DOES SYLLABLE FREQUENCY AFFECT PRODUCTION TIME IN A DELAYED NAMING TASK?

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ABSTRACT

In a delayed naming task the effect of syllable frequency on the production time of syllables was investigated. Participants first heard either a low- or a high-frequency syllable and were then asked to repeat this syllable as often as they could for a time span of eight seconds. Mean production times per syllable were determined. When the segmental make-up of high- and low-frequency syllables was completely matched, there was no frequency effect on production time. It is concluded that syllable frequency does not play a role on the articulatory-motor level in speech production.

INTRODUCTION

Speech production involves the retrieval of lexical items from the mental lexicon. According to Levelt's ([10], [11]) two-stage model of lexical access, first the syntactic properties of a lexical item are selected. This process is known as lemma selection. In a second stage called word form retrieval, phonological information for each lemma is accessed. This information is used during phonological encoding to generate a sound form for the selected lemmas. Two kinds of phonological information can be distinguished, i.e., segmental and metrical information. During segment-to-frame association segments are associated to metrical frames according to the syllabification principles of the language. The output of phonological encoding is an abstract phonetic plan. This phonetic plan is translated into motor programs for articulation.

Frequency effects and production time

An important determinant for lexical access time is word frequency. The frequency of occurrence of a word is known to influence lexical access in speech perception ([3], [4], [7], [8]) as well as in speech production ([9]). Using a delayed pronunciation task, Balota and Chumbley ([1]) showed that word frequency may not only influence lexical access time but also production time of a lexical item, i.e., the translation of an abstract phonological code to a sequence of motor commands. The naming latencies for high-frequency (HF) words were significantly shorter than for low-frequency (LF) words of the same length in an immediate naming task. However, the effect persisted even in delayed naming suggesting that a large component of the word frequency effect in the naming task involves production instead of lexical access. Balota and Chumbley ([1]) conclude that a large portion of the frequency effects in naming is traceable to the output of a word form rather than only to its encoding. This result agrees with Umeda's ([26]) finding that the duration of phonemes can vary as a function of word frequency. However, a possible confound in the Balota and Chumbley ([1]) study may be that the HF and LF words used in their experiments were only matched with respect to their length in graphemes but not in phonemes. More importantly, the segmental make-up differed between HF and LF words. This may have had an effect on the production times since it is known that there are differences between the durations of different consonants and vowels ([17], [25], [26]).

McRae, Jared, and Seidenberg ([15]) investigated the role of word frequency in immediate and delayed naming using materials that differed in frequency but was equated in terms of segmental characteristics (e.g., homophones, rhyme pairs, and pseudohomophones). Robust frequency effects were only obtained in the immediate naming conditions suggesting that the word frequency effect disappears when participants could fully prepare their responses. That is, when segmental differences between HF and LF words are controlled for, there is no effect of frequency on production time.

Syllables in speech production

Experimental evidence suggests that the syllable plays a role in speech production, at least in some languages ([6]). In current models of speech production the syllable is generally conceived of as an articulatory-motor unit ([10], [11]). In normal conversational speech speakers typically utter 5-6 syllables per second ([5]). This speaking rate equals a mean syllable duration of 160-200 ms ([12]). Although the syllable provides a fairly fixed time frame for the coordination of consonants and vowels, there are differences between the access and production latencies of certain types of syllables. It is known that structural effects may influence the latencies in syllable naming ([14], [16], [23], [24], [27]). The main result of MacKay's ([14]) study was that the production times for syllables of equal length varied as a function of syllable structure, i.e., CV structure. Other researchers have shown that syllables being similar but not identical in structure may inhibit each other in a production task (see, e.g., [23], [24], [27]). These effects are generally accounted for on an abstract level of phonological planning, not on an articulatory-motor level.

Levelt and Wheeldon ([13]) provided some experimental evidence showing that not only structural effects may play a role in the naming of syllables but that the production of syllables may also be frequency-sensitive. In a production task bisyllabic Dutch words consisting of HF syllables were named faster than words of equal length made up of LF syllables. This effect was independent of word frequency. This led to the hypothesis of a *mental syllabary*, i.e., a store of articulatory motor programs where (HF) syllables are stored in form of their gestural scores. Lexico-statistical analyses of the Dutch syllable inventory showed that 85% of all syllable tokens can be covered by the 500 most frequent syllable types, which adds further plausibility to the idea of a separate store for (HF) syllables ([21]).

Meta-linguistic tasks showed that speakers of Dutch can make use of syllabic units at some level of processing ([22]), whereas priming studies did not reveal any syllabic effects in Dutch speech production. Baumann ([2]) used a primed word production task to investigate the influence of interfering auditory stimuli on the production of verb forms. However, she did not find the predicted syllable match effect between unmasked primes and targets. Using the masked priming paradigm Schiller ([20]) did not find a syllable priming effect for Dutch, either. The naming of words and pictures was facilitated when targets were preceded by visually masked syllable primes, but the size of the priming effect was not dependent on the relationship between the syllable structure of prime and target. Instead, the facilitation effect increased when the segmental overlap between prime and target was increased. That is, orthographically and phonologically related CVC primes yielded larger facilitation effects than CV primes independently of the syllable structure of the targets.

These results do not necessarily stand in contradiction to Levelt and Wheeldon's ([13]) findings. It is conceivable that the tasks used by Baumann ([2]) and Schiller ([20]) tapped into earlier stages of phonological encoding than the associate naming task used by Levelt and Wheeldon. Possibly, they tapped into phonological encoding processes that follow segment-to-frame association.

EXPERIMENT

The question arises whether the syllable frequency effect found by Levelt and Wheeldon ([13]) was located at the access level to the syllabary or at the articulatory level. It might be hypothesized that the naming latencies of sublexical units such as syllables involve a production effect on top of the access effect. The effect might be expected because motor programs of (HF) syllables constitute highly over-learned patterns that are accessed as whole units whereas motor programs for (LF) syllables possibly have to be assembled on-line on a segment-by-segment basis. The experiment reported in this study investigated the effect of syllable frequency on production time using a sequential production paradigm.

Method

Materials

16 pairs of HF and LF syllables that only differed with respect to the onset or the coda consonant were selected (see Table 1). The segmental make-up of both types of syllables was exactly matched. Onset and coda consonants as well as vocalic nuclei occurred equally often in the set of HF and LF syllables (i.e., pairs of HF - LF syllables were, for instance, /hɑp/ - /hɑs/ and /bɑs/ - /bɑp/). The CELEX (CEntre for LEXical information) lexical database was used to determine syllable frequencies. Mean syllable frequency of the HF syllables was 300 (per one million syllables), LF syllables had a mean frequency of occurrence smaller than 1 (per one million syllables).

Procedure

The sequential production paradigm used here is an adapted version of the parameter remapping paradigm developed by [18], [19] and used by [23], [24]. Participants were tested individually. They were seated in a sound-proof booth. The trial sequencing was controlled by NESU (Nijmegen Experimental Set Up). On each trial participants heard one syllable at a time binaurally via headphones. 500 ms after the acoustic syllable onset a fixation cross appeared on a computer screen in front of them indicating the begin of the production task. Participants then produced the syllable they had heard as fast as they could until the fixation cross appeared on the screen again after eight seconds. After three seconds the next trial started. Participants' responses were recorded on DAT for subsequent analyses via a Sennheiser ME 40 microphone.

Design

There were four test blocks. The 32 syllables were presented once per block, and each block was fully randomized for each participant. All participants received all the four blocks. There was a short pause between each block. The whole experiment lasted approximately 40 minutes.

Analysis

Mean production times per syllable were calculated by determining the production interval from the onset of the third syllable to the offset of the twelfth syllable of each response. This production interval was determined by means of acoustic wave form, sonagraphic, and auditory analyses using the ESPS/waves speech analysis package.[1] The mean production time per syllable was obtained by dividing the length of the whole production interval by ten.

Results

An ANOVA was run with Syllable Frequency (high or low) and Repetition (block 1, 2, 3, or 4) entered as main factors. F values are reported separately for participants (F_1) and items (F_2).

The main effect of Repetition was significant (F_1 (3,27) = 12.82, MS_e = 1518.90, p < .001; F_2 (3,90) = 718.60, MS_e = 36.36, p < .001). The syllables' production times decreased over blocks. Mean production times per syllable were 285 ms in block 1, 254 ms in block 2, 227 ms in block 3, and 224 ms in block 4. The effect of Repetition did not interact with Frequency (F_1 (3,27) = 1.19, n.s.; F_2 (3,90) = 2.23, n.s.).

The main effect of Frequency was significant by participants but not by items (F_1 (1,9) = 18.01, MS_e = 51.07, p = .002, F_2 (1,30) < 1). Mean production times for HF and LF syllables were 244 ms and 249 ms, respectively. As inspection of the item means showed there were large differences between items that were unrelated to their frequencies.

Discussion

Production times for HF syllables were on the average 5 ms shorter than for LF syllables. However, statistical analyses revealed that this effect was only significant by participants but not by items. This suggests that there is no production effect in the naming of syllables when segmental characteristics are controlled for.

However, since syllables were repeatedly produced, the transitions between coda and onset consonants differed between the HF and the LF syllables. Therefore, differences in coarticulatory effects between coda and onset consonants may have interfered with syllable frequency effects.

CONCLUSION

Although the slight production time advantage for HF syllables over LF syllables was stable across participants and repetitions, it is to be concluded that the difference in production times between HF and LF syllables was specific to the set of syllables used in this experiment. Further research is needed to confirm this finding.

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APPENDIX

Table 1
Stimulus materials in the experiment.

Target Syllables			
HF Syllables		LF Syllables	
Ortho-graphic trans-cription	Phono-logical trans-cription	Ortho-graphic trans-cription	Phono-logical trans-cription
hap	/hɑp/	has	/hɑs/
bas	/bɑs/	bap	/bɑp/
zog	/zɔx/	zom	/zɔm/
som	/sɔm/	sog	/sɔx/
sef	/sɛf/	seg	/sɛx/
reg	/rɛx/	ref	/rɛf/
hit	/hɪt/	his	/hɪs/
nis	/nɪs/	nit	/nɪt/
zal	/z ɑl/	jal	/jɑl/
jam	/jɑm/	zam	/zɑm/
gol	/xɔl/	jol	/jɔl/
jong	/jɔŋ/	gong	/xɔŋ/
sep	/sɛp/	dep	/dɛp/
deng	/dɛŋ/	seng	/sɛŋ/
nim	/nɪm/	dim	/dɪm/
dit	/dɪt/	nit	/nɪt/