# Do phonological neighbourhood density and phonotactic probability influence speech output accuracy in acquired speech impairment?

This study aimed to determine the effects of phonological neighbourhood density (ND) and phonotactic probability (PROB) on speech output accuracy in English speakers with acquired speech impairment. ND refers to the total number of other words that can be created by altering one sound in that word through substitution, deletion or addition. PROB is a measure of the likelihood of given sequences of sounds in a language.

Both ND and PROB have been reported to exercise a significant, inhibitory effect on speech perception and a facilitatory effect on production in healthy speakers (e.g. Vitevitch & Luce, 1998, 1999; Luce & Pisoni, 1998; Lipinski & Gupta, 2005; Stemberger, 2004). Consequently, healthy speakers repeat targets with high PROB (with ND controlled) and high ND (with PROB controlled) quicker than those with low PROB/ND. In contrast, healthy speakers tend to require longer response times for high PROB/ND items in a lexical decision task.

Whilst this offers a general characterisation of findings, there remain many issues in fully understanding the role in and effects of ND/PROB on speech/language processes, especially in disordered speakers. Firstly, the majority of studies involved healthy speakers. Very few investigations (e.g. Gordon, 2002) included individuals with output impairment. Secondly, studies have considered PROB and/or ND plus typically only one other variable (e.g. word frequency) for analyses. This study looked at the issues of ND and PROB in people with acquired output impairment after stroke in a repetition task for single words that were also controlled for other factors known to influence output (i.e. number of syllables, clusters and phonemes, word and syllable frequency). Through this it is hoped to gain insights not just into the prime variables of interest (ND, PROB) but also about the nature of speech output impairment and our understanding of features associated with claimed different disorders. A subsidiary issue was to examine whether or not these variables can assist in issues surrounding differential diagnosis of acquired output impairments. The study answered two main questions:

1. Do ND and /or PROB have a significant effect on production accuracy in native English speakers with output impairment after stroke?
2. If there is a significant effect is it a positive or a negative effect regarding production accuracy?

## METHOD

### Participants

Twenty participants (12 male) with CVA related speech output impairments were recruited from speech language pathology clinics (age range 44 to 85 years, mean 63.6 years, SD 11.34 years; time since stroke 4-111 months, mean 33.53 months, SD 28.01 months at time of testing) . Given that there is some considerable ongoing debate regarding the labelling of apraxia of speech (AoS) versus phonemic paraphasia (PP) participants were not diagnostically labelled as having either AoS or PP. All 20 recruited participants satisfied the following inclusion criteria:

1. Viable attention, memory, visual and auditory-perceptive skills
2. Native English speaker
3. CVA aetiology
4. At least 4-months post onset
5. Speech output impairment present judged on basis of perceived production errors including perceived omission, substitution, addition, and distortion errors during spontaneous speech production and/or reading aloud

6. Speakers showing speech output impairment due to neuromuscular impairment alone were excluded
7. Hearing was within the normal range

**Materials**
A list of 847 real English and 59 nonsense words (phonotactically legal in English) varying in length (one to five syllables) and complexity (simple V- to complex CCVC/VCC-syllable structure) was used.

**Procedure**
An auditory single-word repetition task was chosen for several reasons. There was difficulty in obtaining representable pictures, drawings, or objects for sufficient stimuli. A repetition task minimises confounding effects on output from reading problems and semantic impairment. No time constraints were placed on the participants regarding production. Participants could make as many attempts as they wanted to produce each stimulus, but they heard the stimulus only once. The participants' responses were recorded. No form of direct feedback was given to the participants regarding production, only general encouragement to maintain motivation.

**Scoring**
Each response was scored as either correct/incorrect. A response was scored as incorrect if it contained any substituted, deleted, added or distorted phoneme(s) compared to the target. Suprasegmental aberrations, hesitations, intraword/intrasyllable pauses did not constitute an error if they occurred without a phonemic error. The first attempt to produce the entire target (where that attempt was a possible phonological word) was scored as a response.

**Data Analysis**
For each stimulus measures of the number of syllables, clusters and phonemes, word and syllable frequency, plus ND and PROB were obtained. PROB was defined as the sum of the log transformed conditional probabilities of the next phoneme given the previous phoneme; phoneme position within the onset, nucleus and coda of a syllable was taken into account. ND was computed based on the single-edit distance definition. A neighbour can be obtained by substituting, deleting, or adding exactly one phoneme of the target.

Individual simultaneous logistic regression analyses entering the participants' repetition accuracy for all stimuli as the dependent variable and the number of syllables, clusters and phonemes, word and syllable frequency, PROB and ND as the predictor variables were completed to answer the two main questions.

## RESULTS

Fourteen speakers showed a significant positive effect of PROB on repetition accuracy for all stimuli. Only two individuals displayed a positive effect of ND on accuracy. Twelve participants showed a significant positive effect of word frequency. Eight participants displayed a significant negative effect of the number of syllables. The number of phonemes had a significant negative effect for four speakers and a positive effect for one individual. Four participants showed a negative significant effect of the number of clusters. Four individuals displayed a positive effect of lexicality. No double dissociations regarding the effect of ND/PROB were noted. A cluster analysis did not reveal clusters of specific groups within the participants that were congruent with a supposed AoS, PP distinction.

## DISCUSSION

Repeating single-word items English speakers with acquired output impairment show a significant positive effect of PROB on accuracy for almost all of the participants. ND had a minimal significant positive effect on accuracy although the number of items sampled was large. This picture is not as straightforward as it seems. Twelve speakers showed a significant positive effect of word frequency which, according to Levelt and Wheeldon (1994), is located at the lexical access level. However, the employed repetition task does not necessarily require access to the lexical level which begs the question why a word frequency effect was observed at all and why only a minimal ND effect was seen which presumably is located at the same/similar level as the word frequency effect. A possible explanation is an interaction between later and earlier occurring levels in speech production. The minimal effect of ND might be explained by the confoundedness between word frequency and ND – they are positively correlated. Not having found dissociations between the ND/PROB effect implies that the usefulness of the two effects regarding the differential diagnosis of AoS and PP is restricted. However, PROB/ND may still have potential roles in the assessment and treatment of AoS and PP. Presumably ND/PROB have effects at different stages in output. Stages are differentially affected in AoS vs. PP. Therefore, contrasting tasks looking at ND/PROB and tapping into the different stages should show different performance profiles in the different groups.

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