Abstract
Influences on speech output in acquired apraxia of speech: a comparison of English and German

The nature of breakdown in apraxia of speech (AoS) continues to be a subject of debate. Determining which output variables influence production could assist in settling this debate. This study with 7 German and 7 English speakers with post-stroke output impairment showed significant independent effects of word frequency and phonotactic probability on repetition accuracy of (near) homophones in English and German. Only a moderate correlation existed between accuracy for the English and German subjects. Results are discussed in terms of the possible loci of breakdown in models of speech output and the implications for the assessment and treatment of AoS.

Full Text

Background:

This study investigates factors which influence output accuracy in people with speech output problems after stroke, in particular in apraxia of speech (AoS), and phonemic paraphasia (PhPa). The nature of breakdown in apraxia of speech (AoS) continues to be a matter of debate. One inroad into establishing where the disruption lies involves investigating which output variables influence performance.

Numerous factors have been shown to influence word comprehension/production including imageability, frequency, age of acquisition and word class. Two further factors are phonological neighbourhood density (ND) and probabilistic phonotactics (PROB). These are the focus of this study. ND is a measure of the extent to which a sequence of sounds is similar to known real words. Thus the ND of a sequence of sounds equals the number of real words (neighbours) the target sequence is similar to in the target's phonological neighbourhood (cat → mat, hat, pat). Targets with many neighbours have high ND (e.g. cat); targets with few or no neighbours have low ND (e.g. elf → elk). PROB deals with the frequency with which a particular sequence of phonemes occurs in a language. For instance /sp-/ in word initial position in English has a high probability, whereas /sf-/ has low predictability. As a sequence of phonemes "wasp" is very much less likely than "hand".

Numerous studies have found effects of ND and PROB on speech perception. The aim of this study was to see:
Do ND and PROB influence speech output in individuals with speech programming disorders after stroke?
If so is the effect facilitatory or inhibitory and is the effect in the same direction for all speakers?

This study exploits the fact that English and German share a large number of (near) homophones. We compared the influence of the language-specific variables word frequency, phonotactic predictability, lexicality and phonological neighbourhood density on accuracy of word repetition in German and English speakers.

Methods:

7 German and 7 English speakers with post-stroke AoS, matched on the English and German versions of the Aachen Aphasia Test, repeated each a list of stimuli including real and nonsense words. Each list contained 480 real words that are (near)-paired across German and English (e.g. fiel-feel; Bank-bank; Wende-vendor). The stimulus list for the English speakers entailed another 59 nonsense words whereas the German speakers' list had 58 non-words. We examined speakers' accuracy in repeating these items and compared differences in accuracy to differences in the language-specific properties derived from the CELEX database.

Recorded responses were transcribed phonetically. For the purpose of the work reported here they were coded as right (no perceptually detected errors) or wrong (perceived error). Errors were noted if there was a perceived addition, omission, substitution, distortion, distorted substitution, transposition of sounds, or if a word was preceded by trial and error struggle or intraword or intrasyllable pauses. 10% of productions were transcribed by a second listener and re-transcribed by the first transcriber. Inter-rater reliability was good (0.79 – 0.82).

Data for the number of phonemes, syllables, clusters, phonological neighbours, word frequency and phonotactic probability were derived from the CELEX database of British English and German. Probability 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 on this calculation.

Logistic regression was used to examine for the effects of ND and PROB on word repetition accuracy for each subject, first when used as the sole predictor, and secondly when log transformed word frequency, and the number of syllables, phonemes and clusters had been entered into the regression. This second analysis allows us to test for effects of ND and PROB on word repetition accuracy once the effects of other variables already known to affect production have been taken into account.

Results:

Only a moderate correlation existed between accuracy on near-homophones for English and German subjects ($r=0.28$, $p<.001$), presumably reflecting language-independent determinants of accuracy common to patients speaking different languages. There was evidence of language-specific determinants of performance: while there was only slight similarity between patients, within-language chance-corrected correspondence was on average greater within than between-language correspondence (9.2% vs. 5.2%; $p<.00001$).

Language-specific determinants were investigated by correlating differences in accuracy in English and German with differences in word frequency, phonotactic probability, lexicality and phonological neighbourhood density. In simple correlations there was a small but significant effect of lexicality ($r=0.114$, $p=.014$, two tailed). Restricting the analysis to the 480 real word items in both languages, differences in accuracy between the languages were significantly related to both log-transformed word frequency ($r=0.215$, $p<.001$) and length-corrected phonotactic

probability (r=0.099, p=.030, two tailed), but not phonological neighbourhood density (r=0.040, p=0.38). When all three variables are entered into simultaneous multiple regression, the effects of both differences in word frequency ($t(478)=4.84$, $p<.001$) and phonotactic probability ($t(478)=2.35$, $p=.019$) were independently significant; the effect of the number of neighbours remained non-significant (p=0.32).

We investigated the effects of variables common to both German and English by correlating mean accuracy for speakers combined across both languages with the number of phonemes, syllables and consonant clusters in the target word. Simple correlations showed accuracy in production was related to all three variables (syllables, $r=-0.27$, $p<.001$; phonemes, $r=-0.47$, $p<.001$ and clusters, $r=-0.32$, $p<.001$). When these variables were used as predictors in multiple regression, there remained significant independent effects of the number of phonemes ($t(476)=4.63$, $p<.001$) and the number of clusters ($t(476)=3.83$, $p<.001$) but no effect of the number of syllables ($t(476)=0.56$, $p=0.57$).

Discussion:

Numerous studies have shown a significant effect of phonological neighbourhood density and phonotactic probability on speech perception. Neighbourhood density does not show such an effect on the repetition accuracy in these German or English speakers with output difficulties after stroke.

Furthermore, both German and English speakers were asked to produce words that were near-homophones in both languages. But it appears that the two speaker groups encountered difficulty of production with different words. Consequently, the significant effect of phonotactic probability on the production of auditorily presented stimuli probably does not lay at the motor execution level. The results would have shown a strong cross-language relationship.

We further discuss these results in terms of the possible loci of breakdown in models of speech output and the implications for the assessment and treatment of AoS.