	tov	rɒp	tɒv	0.71	17
	vip	zib	vɪp	zɪb	0.81	21
Vowel + Final	booj	bef	buːʒ	bɛf	0.87	30
	diz	doke	dɪz	doʊk	0.88	17
	gode	gish	goʊd	gɪʃ	0.86	21
	nase	nath	nɛɪs	næθ	0.88	17
	pob	pum	pɒb	pʌm	0.71	17
	seev	sif	siːv	sɪf	0.81	21
	tuv	tooch	tʌv	tuːʧ	0.77	17
	zob	zeg	zɒb	zɛg	0.67	30

Table A4. List of Words Used for Different Trials in the Disambiguation Task for 3- to 6-year-olds Featuring Three Phoneme Differences, Number of Occurrences in the Sample, and Proportion of Novel Objects Chosen

Position	*Word 1*	*Word 2*	*Word 1 Phonemes*	*Word 2 Phonemes*	*Proportion (Novel)*	*N*
Initial + Vowel +Final	bafe	pav	beɪf	pæv	0.90	30
	gathe	choop	gɛɪθ	ʧu:p	0.71	17
	leck	voom	lɛk	vu:m	0.92	38
	shoon	feez	ʃu:n	fi:z	0.77	17
	thole	sot	θoʊl	sɒt	0.90	21
	tush	meeg	tʌʃ	mi:g	0.82	17
	waf	kud	wɒf	kʌd	0.73	30
	zeb	nid	zɛb	nɪd	0.76	17

Appendix B

B1. *Logit mixed effects model for number of phonological differences fit to disambiguation data of 3-6-yr.-olds*
glmer(Correct ~ PD + (1|Participant) + (1 + PD|Trial)

B2. *Logit mixed effects model for phonological difference by position fit to disambiguation data of 3-6-yr.-olds for same word pairs and word pairs differing in a single phoneme*
glmer(Correct ~ P1_SameDiff + P2_SameDiff + P3_SameDiff + (1|Participant) + (1 + P1_SameDiff + P2_SameDiff + P3_SameDiff|Trial)

B3. *Logit mixed effects model for number of feature differences by position fit to disambiguation data of 3-6-yr.-olds for same word pairs and word pairs differing in a single phoneme*
glmer(Correct ~ P1_FD * P3_FD + (1|Participant) + (1|Trial)

B4. *Logit mixed effects model for specific feature differences for the initial consonant fit to disambiguation data of 3-6-yr.-olds for same word pairs and word pairs differing in a single phoneme*
glmer(Correct ~ P1_FD_P * P1_FD_V * P1_FD_M + (1|Participant) + (1|Trial)

B5. *Logit mixed effects model for specific feature differences for the final consonant fit to disambiguation data of 3-6-yr.-olds for same word pairs and word pairs differing in a single phoneme*
glmer(Correct ~ P3_FD_P * P3_FD_V * P3_FD_M + (1|Participant) + (1|Trial)

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