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‘Clap your hands’ or ‘take your hands’? One-year-olds distinguish between frequent and infrequent multiword phrases

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Abstract

Although words are often described as the basic building blocks of language, there is growing evidence that multiword sequences also play an integral role in language learning and processing. It is still not known, however, whether children become sensitive to multiword information at an age when they are still building knowledge of individual words. Using a central fixation paradigm, the present study examined whether infants between 11 and 12 months (N=36) distinguish between three-word sequences (trigrams) with similar substring frequencies but different multiword frequency in infant-directed speech (e.g., high frequency: *'clap your hands'* vs. low frequency: *'take your hands'*). Infants looked significantly longer at frequent trigrams compared to infrequent ones. This provides the first evidence that infants at the cusp of one-word production are already sensitive to the frequency of multiword sequences, and suggests they represent linguistic units of varying sizes from early on, raising the need to evaluate knowledge of both words and larger sequences during development.

Keywords: infants/children; multiword units; language learning; input

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Introduction

While words are often considered the basic building blocks of language, recent work shows that multiword sequences also play an important role in language alongside individual words (see Arnon, in press; Christiansen & Arnon, 2017 for reviews). This idea is found in linguistic approaches that emphasize the role of constructions (Culicover & Jackendoff, 2005; Goldberg, 2006), and is advocated in single-system models of language where all linguistic material (from sounds, through words to multiword sequences) is processed by the same cognitive mechanisms (Bybee, 1998; Christiansen & Chater, 2016; Elman, 2009; McClelland, 2010). Multiword units also play a prominent role in usage-based models of language learning where grammatical knowledge is learned by abstracting over stored exemplars of varying sizes and levels of abstraction (e.g., Abbot-Smith & Tomasello, 2006; Bannard & Lieven, 2012; McCauley & Christiansen, 2019; Tomasello, 2003). Under such approaches, speakers are predicted to represent both words and multiword sequences.

Consistent with this prediction, there is evidence that speakers draw on multiword information in language learning, processing and use. Adults are sensitive to multiword frequency, with more frequent phrases recognized faster (Arnon & Snider, 2010), remembered better (Tremblay, Derwing, Libben & Westbury, 2011), and produced with shorter duration (Arnon & Cohen Priva, 2013). These effects hold when controlling for all part frequencies, indicating knowledge about the frequency of the larger sequence. Furthermore, adults process three-word phrases acquired earlier during childhood faster than those that are acquired later, mirroring the well-documented Age-of-Acquisition effects for individual words and suggesting that multiword sequences also serve as units of learning (Arnon, McCauley & Christiansen, 2017). These findings highlight the parallels between words and larger sequences and indicate that speakers represent both words and multiword units.

The evidence emerging from child language suggests that multiword information also influences children's production and processing. Four-year-olds are better at producing irregular plurals when they are part of a more frequent sequence (e.g., *teeth* in *'brush your teeth'*, Arnon & Clark, 2011). Two- and three-year-olds are faster and more accurate in repeating higher frequency four-word phrases compared to lower frequency ones (e.g., *'sit in your chair'* vs. *'sit in your truck'*, Bannard & Matthews, 2008) and show faster recognition and better production of nouns when they are embedded in a familiar phrase (*'where's the baby?'* vs. *'the baby'*, Fernald & Hurtado, 2006), or in more frequent bigrams (Jones, Cabiddu & Avila-Varela, 2020). Many of children's early productions are 'frozen' or 'formulaic' multiword expressions (e.g., Lieven, Pine & Barnes, 1992; Lieven, Behrens, Speares & Tomasello, 2003; Lieven, Salomo & Tomasello, 2009; Peters, 1983) and are better accommodated by a computational model that extracts both words and multiword units (McCauley & Christiansen, 2019). Furthermore, production errors are related to children's knowledge of larger sequences that frequently occur in caregiver speech (e.g., Kirjavainen, Theakston & Lieven, 2009). Taken together, these findings demonstrate that, like adult speakers, children represent multiword sequences as well as words.

However, the existing evidence leaves open an important theoretical question about how children come to learn multiword sequences. One possibility, in line with standard descriptions of language acquisition, is that children first learn individual words, and then begin to store information about their combinations. If true, sensitivity to multiword frequency should emerge only after children acquire substantial knowledge about words and their co-occurrence patterns. Alternatively, children could extract multiword sequences alongside and in parallel with individual words and represent both from the very start. This prediction is explicitly made by the Starting Big approach to language learning (Arnon, 2010; Arnon & Christiansen, 2017; Arnon, in press). Under this approach, children's initial linguistic inventory corresponds to prosodic boundaries, and consequently includes both word and multiword units, which serve an important role in learning grammatical relations (Arnon & Ramscar, 2012; Siegelman & Arnon, 2015). The prediction that young infants are not limited to individual words but also attend to larger sequences is consistent with the presence of frequent multiword combinations in child-directed speech (Cameron-Faulkner, Lieven, & Tomasello, 2003) and with infants' early perceptual abilities: Infants show short-term memory of prosodically-coherent multiword strings early on (Mandel, Nelson, & Jusczyk, 1996), and perceive the acoustic boundaries of larger units before smaller ones (e.g., utterance boundary before word boundary, Soderstrom, Seidl, Kemler Nelson & Jusczyk, 2003).

Here, we go beyond existing findings and ask whether infants are sensitive to multiword frequency before they start producing multiword combinations, and when their productive and receptive vocabulary is still in its early stages. Such a finding would demonstrate that infants represent multiword information alongside words, underscoring their role in language acquisition, and opening up new questions about infants' initial linguistic inventory. Specifically, we ask whether 11- to 12-month-olds can distinguish between three-word sequences with similar plausibility and lexical frequency but different multiword frequency in infant-directed speech. At this age, English-learning children recognize some individual words and show awareness of formulaic expressions, such as *'peek-a-boo'* or *'all gone'* (Caselli, Bates, Casadio, Fenson, Fenson, Sanderl, & Weir, 1995). However, there is currently no evidence that their knowledge extends to non-formulaic multiword sequences until around 18 months of age when they begin to produce two-word utterances (Bloom, 1993; Goldin-Meadow & Butcher, 2002). If infants already represent information about multiword sequences at the same time as they are learning words, we predict that 11- to 12-month-olds should distinguish between multiword sequences that occur frequently in the input (e.g., '*clap your hands'*) and ones that are matched on lexical frequency but are infrequent in the input (e.g., '*take your hands'*). We tested this prediction using an infant-controlled sequential looking procedure to measure infants' gaze fixation to a visual stimulus while they listened to frequent and infrequent three-word combinations (trigrams).

Method

Participants

Participants were 36 (18 females) typically developing 11- to 12-month-olds (Range: 335 to 377 days; Mean: 359 days). All infants were growing up in the U.K. in a monolingual or predominantly English-speaking family. They were all full-term births, and had no reported hearing problems. Five additional infants were tested but not included in the analysis due to fussiness/crying (3) or noncompletion (2).

Materials

Trigram selection

The test items consisted of pairs of three-word sequences that differed by one word (e.g., *clap.your.hands – take.your.hands*). In each pair, the sequences differed in trigram frequency (high vs. low), but were matched for substring frequency (i.e., each word, or unigram, and bigram). For example, *clap.your.hands* had a higher trigram frequency than *take.your.hands*, but *clap* and *take* were matched in frequency and so were *clap.your* and *take.your*. The items were constructed based on naturalistic British English infant-directed speech from the Nuffield corpus (McGillion, Pine, Herbert, & Matthews, 2017) and the Edinburgh corpus (Ota, Davies-Jenkins, & Skarabela, 2018). Combined, they yielded a dataset of 363,081 words. The sampled caretaker speech was addressed to 11-month-olds in the Nuffield corpus and to 9- and 15-month-olds in the Edinburgh corpus. Two criteria were used to select the initial set of trigrams: a) the high-frequency trigrams must occur at least 20 times per million in the corpus, which is higher than the ten-per-million criteria often used to define high frequency in adult corpora (Arnon et al., 2017); and b) the substring frequencies between the high- and low-frequency trigrams must not differ by more than 20%. The initial selection consisted of 19 pairs of trigrams that differed in only one word and could be construed as a constituent.

To assess their grammatical acceptability, we presented these trigrams to adult native speakers of English (N = 24), together with 16 filler trigrams. Participants were asked to rate each word combination from 1 (‘completely unacceptable, sounding bad in English’) to 5 (‘completely acceptable, sounding good in English’). The mean rating of these trigrams was 3.52 (SD=1.59). We selected 12 pairs of trigrams with the highest grammaticality ratings (mean = 4.67, range: 4.0 – 5.0). The frequent members of these pairs were on average 42.5 times more frequent than the infrequent members. The pairs did not differ significantly in substring frequency (all t’s < .1) or grammaticality ($t = 2.49$, $df = 22$, $p = .21$) (see Table 1 with summary unigram, bigram and trigram frequencies, and the Appendix B for frequency information for individual items).

Table 1. Mean frequencies per million words (and standard deviations) of trigrams and their substrings.

Condition	N	Trigram	Unigram1	Unigram2	Unigram3	Bigram1	Bigram2
Frequent	12	39.1 (17.2)	1165.1 (1265.4)	8251.5 (3238.9)	970.1 (1370.0)	186.4 (296.3)	149.8 (149.8)
Infrequent	12	0.9 (2.3)	1136.1 (1259.3)	8251.5 (3238.9)	965.4 (1372.2)	184.3 (297.6)	151.1 (149.9)

Note: UnigramN refers to the frequency of the Nth word (e.g., Unigram1 in ‘clap your hands’ is *clap*). BigramN refers to the frequency of the Nth two-word combination (e.g., Bigram1 in ‘clap your hands’ is *clap.your*).

Auditory properties of the stimuli

The trigrams were read by a female speaker of Southern British English using infant-directed speech. They were all produced with the same prosodic pattern marked by a low tone at the initial and final boundaries and a fall-rise nuclear pitch accent on the final word. All stimuli were normalized to 70dB, and the frequent and infrequent trigrams were comparable in their fundamental frequency (F0) measures and duration (see Table 2, all *t*'s < 1). The sound stimuli are available at https://osf.io/f6cgb/.

Table 2. Mean (and standard deviation) of mean F0, maximum F0, minimum F0 and duration of trigram stimuli in the frequent versus infrequent conditions.

	N	F0 mean (Hz)	F0 max (Hz)	F0 min (Hz)	Duration (s)
Frequent	12	263 (28)	480 (29)	158 (44)	1.16 (0.15)
Infrequent	12	274 (31)	500 (52)	147 (45)	1.19 (0.11)

Test sets

For counterbalancing purposes, the 12 trigrams were divided into two lists, each with 6 frequent and 6 infrequent trigrams. Members of each pair (frequent/infrequent) were assigned to separate lists, A or B, so that a participant does not hear both. For example, Set A included the frequent variant *clap.your.hands*, and Set B included the infrequent variant *take.your.hands*. The lists did not significantly differ in whole-string or substring frequency (all *t*'s < 1, except $t = 1.48$, $p = .16$ for bigram2 in Lists A & B).

Procedure

The experiment was carried out in a dimly-lit sound-attenuated room, equipped with a 47-inch TV set to present the stimuli. Stimulus presentation was controlled by the Habit X 1.0

program (Cohen, Atkinson, & Chaput, 2004). During the experiment, the infant sat on the caregiver's lap, seated approximately 1.5 meters away from the display monitor. The caregiver listened to masking music played over headphones, instructed not to speak to the infant or point at the monitor during the experiment. An experimenter in a separate room, with no access to the auditory stimuli played in the test room, recorded the infant's visual fixation to the monitor by observing their eye-gaze through a video camera located underneath the stimulus presentation monitor.

Warm-up

The experiment began with a warm-up phase when infants were presented with an animation sequence on the TV screen while listening to a classical piano piece for 18s. The animation was a green ball changing in size in the center of the screen, against a grey background. This was followed by an attention-getter sequence with animated bubbles moving toward the center of the screen and a background soundtrack of children's laughter. This sequence was also used to draw the infants' attention to the center of the screen between test trials.

Test trial

During test trials, the same green ball animation from the warm-up was shown with the auditory test stimuli. There were 6 frequent trigram trials and 6 infrequent trigram trials. In each trial, the participants heard either six different frequent trigrams or six different infrequent trigrams, played with a 2s silence at the beginning and an inter-stimulus interval of 1.5s. For example, a participant would hear {*clap.your.hands*, *for.a.walk*, *sing.a.song*, *in.the.sky*, *open.it.up*, *yes.you.are*} in the frequent trial and {*shake.it.off*, *turn.the.box*, *on.your.mouth*, *watch.your.boat*, *get.that.one*, *making.a.tower*} in the infrequent trial. As explained above, the trigram pairs were counterbalanced across participants such that each participant heard only one of the variants from each pair (either the frequent or the infrequent trigram) and not both members of the pair. The order of the trigrams within each trial was pseudorandomized. The trial ended when the infant looked away for 2 consecutive seconds. Otherwise, the trial lasted for 22s (the length of the sound file). Trial order was pseudorandomized such that no condition (frequent vs. infrequent) was played more than twice in a row and each condition was played once during the first two trials of the experiment.

Results

The critical variable was the duration of central fixation in each trial. Following the standard procedure for this type of paradigm, the first trial for each individual child was excluded from the analysis (Cooper, Abraham, Berman, & Staska, 1997; Shi & Werker, 2001). Figure 1 displays the mean listening times for individuals and the grand means for the two conditions. On average, fixation times were longer for the frequent trigram trials (mean = 9.29s, sd = 3.00) than for the infrequent trigram trials (mean = 8.39s, sd = 2.96), exhibiting a familiarity effect which is typical of infant perception experiments without pre-exposure to stimuli (e.g., Houston-Price & Nakai, 2004). This pattern was found individually in 23 out of the 36 infants.

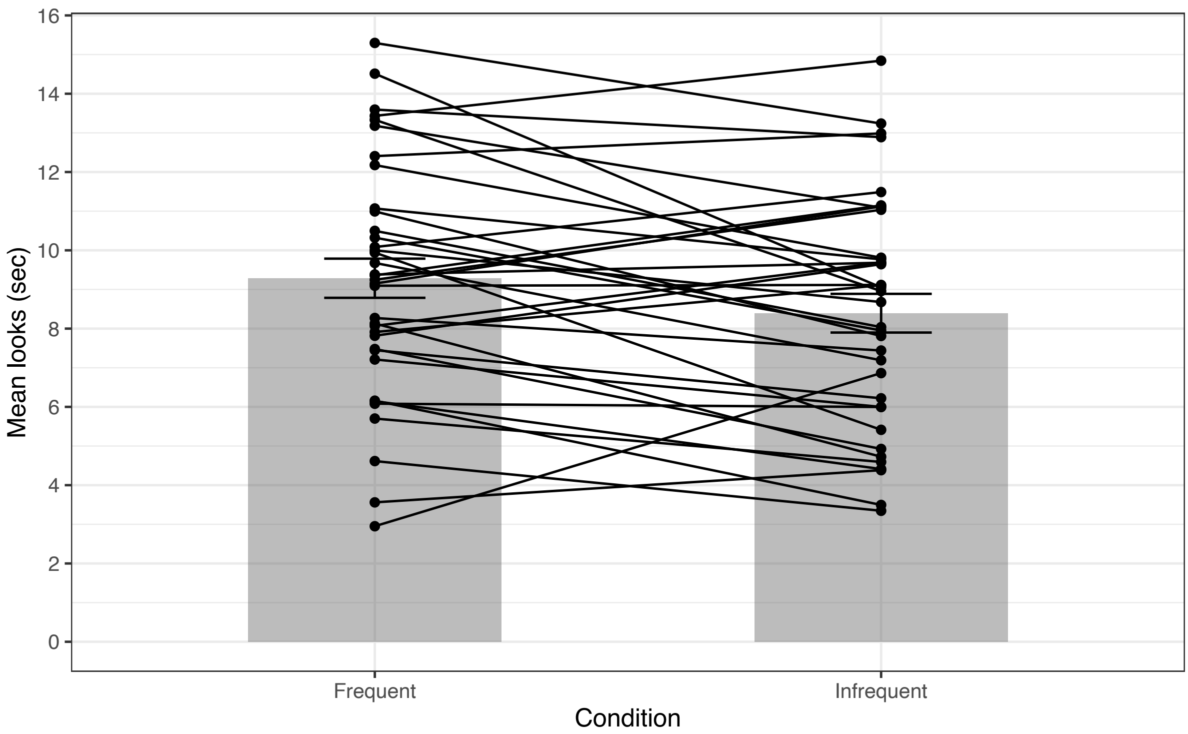

Figure 1. Mean looking times (seconds) by condition. Bars represent the mean and standard error per condition. Lines represent means of individual participants.

We conducted a linear mixed-effects analysis using the lmer function in R, with looking time as a dependent factor and condition (frequent vs. infrequent) as a fixed effect. Condition was sum-coded. The model also contained random intercepts and slopes for condition by individuals. There was a significant effect of condition (Estimate = 0.463, SE = 0.220, *df* = 358.3, $t = 2.103$, $p = 0.0362$), confirming the observation that looking times were longer for frequent trigrams compared to infrequent trigrams. In order to explore the source of the individual differences, we carried out a follow-up analysis with age and gender included in the model along with their interactions with Condition. The results showed no effects of age or gender while Condition remained a significant factor.

Discussion

We set out to ask whether infants are sensitive to multiword information at an age when they are building up knowledge of individual words. Specifically, we examined whether 11- to

12-month-olds distinguish between three-word sequences that have similar plausibility and lexical frequency but differ in their multiword frequency in infant-directed speech. In an infant-controlled sequential looking procedure, infants listened longer to frequent trigram trials than to infrequent trigram trials, suggesting that at this age they already represent multiword information. The results expand on previous findings that multiword information impacts language processing and learning in adults and older children (Lieven et al., 2003; Bannard & Matthews, 2008; Arnon & Clark, 2011), and provide the first evidence that infants are sensitive to the frequency of multiword sequences long before they begin producing such combinations.

The observed difference between frequent and infrequent trigrams could not be driven by the individual words, because the words distinguishing the frequent and infrequent trigrams (i.e., '*take*' versus '*clap*' in '*_your hands*') were matched for frequency (as were the bigrams). To show the effect, infants had to have stored the frequency of the entire sequence, indicating they attend to and represent larger sequences alongside words from early on, consistent with the predictions of the Starting Big approach (Arnon, 2010), and usage-based models more generally (e.g., Abbot-Smith & Tomasello, 2006). The extraction of multiword sequences could be driven by infants' perceptual abilities: Segmenting speech according to prosodic boundaries will result in an initial inventory containing single words, sentence fragments and short multiword utterances, all of which can serve as building blocks for learning. This resonates with computational models of speech segmentation that often classify frequent multiword sequences as one word, even when they use only distributional cues: for instance, using transitional probabilities as a cue to word boundary yielded 30% of the proposed "words", which were in fact well-formed multiword sequences (Goldwater, Griffiths, & Johnson, 2009; see also Swingley, 2005). That is, infants seem to extract linguistic units of varying sizes, raising the need to evaluate knowledge of both words and larger sequences during development.

Importantly, our findings do not tell us whether infants represent the multiword sequences as unanalysed chunks or combinations of individually learned words. Given evidence that many of the words in the trigrams we used are not comprehended by infants at this age[1], it is possible that at least some of the sequences, or parts of, were treated holistically as one lexical unit. Such a pattern is consistent with the presence of unsegmented or undersegmented chunks in children's early inventory (Peters, 1983; Arnon & Christiansen, 2017; McCauley & Christiansen, 2019). Whether or not a sequence is treated as one unit will be impacted by input statistics (McCauley & Christiansen, 2019), as well as length, frequency, and other factors (Grimm, Cassani, Gillis, & Daelemans, 2017; 2019). Under emergentist models of language (e.g., Bybee, 1995; McClelland, 2010; Arnon & Snider, 2010), such holistic representations are expected to gradually lead to single word representations (as infants learn individual words), while still maintaining a multiword representation (tied to the individual words). Future work should examine the interplay between word and multiword representation by evaluating individual children's knowledge of the words making up the multiword sequences. Another area for future research is the effects of the syntactic structure on children's extraction of multiword sequences. The trigram variants in our study were complete syntactic constituents but the pairs were not fully matched on syntactic structure. This structural heterogeneity can be seen as an asset since it illustrates multiword sensitivity across different syntactic types (as has been found for adults, e.g., Arnon & Priva, 2014). Nonetheless, further work could compare children's responses to structurally more homogeneous test examples to see if syntactic structure impacts the likelihood of extracting a multiword sequence.

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[1] The 24 trigrams contained 40 unique words. Of these, 21 words could be found on the Words and Gestures form of the McArthur-Bates Communicative Development Inventory (CDI). According to normative CDI data accessed from Word bank (http://wordbank.stanford.edu/), on average only 17.6% of 11-month-olds understand these individual words.

Our results have further implications for how larger units could impact language acquisition more generally. Knowing how words co-occur can free up processing resources and help young children predict upcoming linguistic material: 18-month-olds, for instance, are faster at recognising nouns when embedded in familiar multiword sequences (e.g., '*Look at the doggie!'*, Fernald & Hurtado, 2006), and show better learning of words that appear in more frequent bigrams (Jones et al., 2020). As proposed by usage-based approaches (e.g., Abbot-Smith & Tomasello, 2006; Arnon & Clark, 2011), comparing multiword sequences to each other can also help children discover grammatical regularities, including inflection ('*you walk'* vs. *'you walked')*. Furthermore, under the Starting Big Approach, multiword sequences may be critical in learning of semantically arbitrary relations between words, including gender marking and verb-preposition pairing (Arnon & Christiansen, 2017). This idea is consistent with the observation that adult second language learners typically fail to acquire such relations because of their reliance on individual words instead of multiword combinations (Arnon, 2010, in press; Siegelman & Arnon, 2015; Paul & Gruter, 2016). The current finding provides support for the account's core prediction that the mastery of native language rests on multiword sequences as early units of learning.

Our study also supports the notion that language acquisition does not always progress from smaller to larger units but involves both part-to-whole and whole-to-part processes (Peters, 1977, 1983). Indeed, the presence of whole-to-part or big-to-small learning has been observed for other aspects of language acquisition. For example, there is evidence that phonological development involves learning sound patterns holistically at the word level rather than as a set of smaller phonological units (e.g., segments) (Ferguson & Farwell, 1975; Vihman, 2017; Waterson, 1971). Similarly, a sizable portion of morphological development starts from inflected forms acquired as unanalysed units (or 'amalgams') before the underlying morphological units are identified (MacWhinney, 1978; Wilson, 2003). Our study adds to this work and shows that children may learn individual words from multiword sequences (e.g., Arnon & Clark, 2011; Theakston & Lieven, 2017).

Finally, the results of this experiment offer evidence against a strict division between the lexicon and grammar with rules or constraints used to combine them (e.g., Pinker, 1999; Pinker & Ullman, 2002). Under such dual-system accounts, frequency is not expected to impact forms generated by grammar, like the compositional trigrams we used as our test items. Instead, our findings are more compatible with single-system approaches to language, where speakers store and represent linguistic units of varying sizes and levels of abstraction (e.g., Bybee, 1995; McClelland, 2010; Tomasello, 2003), and where similar associative memory mechanisms impact the learning and processing of all linguistic experience (Arnon & Snider, 2010; Tremblay & Baayen, 2010). In this sense, the current study joins a growing literature questioning the qualitative division between 'stored' and 'computed' forms (e.g., Bybee, 1998; McClelland, 2010).

In conclusion, this is the first study to provide evidence for preverbal infants' sensitivity to multiword frequency. The ability to distinguish frequent and infrequent three-word sequences at this stage strongly suggests that infants build on linguistic material of various sizes and demonstrates that multiword sequences alongside individual words form an integral part of early language learning.

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Appendix A

Supplementary information

The data of this study are publicly available via the Open Science Framework (https://osf.io/f6cgb/).

Appendix B

List of trigrams

Pair	Trigram	Fruequency	Bigram1	B1.freq	Bigram2	B2.freq	Onigram1	U1.freq	Unigram2	U2.freq	Unigram3	U3.freq	Set	Condition
1	take.it.off	29	take.it	79	it.off	89	take	443	it	8178	off	780	B	Freq
1	shake.it.off	0	shake.it	67	it.off	89	shake	455	it	8178	off	780	A	Infreq
2	clap.your.hands	55	clap.your	60	your.hands	148	clap	552	your	5010	hands	302	A	Freq
2	take.your.hands	0	take.your	62	your.hands	148	take	443	your	5010	hands	302	B	Infreq
3	turn.the.page	79	turn.the	98	the.page	94	turn	302	the	10261	page	204	B	Freq
3	turn.the.box	0	turn.the	98	the.box	99	turn	302	the	10261	box	218	A	Infreq
4	for.a.walk	35	for.a	244	a.walk	42	for	1890	a	8147	walk	123	A	Freq
4	for.a.cow	0	for.a	244	a.cow	39	for	1890	a	8147	cow	120	B	Infreq
5	sing.a.song	21	sing.a	26	a.song	46	sing	82	a	8147	song	99	A	Freq
5	thats.a.song	0	thats.a	22	a.song	46	thats	88	a	8147	song	99	B	Infreq
6	in.the.sky	32	in.the	1079	the.sky	49	in	3260	the	10261	sky	64	A	Freq
6	in.the.end	1	in.the	1079	the.end	50	in	3260	the	10261	end	64	B	Infreq
7	yes.you.are	38	yes.you	75	you.are	293	yes	948	you	16661	are	3836	A	Freq
7	so.you.are	0	so.you	89	you.are	293	so	1115	you	16661	are	3836	B	Infreq
8	on.your.head	54	on.your	346	your.head	156	on	3524	your	5010	head	372	B	Freq
8	on.your.mouth	1	on.your	346	your.mouth	168	on	3524	your	5010	mouth	305	A	Infreq

9	want.that.one	22	want.that	68	that.one	560	want	2377	that	6008	one	3364	B	Freq
9	get.that.one	8	get.that	80	that.one	560	get	2122	that	6008	one	3364	A	Infreq
10	build.a.tower	32	build.a	46	a.tower	57	build	139	a	8147	tower	164	B	Freq
10	making.a.tower	1	making.a	39	a.tower	57	making	112	a	8147	tower	164	A	Infreq
11	row.your.boat	49	row.your	50	your.boat	63	row	167	your	5010	boat	106	B	Freq
11	watch.your.boat	0	watch.your	43	your.boat	63	watch	163	your	5010	boat	106	A	Infreq
12	open.it.up	23	open.it	66	it.up	201	open	297	it	8178	up	2227	A	Freq
12	leave.it.up	0	leave.it	42	it.up	201	leave	159	it	8178	up	2227	B	Infreq