VERBO-MOTOR PRIMING IN THE PHONETIC ENCODING
OF REAL AND NON-WORDS

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ABSTRACT
We report an investigation of the production of real
and non-words in two normal speaker groups. Group 1 consists of 6 young females (mean age 26
years) and Group 2 consists of 5 older females
(mean age 54 years). The speech material used in
the study consisted of two repetitions of 10 real, 10
pseudo-real and 10 non-words. The results from
both repetitions for measures of response latency,
utterance duration and word duration of both
groups are presented and discussed with reference
to observed patterns of verbo-motor priming. These
patterns are discussed together with implications
for phonetic encoding and the motor execution of
speech.

Keywords: phonetic encoding, verbo-motor
priming

1. INTRODUCTION
There is some debate about whether articulatory
sequences are calculated anew each time or
retrieved from storage as and when necessary
during speech production [3]. Some psycholinguistic models advocate that the segment
plays a critical role in the encoding of speech [2, 5,
6]. Alternatively, some psycholinguistic research
suggests that there may be two routes that are
employed in phonetic encoding [4, 7]. One route
involves storage of frequently used syllables in a
mental syllabary, (which we refer to here as a
'direct' route) and the second is used for novel or
low frequency syllables (which we refer to here as
the 'indirect' route). The former encoding route is
more dependent on storage and therefore more
efficient, in computational terms, whereas the latter
is more dependent on on-line computational
resources. Dual route models have been proposed
for other cognitive functions such as reading aloud
[1].

Some of the measures that have been used to
gauge the employment of direct and indirect routes
have included response latencies and the duration
of utterances, where greater values for both
measures would be interpreted as a sign of the
greater planning and encoding demanded by the
'indirect' route [4]. Along these lines, it is
suggested that these measures also serve as useful
indices for evidence of verbo-motor priming. One
would predict that decreases in response latency,
utterance duration and word duration values, with
repeated elicitation may be indicative of verbo-
motor priming.

The current study aims to investigate patterns of
verbo-motor priming in the phonetic encoding of
monosyllabic real, pseudo- and non-words elicited
via a repetition task, in two groups of speakers by
investigating the response latencies, utterance and
word durations of these word data across two
repetitions. The results of both repetitions of the
acoustic measures (response latency, utterance
duration and word duration) from the two groups
of subjects are presented and discussed with
reference to observed patterns of verbo-motor
learning effects, together with implications for
phonetic encoding and the motor execution of
speech. In addition, age effects are investigated by
examining the data from both subject groups.

2. METHODOLOGY

2.1 Subjects
Two groups of subjects participated in the study.
Group 1 consisted of 6 female speakers (mean age
= 26 years). They were all students in tertiary
education. Group 2 consisted of 5 adult women
speakers (mean age = 54 years), who worked in
tertiary education. All speakers in both Groups 1
and 2 had no speech, language or hearing
difficulties.

2.2 Speech Material and Recordings
The speech material used in the study consisted of
two repetitions of 10 monosyllabic real (e.g. soap -
10 monosyllabic pseudo-real (e.g. sote - ['sɔut], containing articulatory sequences that are likely to have been encountered before in real English words and conforming to English phonotactic constraints) and 10 monosyllabic non-words (e.g. soekf - ['sɔukf], containing articulatory sequences that are unlikely to have been encountered before in real English words). This gave a total of twenty tokens for each of the word groups, which were then randomised into a single list. Subjects were instructed to repeat each word on the list after the experimenter. They were also required to prefix each word with the definite article ‘the’. All sessions were recorded in a quiet room using a DAT recorder. All speech samples were subsequently digitized (sampling rate 10kHz) and analysed using a KAY Computerized Speech Lab (CSL) Model 4300.

2.3 Temporal measures
Speech pressure waveforms, wideband FFT spectrograms and LPC analyses were used to obtain a number of temporal acoustic measures. The temporal measures that were taken were: i) response (or repetition) latencies - these were measured from the end of the experimenter's prompting utterance to the start of the participant's utterance - responses which were initiated before the end of the experimenter's prompt were assigned a response latency of zero ms; ii) utterance durations - these were measured from the start to the end of the entire utterance; and iii) word durations - these were measured from the start to the end of the stimulus word. Incorrect responses were excluded from analysis.

3. RESULTS
Mean and standard deviation values for response latency, utterance duration and word duration are given in Tables 1, 2 and 3 respectively for Group 1 and Group 2, by word status and repetition. A series of three-way repeated measures ANOVAs was carried out on the combined data of Group 1 and Group 2 for response latency, utterance duration and word duration. Within-subjects comparisons of word status and repetition and between subject comparisons by group were tested to examine age effects.

<table>
<thead>
<tr>
<th>Speaker Group</th>
<th>Non-words</th>
<th>Pseudo-words</th>
<th>Real words</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Repetition 1</td>
<td>Repetition 2</td>
<td>Repetition 1</td>
</tr>
<tr>
<td>Group 1 (n=6)</td>
<td>143.7 (91.1)</td>
<td>112.8 (80.5)</td>
<td>104.1 (80.1)</td>
</tr>
<tr>
<td>Group 2 (n=5)</td>
<td>231.1 (117.5)</td>
<td>158.1 (100.5)</td>
<td>180.6 (93.9)</td>
</tr>
</tbody>
</table>

Table 1. Mean and standard deviation values (given in milliseconds) of response latency for groups 1 and 2 by word status and repetition.

<table>
<thead>
<tr>
<th>Speaker Group</th>
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<th>Real words</th>
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<tbody>
<tr>
<td></td>
<td>Repetition 1</td>
<td>Repetition 2</td>
<td>Repetition 1</td>
</tr>
<tr>
<td>Group 1 (n=6)</td>
<td>668.9 (90.1)</td>
<td>643.3 (75.5)</td>
<td>655.8 (63.4)</td>
</tr>
<tr>
<td>Group 2 (n=5)</td>
<td>694.1 (122.0)</td>
<td>685.5 (105.2)</td>
<td>709.6 (91.4)</td>
</tr>
</tbody>
</table>

Table 2. Mean and standard deviation values (given in milliseconds) of utterance duration for groups 1 and 2 by word status and repetition.
Table 3. Mean and standard deviation values (given in milliseconds) of word duration for groups 1 and 2 by word status and repetition.

<table>
<thead>
<tr>
<th>Speaker Group</th>
<th>Non-words Repetition 1</th>
<th>Non-words Repetition 2</th>
<th>Pseudo-words Repetition 1</th>
<th>Pseudo-words Repetition 2</th>
<th>Real words Repetition 1</th>
<th>Real words Repetition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (n=6)</td>
<td>520.9 (93.6)</td>
<td>498.6 (76.1)</td>
<td>571.0 (88.2)</td>
<td>503.2 (70.6)</td>
<td>499.2 (71.1)</td>
<td>487.1 (65.6)</td>
</tr>
<tr>
<td>Group 2 (n=5)</td>
<td>558.6 (126.1)</td>
<td>552.2 (115.3)</td>
<td>513.0 (58.1)</td>
<td>562.9 (98.5)</td>
<td>549.8 (72.0)</td>
<td>528.7 (69.9)</td>
</tr>
</tbody>
</table>

Results of the three way repeated measures ANOVA (word status x repetition x group) for the response latency data indicated that there were significant word status effects ($F(2, 73)=6.3$, $p<.01$), with the non-words and pseudo-words showing the longest and shortest response latencies respectively. Post-hoc paired samples t-tests indicated that there were significant differences between the response latencies of the non-words and pseudo-words and between those of the non-words and real words. No significant differences were found between the pseudo-words and real words.

In addition, significant effects were found for repetition ($F(1, 74)=27.2$, $p<.0001$), with shorter response latencies being observed for the second repetition. There were significant interaction effects for repetition-by-group ($F(1, 74)=11.3$, $p<.01$) with Group 2 showing greater decreases in response latency for the second repetition compared to Group 1. There were also significant interaction effects for word status-by-repetition ($F(2, 73)=12.7$, $p<.0001$), with the non-words and pseudo-showing shorter response latencies for the second repetition, this contrasted with the real words, which showed a slight increase (2.7 ms). No significant interaction effects were found for word status-by-group, or word status-by-repetition-by-group. In addition, there were significant differences between group ($F(1, 74)=12.4$, $p<.01$) differences, with Group 1 showing shorter response latencies than Group 2, thereby demonstrating a significant age effect.

Results of the three way repeated measures ANOVA (word status x repetition x group) for the word duration data indicated that there were significant word status effects ($F(2, 73)=5.0$, $p<.05$), with the non-words and pseudo-words both showing longer word duration values than the real words. Post-hoc paired samples t-tests indicated that there were significant differences between the word duration values of the non-words and real words. No significant differences were found between the pseudo-words and non-words, or between the non-words and real words.

In addition, significant effects were found for repetition ($F(1, 75)=12.9$, $p<.01$), with shorter word durations for the second repetition. No significant interaction effects were found for word status-by-group, repetition-by-group, word status-by-repetition or word status-by-repetition-by-group. In addition, there were significant between group differences ($F(1, 74)=9.3$, $p<.01$), with Group 2 showing longer word duration values than Group 1, thereby replicating the age effect observed for response latency.

Results of the three way repeated measures ANOVA (word status x repetition x group) for the utterance duration data indicated that there were significant word status effects ($F(2, 74)=6.0$, $p<.01$) with the non-words and pseudo-words both showing longer utterance duration values than the real words. Post-hoc paired samples t-tests indicated that there were significant differences between the word duration values of the pseudo-words and real words. No significant differences were found between the pseudo-words and non-words, or between the non-words and real words.

In addition, significant effects were found for repetition ($F(1, 75)=12.9$, $p<.01$), with shorter word durations for the second repetition. No significant interaction effects were found for word status-by-group, repetition by group, word status by repetition or word status by repetition by group. In addition, there were significant between group differences ($F(1, 75)=12.6$, $p<.01$), with Group 2 showing longer utterance durations than Group 1, thereby replicating the age effects observed for response latency and utterance duration.

4. DISCUSSION

There is some evidence in the data reported here to suggest that there may be differences in the phonetic encoding of the real words, pseudo-words and non-words. These differences are illustrated by the significantly slower response latencies of the
non-words when compared to those of the pseudo-words and real words. Response latency however, is a difficult parameter to interpret. It is difficult to ascertain to what degree response latency is determined by either auditory recognition or motor encoding, or indeed both. Therefore it not clear whether the results reported here are evidence for differences in motor encoding and/or auditory recognition. In addition, the utterance durations and word durations of the pseudo-words were significantly longer than those of the real words for the combined data of Groups 1 and 2. These findings could be interpreted as some evidence for a greater reliance on 'indirect' route mechanisms in the motor encoding of the pseudo-words that were elicited in this study, with greater time required for their articulation.

Significant repetition effects were found with shorter response latency, utterance duration and word duration values for the second repetition of all non-, pseudo- and real word data. These data present some evidence for verbo-motor facilitation in the phonetic encoding of non-, pseudo- and real words, through the repeated elicitation of speech within a repetition paradigm. It is suggested that the shorter utterance and word durations are a result of verbo-motor memory facilitating the more efficient activation, initiation, and execution of recently executed verbo-motor schemas.

It has been suggested that dual-routes may be operating in speech encoding [4, 7], with novel and low frequency words/syllables being largely reliant on 'indirect' mechanisms. There were some differences between the data of the non-words versus the pseudo- and real words. For example, the response latencies of the non-words were found to be significantly longer than both the pseudo- and real words. However, the issue of how much auditory recognition affected this pattern of results should not be overlooked. Some of the patterns in the response latency data may reflect fast lexical access in the case of real words, but failed lexical access in the case of the non-words. This issue merits some further investigation. However there is some evidence which could be interpreted as support for the dual-route hypothesis. For example, the utterance durations of the non-words and pseudo-words, were both significantly longer than those for the real words. In addition, the word durations of the non-words and pseudo-words were longer compared to those for the real words. These differences were significant between the pseudo- and real words. The longer utterance and word durations could be interpreted as evidence for a greater reliance on 'indirect' route mechanisms.

The results of the repeated measures ANOVAs indicated significant age-effects in the response latencies, utterance durations and word durations of Groups 1 and 2. The older subjects displayed longer response latencies compared to the younger subjects. This could be interpreted as evidence that either a greater level of planning time, or less efficient auditory recognition to motor encoding processing, or indeed some degree of both, was required by the older subjects in the production of the non-words, pseudo-words and real words. However, significant interaction effects for group-by-repetition for the response latencies were found which were due to the older speakers (Group 2) showing greater facilitation effects than the younger group (Group 1). In addition, the utterance and word durations were also significantly longer for the older subjects compared to the younger subjects. This suggests a slower articulation rate in the older subjects and could be interpreted as evidence for some degree of reduction in the efficiency of motor speech production, with increasing age. Further work is planned in this area.

5. ACKNOWLEDGMENTS
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6. REFERENCES