J Psycholinguist Res (2007) 36:65–78
DOI 10.1007/s10936-006-9033-8

ORIGINAL PAPER

Processing of Syllables in Production and Recognition Tasks

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Published online: 29 January 2007

Abstract Empirical evidence for a functional role of syllables in visual word processing is abundant, however it remains rather heterogeneous. The present study aims to further specify the role of syllables and the cognitive accessibility of syllabic information in word processing. The first experiment compared performance across naming and lexical decision tasks by manipulating the number of syllables in words and non-words. Results showed a syllable number effect in both the naming task and the lexical decision task. The second experiment introduced a stimulus set consisting of isolated syllabic and non-syllabic trigrams. Syllable frequency was manipulated in a naming and in a decision task requiring participants to decide on the syllabic status of letter strings. Results showed faster responses for syllables than for non-syllables in both tasks. Syllable frequency effects were observed in the decision task. In summary, the results from these manipulations of different types of syllable information confirm an important role of syllabic units in both recognition and production.

Keywords Lexical decision · Naming · Syllable number · Syllable frequency · Visual word processing

Introduction

From the field of language production, numerous results exist that provide evidence in favor of syllables as production units, leading to the widely accepted conclusion that the syllable is a psychologically real unit in language production (Levelt & Wheeldon, 1994; Santiago, MacKay, Palma, & Rho, 2000). In contrast, evidence from studies in visual word recognition is rather heterogeneous, with a large variety of alternative

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units of different grain size being discussed, for example, graphemes (Rey, Ziegler, & Jacobs, 2000), bigrams (Massaro & Cohen, 1994), or larger grapheme clusters (Seidenberg, 1987). Given the wide range of different sublexical units that are proposed to be functional during the reading process, some authors even have assumed that units in addition to letters and phonemes are not needed in order to account for the process of visual word recognition (Kwantes & Mewhort, 1999). Still, most approaches agree on the relevance of sublexical units in word processing (see, discussion in Aichert & Ziegler, 2005; Hofmann, Stenneken, Conrad & Jacobs, 2006).

Empirical support for the role of syllables as units relevant in both recognition and production is provided by experimental paradigms such as priming (Ferrand, Segui, & Grainger, 1996), monitoring of inner speech (Wheeldon & Levelt, 1995), and illusory conjunctions (Prinzmetal, Treiman, & Rho, 1986; Rapp, 1992). However, some of the studies reported partly incompatible results which may be attributed to the characteristics of different languages or the use of slightly different paradigms (Schiller, 1998). Empirical studies also differ according to the experimental operationalization used to investigate syllabic processing. Two groups of studies which form the empirical basis for the present study will be discussed here in more detail, i.e., studies that manipulate the number of syllables in words and studies that manipulate the frequency of syllables.

The experimental manipulation of the *number of syllables* within words has repeatedly resulted in longer response latencies for stimuli with increasing number of syllables. This has been reported in picture naming (Klapp, Anderson, & Berrian, 1973; Santiago et al., 2000), word naming (Lee, 2001; Ferrand & New, 2003), two-digit number naming (Spoehr & Smith, 1973), and a same-different judgment task (Klapp, 1971). Results are not always consistent, for example, the typical syllable-number effect has been reported for words with four letters but a reversed tendency for words with six letters (Lee, 2001). The syllable number effect was also found to be restricted to the naming of low frequency words (Jared & Seidenberg, 1990), and it was found to be inexistent in some picture and symbol naming studies (e.g. Forster & Chambers, 1973; Bachoud-Levy, Dupoux, Cohen, & Mehler, 1998). The influence of syllable number has seldom been investigated in lexical decision, however one recent study does report a syllable number effect for lexical decision on low-frequency words in French (Ferrand & New, 2003). In general, interpretations of the results are constrained by the fact that the number of syllables is typically correlated with word length. Accordingly, results have been controversially discussed (Eriksen, Pollack, & Montague, 1970; Santiago, MacKay, & Palma, 2002; Roelofs, 2002).

Recently, another approach has emerged to investigate the role of syllables in language processing where the *frequency of syllables* in words is manipulated. Lexical decision studies in a variety of languages have demonstrated an inhibitory syllable frequency effect, i.e., a slower processing of words when the first syllable is of high frequency as to low frequency (for Spanish: Carreiras & Álvarez, & de Vega, 1993; Perea & Carreiras, 1998; for German: Conrad & Jacobs, 2004; for French: Mathey & Zagar, 2002). Explanatory accounts have attributed this effect to an inhibition of target word processing by interference from syllabic neighbors (i.e., words sharing a syllable with the target word). In contrast, facilitatory effects of high syllable frequency have been reported in language production studies involving symbol and word naming tasks (e.g., for Dutch: Levelt & Wheeldon, 1994; Cholin, Levelt, & Schiller, 2006 for Spanish: Perea & Carreiras, 1998, Carreiras & Perea, 2004a). Effects of syllable frequency can be considered reliable and have been reflected in different methodologies, including event-related potentials (Barber, Vergara, & Carreiras, 2004; Hutzler et al., 2004), and eye movement measures (Carreiras & Perea, 2004b; Hutzler, Conrad, & Jacobs, 2005). Additionally, syllable frequency effects have been reported in special populations, such as participants with acquired disorders in language production (Aichert & Ziegler, 2004; Laganaro, 2005; Stenneken, Hofmann, & Jacobs, 2005), and those with acquired reading disorders (Stenneken, Conrad, Goldenberg, & Jacobs, 2003; Stenneken, Conrad, Hutzler, Braun, & Jacobs, 2005) or developmental reading disorders (Rodrigo López, & Jiménez González, 2000).

To summarize, various empirical studies support the status of syllables as functional units in visual word processing, but partly provide diverging results coming from a variety of different tasks. To further explore the relevance of syllables in German, a language with rather regular orthography, we conducted a series of experiments investigating visual processing of an identical stimulus set used in production and in recognition tasks. This allowed us to investigate performance in tasks either requiring explicit phonological output (naming tasks) or access to stored representations without overt pronunciation (decision tasks). Specifically, different aspects of syllabic information were manipulated. In study 1, the number of syllables within words of equal length were varied and in study 2 the syllable status and the syllable frequency of monosyllabic letter strings were manipulated.

Study 1: Manipulating the Number of Syllables

The empirical basis of the first study is the syllable-number effect reported in previous studies on word naming, specifically, the naming latencies for words increase with the number of syllables they contain. In the first place, the present study investigated whether the syllable-number effect in the naming task described for English and French can be replicated for German. The German language contains considerably complex syllable structures allowing for larger clusters of segments in onset and coda positions. Thus, the manipulation of syllable number can be realized with a comparatively large number of words with one, two or three syllables while controlling for word frequency and length. For the naming task, we expected longer latencies with an increasing number of syllables, which would support previous interpretations of the syllable-number effect as an output preparation effect (Santiago et al., 2000). Second, the comparison of a naming task and a lexical decision task aimed to further specify the relevant processing level of the syllable-number effect. For the lexical decision task, expectations were based only on a small empirical basis, where a syllable-number effect in lexical decision has been recently reported for French low-frequency disyllabic and trisyllabic words (Ferrand & New, 2003). No results are available for non-words in lexical decision. Accordingly, we sought to replicate the syllable number effect in the present lexical decision task for German words consisting of one to three syllables.

Method

Participants

Two tasks using identical stimulus material were administered in a between-subjects design. The naming task (task 1) was performed by 27 participants (23 female, four male) aged between 19 and 37 years (mean 21). The lexical decision task (task 2) was performed by 27 participants (19 female, eight male) aged between 18 and 29 years (average 22.6). All participants were native German speakers, right-handed and had normal or corrected to normal vision. They were students of Eichstätt-Ingolstadt University and received credit for course requirements.

Stimuli

The stimulus set included 294 items, 147 words, and 147 legal non-words, each consisting of six letters. Words and non-words had equal numbers of monosyllabic, disyllabic, and trisyllabic items, leading to six subsets of 49 items each. Initial phonemes were equally distributed in these six subsets. The three subsets of word stimuli were matched for word frequency, and as closely as possible for the density and frequency of orthographic neighborhood. That is, neighborhood density and the number of higher frequency orthographic neighbors did not differ between monosyllabic and disyllabic words. Both measures were diminished for trisyllabic words relative to mono- and disyllabic words. All non-word subsets were matched for the number of orthographic neighbors.

Procedure

Participants were tested individually in a quiet room, where they were seated at a distance of 0.5 m from a computer monitor. Stimulus presentation started with a fixation cross (duration 500 ms), followed by an interval of 100–900 ms in the naming task and a fixed interval of 500 ms in the lexical decision task and then the target letter string. All stimuli were displayed in font Courier size 24 in black color and were presented on a white background in the center of the computer screen (17" ProNitron 17/200 -Monitor). The computer (Power Macintosh G3, Mac OS 9.04) controlled the procedure and responses were recorded via a button box (New Micros). In the word naming task, the onset times of the verbal responses were measured via a voice key microphone and responses were recorded on DAT tape. In the lexical decision task, participants pressed one of two response keys with their left or right index fingers to indicate that the displayed stimulus was either a standard German word or not. The assignment of keys was reversed for half of the participants. In both tasks, participants were instructed to respond as fast as possible without making errors. The experiment started with a practice block of ten trials.

Results

Data Analyses

Responses with latencies outside the range of two standard deviations from the individual means of participants were excluded (7.95% in the naming task and 0% in the lexical decision task). In the item-based analyses of the naming task, 11 items were excluded due to an incorrect response in the majority of participants. Data analyses focused on reaction times, considering correct responses only.

Naming Task

Reaction times in the naming task were submitted to an analysis of variance (*ANOVA*) with the factors lexicality (word, non-word) and number of syllables

[1, 2, or 3 syllables). Results showed a significant main effect of lexicality in analyses by subjects and by items ($F_1[1,26] = 55.87, p < 0.001; F_2[1,227] = 80.69, p < 0.001$) indicating faster responses to words than to non-words. Moreover, results show a significant effect of syllable number ($F_1[2,52] = 14.09, p < 0.001; F_2[2,227] = 3.19$, $p = 0.043$) and a significant interaction of the two factors in the subject analysis ($F_1[2,52] = 5.97$, $p = 0.005; F_2[2,277] = 1.51$, $p = 0.222$). Additional pairwise comparisons within the subgroup of word stimuli revealed significant differences between monosyllabic words and disyllabic words ($t[26] = 2.89$, $p = 0.008$), where both categories were not different from trisyllabic words (p-values > 0.120). Within the group of non-words, differences were significant between monosyllabic and disyllabic stimuli ($t[26] = 2.38$, $p = 0.025$) and between disyllabic and trisyllabic stimuli ($t[26] = 3.60$, $p = 0.001$). Mean response latencies were 572 ms (SD103.16) for monosyllabic words, 582 ms (SD109.37) for disyllabic words, and 578 ms (SD101.18) for trisyllabic words. Within the group of non-words, mean response times were 613 ms (SD124.59) for monosyllabic, 622 ms (SD132.57) for disyllabic, and 637 ms (SD141.91) for trisyllabic stimuli (Fig. 1). Errors (below 3.5% in each condition) were not included in statistical analyses.

Lexical Decision Task

Reaction times in the decision task were submitted to an *ANOVA* with the factors lexicality (word, non-word) and number of syllables (1, 2, or 3 syllables). A significant main effect for lexicality was observed ($F_1[1,26] = 28.77$, $p < 0.001; F_2[1,288] = 37.15$ $p < 0.001$), indicating faster responses to words than to non-words. No significant main effect was obtained for syllable number ($F_1[2,52] = 0.645$, $p = 0.529; F_2[2,288] = 0.23$, $p = 0.795$), however the interaction of the two factors was significant in subject analysis ($F_1[2,52] = 6.17$, $p = 0.004; F_2[2,288] = 0.90$, $p = 0.410$). Separate pairwise tests revealed that reaction times for word stimuli increased as the number of

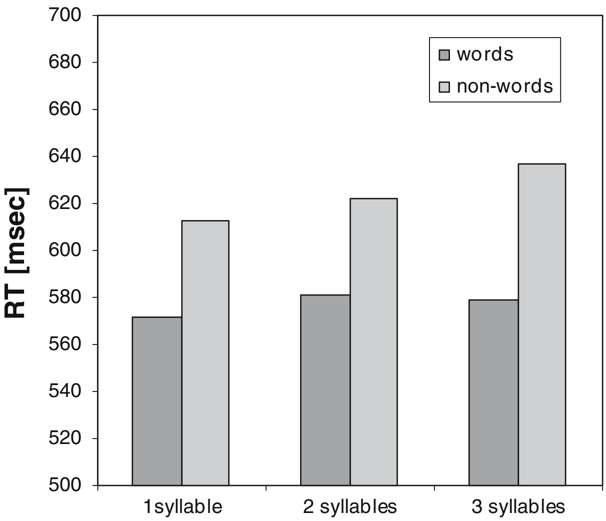

Fig. 1 Mean reaction times in the naming task as a function of the number of syllables in words and non-words

syllables increased. On the contrary, reaction times for non-words decreased as the number of syllables increased. These differences reached significance only between monosyllabic and trisyllabic stimuli (words: $t[26] = 2.35$, $p = 0.027$, non-words: $t[26] = 2.88$, $p = 0.008$). In the subgroup of word stimuli, the mean reaction times were 611 ms (*SD*107.39) for monosyllabic stimuli, 615 ms (*SD*112.16) for disyllabic stimuli, and 626 ms (*SD*114.96) for trisyllabic stimuli. In the subgroup of non-word stimuli, mean reaction times were 714 ms (*SD*179.01) for monosyllabic stimuli, 702 ms (*SD*164.95) for disyllabic stimuli, and 690 ms (*SD*180.78) for trisyllabic stimuli (Fig. 2). As in the naming task, errors in lexical decision (below 6% in all conditions) were not included in statistical analyses. Numerical tendencies in error rates correspond to the reaction time results for words and non-words, respectively.

Discussion

As expected, the manipulation of the number of syllables in stimuli of equal length systematically affected the performance in word and non-word naming. Naming latencies were larger with increasing number of syllables. A comparable finding, where more syllables elicited longer response latencies, was obtained in the lexical decision task for word stimuli. In contrast, non-words showed increased lexical decision latencies for a smaller number of syllables.

The results of the naming task are in accordance with previous findings from a variety of naming paradigms and languages investigated (for recent overviews, see Ferrand & Segui, 2003; Ziegler, 2005). In general our data support a role of syllables in overt naming, although the syllable number effect did not reach significance for the comparison of bi- and tri-syllabic word stimuli. Additionally, these results provide the first evidence for syllabic effects in visual word naming in German, a language with considerably complex syllable structure. With regard to the processing levels in language production, the findings support the notion that the syllable number effect

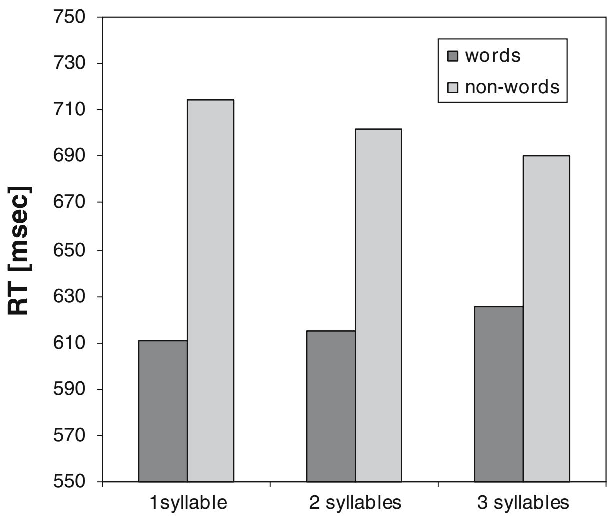

Fig. 2 Mean reaction times in the lexical decision task as a function of the number of syllables in words and non-words

is related to processes of phonological encoding and speech output preparation, in that a higher number of syllables would require longer processing times. This view of a non-lexical effect is strengthened by the present finding that both words and non-words were affected in a similar manner, indicating no or only weak lexical influences. Finally, the results of the present study have ruled out alternative explanations based on possible confounds, like the number of letters or word frequency, as these factors were controlled for. In addition, with regard to the control for neighborhood density within the non-word material we concluded that the observed effect cannot be attributed to this measure. Thus, based on previous findings, the syllable number effect in the naming task of the present study can be characterized as reflecting phonological encoding mechanisms in which the syllable constitutes a relevant unit.

More specific conclusions about the locus of the syllable number effect can be drawn from the results in the lexical decision task. Here, the number of syllables within a given stimulus affected response times for both words and non-words. As far as word stimuli are concerned, this finding is comparable to the results from the naming task and replicates previous empirical evidence for an influence of the number of syllables on lexical decision times from Ferrand & New (2003), who obtained the effect for low frequency French words. Since no overt pronunciation is required in the lexical decision task, this finding is unlikely to reflect preparation of phonological output. Moreover, in the lexical decision task of study 1 significant syllable number effects are present in the data for both words and non-words. We therefore conclude that this effect relates to pre-lexical processing where the orthographic input is segmented into syllabic constituents. Thus access to word forms would take longer for stimuli with more syllables than for those with fewer syllables. For the rejection of non-words, our results showed that response latencies decreased as the number of syllables within a non-word letter string increased, which is a novel finding. This dissociation of the syllable number effect for words and non-words can easily be accounted for assuming that the number of syllables within a given letter string of fixed length is a good indicator for the probability that this letter string would be a word. Given the general syllabic structure of the German language, where syllables tend to be far more complex than, for instance, in Romance languages, the percentage of German six letters words containing three syllables is very low. Therefore, the number of syllables within a six letters string can be considered a determinant of "word-likeliness" which would explain why non-words in the lexical decision task of study 1 are rejected more rapidly when containing three syllables. Given the control for orthographic neighborhood, purely orthographic processing that would not refer to the syllabic structure of non-words could not explain the present effect.

A general aim of the present study was to investigate the performance on identical stimulus sets in a production and a recognition task. The present study established the syllable number effect for German in the production task and in the lexical decision task. The fact that the syllable number effect was not restricted to a task requiring phonological output suggests that in German, syllables are functional units not only for the preparation of speech but also during visual word recognition.

Study 2: Manipulating Syllable Frequency

Based on the above evidence for a syllable number effect in German, the second study focused on syllable frequency. As mentioned above, manipulations of syllable frequency have been used as an alternative experimental approach to the investigation of syllabic processing. Effects of syllable frequency in lexical decision have successfully been demonstrated for the German orthography (Conrad & Jacobs, 2004). The present study investigates syllable frequency effects in a novel decision task and a naming task performed on isolated syllables and letter strings rather than word units. The syllable decision task required participants to indicate whether a displayed letter string could occur as a syllable in German. In the naming task, participants read aloud the letter strings. In both tasks, the relevant manipulation affected syllable frequency. Therefore, two groups of syllables were constructed, one with high and one with low-frequency, both matched for letter cluster frequency. Non-syllabic letter strings also consisted of two sub-groups, of which only one was matched in letter cluster frequency to the syllables.

The presentation of isolated syllables in the syllable decision task was used to avoid a methodological weakness of previous studies reporting syllable frequency effects for disyllabic words. Specifically, a high frequency syllable is also a high frequency letter cluster. Therefore, in principle the observed effects could also arise as a consequence of segmental processing relying on letter clusters rather than syllables (Schiller, 1998, 2000). If the present syllable decision task can be performed successfully, this can be seen as evidence that metalinguistic knowledge about syllables is available to subjects. Unlike the widely used lexical decision paradigm, there is no such task that directly accesses this type of response for syllabic units. So far, isolated syllables have typically been used in short term memory tasks to exclude lexical and semantic influences (overview in Baddeley, 2003) but not to investigate the status of syllables as functional units in word processing. Thus, we expected performance in the novel syllable decision task to indicate whether syllables would be represented in a format that is analogous to the concept of the mental lexicon for word forms. Most importantly, in the present experiment syllables were matched on letter cluster frequency. Here, it would be possible to demonstrate syllable frequency effects independent of orthographic processing. For the naming task we expect a processing advantage for syllables relative to non-syllables, according to the assumption that phonological output is organized syllabically (Levelt & Wheeldon, 1994; Ferrand et al., 1996). Following the same assumption, we also expect faster responses to high-frequency syllables than to low-frequency syllables.

Method

Participants

Like in study 1, the two tasks were performed by different groups of participants. The naming tasks were conducted by 19 participants (14 female, five male) aged between 20 and 34 years (average 23 and 9), whereas in the decision task 25 participants (18 female, seven male) took part, in the age range of 19–32 years (average 22.4). Criteria for the selection of participants were as described in study 1.

Stimuli

The stimulus set comprised 180 letter strings, each consisting of three letters. All stimuli were legal trigrams which could occur in the initial position of written German word forms, as derived from the CELEX database (Baayen, Piepenbrock, &

van Rijn, 1993). Half of the stimuli were syllables and half were trigrams that did not correspond to a syllable unit. The group of syllables contained 45 high frequency syllables (positional frequency of occurrence of more than 1,000 per 6 million) and 45 low-frequency syllables (positional frequency of occurrence of less than 100 per 6 million); both groups were matched for trigram frequency. The group of non-syllabic units was subdivided into 45 letter strings with a trigram frequency matched to that of the two syllabic subgroups and 45 letter strings with non-matched, lower trigram frequency. The initial phonemes were equally distributed in all four subsets of stimuli.

Procedure

Procedure and stimulus presentation resembled those of study 1. Instructions differed only in the decision task; here participants were required to indicate by a button press whether the displayed stimulus was a standard German syllable (i.e., whether this letter string could occur as a syllable in a word) or not.

Results

Data Analyses

Data analyses were comparable to those in study 1. According to the predefined criteria, eight items that produced errors in the majority of participants in the naming task were excluded. No trials were excluded in the decision task.

Naming Task

Response latencies in the naming task were submitted to an *ANOVA* with the factor stimulus type revealing a significant effect in subject analysis ($F_1[3, 54] = 4.19$, $p = 0.010; F_2[3, 168] = 0.70 p = 0.554$). This effect can be attributed to a contrast between the total groups of syllabic and non-syllabic units ($t[37] = 3.37$, $p = 0.002$). Pairwise comparisons within the group of syllables showed that syllable frequency did not significantly affect reaction times ($t[18] = 0.78$, $p = 0.446$); nor did trigram frequency within the group of non-syllables ($t[18] = 0.32$, $p = 0.756$). Mean response latencies were 515 ms (SD 48.58) for high frequency syllables, 512.77 ms (*SD*48.57) for low-frequency syllables, 522 ms (*SD*53.72) for matched trigrams, and 523 ms (*SD*55.57) for non-matched trigrams (Fig. 3). Errors in the naming task (below 1.5% for all four stimulus sets) were not included in statistical analyses.

Decision Task

The *ANOVA* with the factor stimulus type revealed a significant effect on reaction times with syllables being responded to faster than non-syllables, ($F_1[3, 72] = 9.86$, $p < 0.001, F_2[3, 176] = 61.89$, $p < 0.001$). Further comparisons focused on the three subgroups with matched trigram frequencies (high-frequency syllables, low-frequency syllables, matched trigrams). Results showed faster reactions for syllables in both frequency groups as compared to non-syllables ($t[24] = 3.65$, $p = 0.001$ for high-frequency syllables, $t[24] = 3.93$, $p = 0.001$ for low-frequency syllables), and thus reflect a syllabicity effect. Moreover, the results showed an effect of syllable frequency, where responses were faster for high-frequency syllables than for

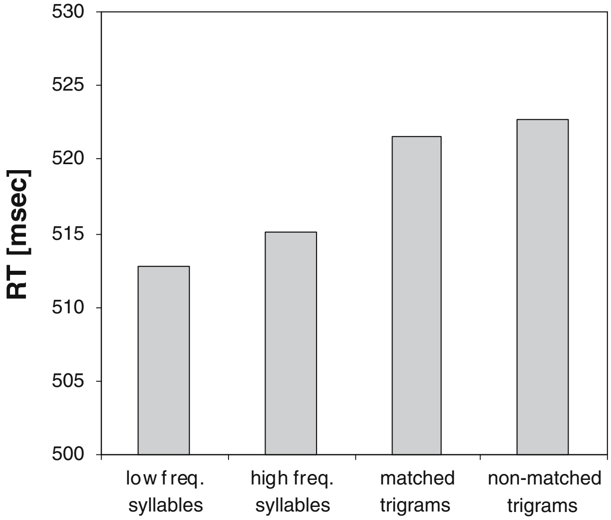

Fig. 3 Mean reaction times in the syllable naming task as a function of the trigram type (high frequency syllables, low frequency syllables, non-syllables with matched trigram frequency, non-syllables not matched for trigram frequency)

low frequency syllables ($t[24] = 2.51$, $p = 0.019$). For the sub-group with a lower (non-matched) trigram frequency the rejection of non-syllables was faster than for trigrams with matched frequency ($t[24] = 3.23$, $p = 0.004$) and in a comparable range to the responses for the syllables (p-values > 0.10). Mean reaction times were 1349 ms (*SD*522.80) for high-frequency syllables, 1742 ms (*SD*570.43) for low-frequency syllables, 2320 ms (*SD*1671.47) for matched trigrams, and 1421.21 ms (*SD*570.43) for non-matched trigrams (Fig. 4).

The syllable decision task also elicited a considerable amount of errors, however performance remained well above chance level. An *ANOVA* with the factor stimulus type (high frequency syllables, low-frequency syllables, matched trigrams, and non-matched trigrams) revealed a significant effect on error rates ($F_1[3, 72] = 27.78$, $p < 0.001$; $F_2[3, 176] = 46.49$, $p < 0.001$). The average values per condition strengthen the reaction time results for the syllable frequency effect, so that a speed-accuracy trade-off can be excluded. Furthermore, also with regard to error rates, performance was better for high-frequency syllables (16% errors) than for low frequency syllables (37% errors). And the rejection of non-syllables produced more errors for trigrams with matched frequency (39% errors) than without frequency matching (8% errors).

Discussion

The outcome of the syllable decision task shows that subjects were able to decide whether a given letter string was a syllable or not. Performance was above chance for both syllables and non-syllables. This enhances the empirical evidence for the functional role of syllabic units in visual word recognition showing that metalinguistic knowledge about syllables is available to subjects. It is important to note that response latencies in this novel task were considerably long. We believe that this shows that unlike for words there seems to be no explicit storage for syllabic units at least in

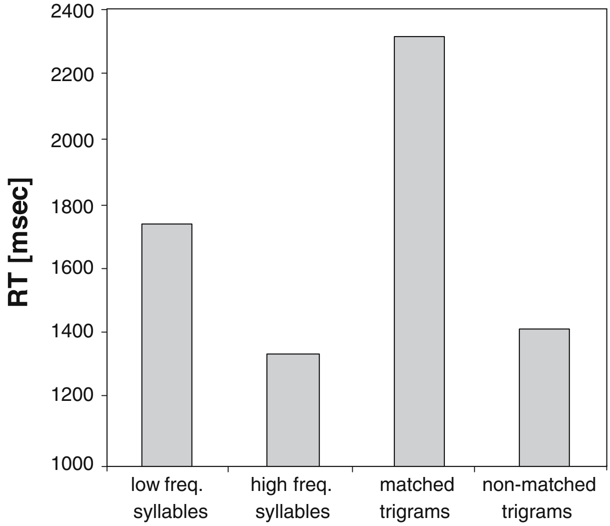

Fig. 4 Mean reaction times in the syllable decision task as a function of the trigram type (high frequency syllables, low frequency syllables, non-syllables with matched trigram frequency, non-syllables not matched for trigram frequency)

German. Instead of accessing a syllable representation of a presented letter string, the long response times in the syllable decision task indicate that subjects gave a "yes" decision to a syllable whenever they were able to find a word containing this syllable. Responses were faster to high-frequency syllables compared to low-frequency syllables, because the former occur in many words and thus a word containing the target syllable can easily be retrieved. This is in accordance with the findings of Rubin (1974) who reported a relatively good ability of participants to directly estimate the relative frequency of isolated syllables. Note that this facilitatory effect of syllable frequency in the syllable decision task is not at all incompatible with the standard inhibitory syllable frequency effect in the lexical decision task. Competition between whole word units sharing a syllable with the target word is held responsible for the inhibitory effect of syllable frequency in lexical decision. In the syllable decision task, all words sharing a target syllable would not compete with each other, but all contribute to enable a subject's "yes" response. The present experiment provides evidence for the assumption that words in the mental lexicon can be activated via their syllabic constituents. This assumption has been implicitly present in the literature on syllable frequency without having been empirically addressed in a sufficient way. Purely orthographic processing that would not rely on syllabic structure cannot be held responsible for the syllable frequency effect in the present syllable decision task, because high-frequency and low-frequency syllables were matched on letter cluster frequency. Still, an influence of orthographic processing in the present task can be seen in the prolonged rejection times for non-syllabic trigrams of high-letter cluster frequency relative to those of low-letter cluster frequency.

For the naming task, the significant processing advantage for syllables compared to non-syllables support the claim that phonological output is organized syllabically. But note that naming onset was unaffected by syllable frequency. These findings in the syllable naming task differ from previous results obtained in word naming. Here, a high word-initial syllable frequency had a facilitative effect on naming performance (cf. Perea & Carreiras, 1998). Even though this effect has been attributed to facilitation of phonological output, it might be restricted to the production of whole word forms and therefore not obtained for letter strings. Alternatively, the lack of a frequency effect in the present naming task could very well be due to a floor effect, since only sequences of three phonemes had to be produced in the present experiment and accordingly naming latencies are rather short (below 525 ms, as compared to up to 640 ms for disyllabic stimuli in study 1).

General Discussion

The present study provides evidence for the relevance of syllabic units in visual word processing making use of two different tasks and two different experimental approaches. Evidence comes from both production and recognition tasks in German, manipulating the syllable number within words and non-words or the syllabic status and the syllable frequency of letter strings.

Study 1 established an effect of the number of syllables in naming and lexical decision. The results provided evidence that the syllable number does not only affect phonological output preparation but also has a comparable effect on lexical decision performance for words, suggesting that syllables are also functional units in processing levels that precede or that are independent of lexical access. Study 2 demonstrated a syllabicity effect in a production and a novel decision task. Moreover, the syllable decision results showed syllable frequency effects while letter cluster frequency was controlled for. These findings are important to the literature on syllable frequency, because syllabic processing can be shown to be independent of orthographic processing. The long response latencies in the lexical decision task seem to indicate that information concerning the syllabic status of an isolated letter string is retrieved via a search process for words containing the target syllable. In general, the results of study 2 support those of previous studies suggesting that word-initial syllables are functional units in the processing of visual word forms. Both studies contribute to the empirical basis specifying the processing mechanisms of complex, polysyllabic word forms. Even though recent investigations of word processing increasingly address the processing of complex, polysyllabic word forms, the current models of visual word processing are typically restricted to simple word forms (e.g. Grainger & Jacobs, 1994; Zorzi, Houghton, & Butterworth, 1998; Ziegler, Perry, & Coltheart, 2000; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Jacobs, Graf, & Kinder, 2003; but see, Ans, Carbonnel, & Valdois, 1998 for a model of naming polysyllabic words). Thus, both of these lines of evidence from the present study may play a role in constraining future models of visual word processing. Finally, the results from the present study suggest that production and recognition tasks can involve syllabic decomposition and that syllabic information may exert an influence at different processing stages, from visual form recognition to overt naming.

Acknowledgments The authors express their gratitude for support with data collection to Katharina Bublath, Roland Dengler, Irma Glas, Stefanie Klis, Anke Limmer, Markus Paulus, Julia Tumewu and Maria Vuori.

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