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Is the homophone advantage influenced by post-lexical effects?

Britta Biedermann [a,b,*], Joana Cholin [c,d], Annett Jorschick [d],
Karen Croot [b,e,f], Solène Hameau [b,f] and Lyndsey Nickels [b,f]
a School of Occupational Therapy, Social Work and Speech Pathology, Curtin University, Australia
b ARC Centre of Excellence in Cognition and its Disorders, Macquarie University, Australia
c Department of Linguistics, Ruhr-University Bochum, Germany
d Department of Linguistics, Bielefeld University, Germany
e School of Psychology, University of Sydney, Australia
f Department of Cognitive Science, Macquarie University, Sydney, Australia

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Homophones are words that share pronunciations but have different meanings. Experiments eliciting spoken homophones provide crucial insights into the nature of the processing in spoken word production. It has been hypothesised that homophones may share a phonological word form (e.g., Dell, 1990; Levelt, Roelofs, & Meyer, 1999) or may be represented as separate lexical entities (e.g., Caramazza, 1997), with implications for the broader question of whether there are one (word form) or two (word form and lemma) levels of lexical representation in spoken word production. In two previous studies (Biedermann & Nickels, 2008a; b), FME, a speaker with aphasia, underwent treatment for impaired picture naming using homographic (same spelling) and heterographic (different spelling) noun homophones. With treatment of one homophone partner (e.g., *seal* [animal]; *flower*), both the treated *and* the untreated homophones improved (e.g., *seal* [animal] and *seal* [crest]; *flower* and *flour*), but untreated phonologically related controls (e.g., *seat* and *floor*) did not. Biedermann and Nickels (2008a; b) interpreted this as evidence for shared phonological word forms for homophones, and, by extension, a two-step account of lexical access in spoken production, rejecting the hypothesis of separate homophone representations at the word form level.

Subsequently, Antón-Méndez, Schütze, Champion, and Gollan (2012) and Cuetos, Bonin, Alameda, and Caramazza (2010) raised concerns about this interpretation of the locus of the homophone advantage in our study, noting that the focus of investigation on the phonological form neglects effects arising from post-lexical levels of processing. Jacobs, Singer, and Miozzo (2004) suggested further that the effect might be due to the amount of overlap in post-lexical articulatory plans.

Recently, Middleton, Chen, and Verkuilen (2015) proposed a Dual Nature account of homophone effects in the word production of people with aphasia, arguing that either an advantage or a disadvantage for homophones might be predicted, depending on the level of breakdown: a semantic deficit predicting a disadvantage and a phonological deficit predicting an advantage. The Dual Nature account therefore extends the debate about the locus of spoken homophone effects to the semantic and the post-lexical phoneme levels, and possibly extending to post-lexical articulatory levels.

To address whether FME's homophone advantage in treatment generalisation was due to effects other than their homophony, and particularly post-lexical effects, we report here the results of further analyses of our data across both studies (Biedermann & Nickels 2008 a; b). In particular, we focus on the possibility that the psycholinguistic variables associated with the stimuli may have influenced our patterns of results. It is feasible that treatment could benefit items preferentially depending on their properties. For example, perhaps treatment works best for items that are more common. Consequently, we had originally ensured that our different types of untreated stimuli were matched for several psycholinguistic variables (see below) to be sure that if treatment effects differed across the sets, these differences did not originate from disparity in these variables (e.g. that one set contained more frequently occurring items than another).

The effects of many psycholinguistic variables can clearly be localised to particular levels of language processing (see, e.g., Alario, et al., 2004). In our original papers, we controlled for two lexical variables (*Spoken Word Frequency, Phonological Neighbourhood Size)* and one post-lexical variable (*Number of Phonemes).* However, some potentially confounding variables were not captured, particularly at the interface of lexical and post-lexical level and the post-lexical level itself, hence, it is possible that the differences found in improvement following treatment between untreated homophones (generalisation) and untreated phonologically related stimuli (no generalisation) was due to this lack of control. Thus, our reanalysis investigated whether sets differed on additional variables known to influence lexical and post-lexical processing in impaired and unimpaired speakers:

(1) *Age-of-Acquisition (AoA)*: Mean ratings from 24 undergraduate students (following Gilhooly & Gilhooly's 1979 procedure). This variable is highly correlated with word frequency and indexes lexical processing as suggested by Alario et al. (2004; see also Ellis & Morrison, 1998).

(2) *Summed Frequency of Phonological Neighbours:* frequency of all words one phoneme different to the target; associated with lexical processes, (e.g., Dell, 1986; Goldrick & Rapp, 2007; Laganaro, 2012; frequency values for this and all other variables were retrieved from CELEX (Baayen, Piepenbrock, & van Rijn, 1993)).

(3) *Initial Syllable Frequency:* summed (position-independent) frequency of the first syllable of a stimulus; associated with post-lexical processing (e.g., Cholin, Dell, & Levelt, 2011; Croot, Lalas, Biedermann, Rastle, Jones, & Cholin, 2017; Perret, Schneider, Dayer, & Laganaro, 2014).

(4) *Summed Phoneme Frequency:* frequency of all phonemes in a stimulus; associated with post-lexical processing (phonological and/or articulatory encoding; e.g., Cholin, et al., 2011; Croot, et al., 2017).

(5) *Summed Biphone Frequency:* frequency of two adjacent phonemes (biphones) in English summed across all stimulus biphones; associated with post-lexical processing (e.g., Goldrick & Rapp, 2007; Ziegler, 2009).

(6) *Phonological Distance* between untreated items and matched treated homophones was measured by the number of distinctive phonological features; indexes post-lexical processes (phonological and/or articulatory encoding; e.g. Dell, 1986; Ziegler, 2009).

Differences in number of phonemes different from the target was examined in our previous paper (REF the right one), however, we did not examine differences in terms of articulatory distinctive features, hence our further analysis here.

Our analyses confirmed that there were *no* significant differences between untreated homophones and untreated phonologically-related controls for most additional variables under investigation (see Table 1), with the exception of *AoA* and *Phonological Distance. AoA* was higher for the untreated homophones (learned later in life) than phonologically-related controls. However, while there was a marginally significant difference between the naming performance of untreated homophones and untreated phonologically-related items in the pre-test naming scores (untreated homophones: mean pretest: 40.82% correct; untreated phonologically-related: mean pretest: 56.12 % correct) the slight advantage of the phonologically-related subtests was not maintained after training as only homophone sets improved significantly, and the untreated phonologically-related set remained unchanged (post test 1: 51.02% and post test 2: 57.14% correct) (see Biedermann & Nickels, 2008a; b). This indicates that lower *AoA* had no advantageous influence on naming accuracy compared to sets with higher *AoA* (for an overview on AoA influences, see Juhasz, 2005). The difference in *Phonological Distance* between homophone partners and phonologically-related controls was expected, by definition.

-----Insert Table 1 about here.-----

Second, we evaluated which of the additional variables influenced the effect of training of one homophone on the untreated homophone and the phonologically-related but untreated control (i.e. the extent of treatment generalisation). Therefore, we examined the correlation between the additional variables 1-6 above and the 'Change in Naming Accuracy' following treatment (post-test accuracy minus mean pre-test accuracy; untreated homophones: mean pretest: 40.82%; immediate post test: 67.35%; untreated phonologically-related: mean pretest: 56.12%; immediate post test: 51.02%). There were no significant correlations between any of the new variables and improvement at immediate post-test (see Table 1).

In summary, our reanalysis focused on additional lexical and post-lexical variables known to influence spoken word production performance. However, none of these variables correlated significantly with the extent of improvement on untreated items as a result of generalisation from treatment of homophones. Hence, we found no support for the claims of Anton-Mendes et al. (2012), Cuetos et al. (2010) and Jacobs et al. (2004) that the homophone advantage in the original studies (Biedermann & Nickels, 2008a; b) might have arisen post-lexically, or any other uncontrolled psycholinguistic variable. Therefore, we have no reason to reject our original interpretation that the treatment generalisation (homophone advantage) resulted from a shared phonological word form representation for homophones as postulated by Dell (1990) and Levelt et al. (1999).

Nevertheless, while we find no evidence for post-lexical effects as a cause for the homophone treatment effect in our design, we cannot exclude potential post-lexical influences on homophone production more broadly. We find appeal in Middleton et al.'s (2015) Dual Nature account to explain *both* homophone advantages and disadvantages within one theoretical framework. Hence, more research is required to explore this account that goes beyond the dichotomy of shared versus independent homophone representations.

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Correspondence concerning this article should be addressed to Britta Biedermann, School of Psychology and Speech Pathology, Curtin University, WA 6102, Australia.

E-mail: b.biedermann@curtin.edu.au

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Table 1. Pairwise comparisons of the untreated conditions (Wilcoxon signed-rank tests for non-normally distributed factors) and Spearman's correlations with 'Change in Naming Accuracy'.

		Pairwise comparisons of the untreated conditions				Spearman's correlations with 'Change in Naming Accuracy'			
		Untreated Homophones (N = 49)	Untreated Phonologically Related (N = 49)	Test Statistic	p-value		Untreated Homophones (N = 49)	Untreated Phonologically Related (N = 49)	All Untreated
Age of Acquisition (AoA)	M	3.41	2.91	*W* = 777	.02	rho	-.023	0.134	0.130
	SD	1.07	0.92			p	.873	.359	.201
Frequency of Phonological Neighbours	M	232	392	*W* = 529	.412	rho	-0.050	-0.052	-0.038
	SD	604	882			p	.735	.725	.713
Initial Syllable Frequency	M	6010	6424	*W* = 723	.274	rho	0.152	0.135	0.165
	SD	10521	23743			p	.297	.354	.105
Summed Phoneme Frequency	M	453118	428449	*W* = 672	.554	rho	0.160	-0.175	0.045
	SD	226876	227565			p	.273	.228	.677
Summed Biphone Frequency	M	16347	11735	*W* = 699	.257	rho	0.166	-0.010	0.101
	SD	19688	13527			p	.255	.947	.321
Phonological Distance	M	0	2.82	*W* = 0	> .001	rho	-	0.013	-
	SD	0	1.51			p	-	.928	-

Note. M = Mean; SD = Standard Deviation; AoA = Age of Acquisition. No correlations were performed between 'Phonological Distance' and 'Change in Naming Accuracy' for homophones as they all have zero distance with their homophone partner, similarly, due to the confound of homophone status and phonological distance, this analysis was also not carried out for 'All Untreated' subsets.