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What Can Homophone Effects Tell Us About the Nature of Orthographic Representation in Visual Word Recognition?

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Abstract

In a lexical decision task (LDT), Pexman, Lupker, and Jared (2001) reported longer response times for homophones (e.g., MAID-MADE) than for non-homophones (e.g., MESS) and attributed these effects to orthographic competition created by feedback activation from phonology. The focus of the present research was the grain-size of the orthographic units activated by feedback from phonology. We created 9 categories of homophones based on the sublexical, orthographic overlap between members of homophone pairs. We also manipulated the type of foils presented in LDT (consonant strings, pseudowords, pseudohomophones) to create conditions involving less vs. more extensive processing. Homophone effect sizes varied by category; effects were largest when spellings of both onsets and bodies differed within the homophone pairs (e.g., KERNEL-COLONEL) and when members of the homophone pairs differed by vowel graphemes (e.g., BRAKE-BREAK). These results suggest that several specific grain-sizes of orthographic representation are activated by feedback phonology.

Introduction

In a number of recent articles in the word recognition literature, the notion of feedback activation has been invoked to explain particular findings (e.g., Hino & Lupker, 1996; Pecher, in press; Pexman & Lupker, 1999; Pexman, Lupker, & Jared, 2001; Stone, Vanhoy, & Van Orden, 1997; Taft & van Graan, 1998; Ziegler, Montant, & Jacobs, 1997). In a fully interactive model of word recognition (e.g., the PDP model of Plaut, McClelland, Seidenberg, & Patterson, 1996) activation between sets of units can be bi-directional. For instance, in a lexical decision task, when a target word is presented, there is initial activation of an orthographic representation for the target, and then very quickly there is also activation of semantic and phonological representations for that word. Those semantic and phonological representations then re-activate, via feedback connections, the orthographic representation. This bi-directional flow of activation can help the system settle on a representation for the target word. The purpose of the present research was to address an unresolved issue regarding feedback activation: What is the nature (grain-size) of the orthographic units that are activated by feedback from phonology?

Feedback activation is assumed to operate between all sets of units in the word recognition system. The focus of the present research, however, was feedback activation from phonology to orthography. Taft and van Graan (1998; see also Taft, 1991) argued for bi-directional activation between orthography and phonology by what they termed “orthography-phonology-orthography rebound”. The model of word recognition they described was similar to models proposed by Grainger and Ferrand (1994), Plaut et al. (1996), and Van Orden and Goldinger (1994). A version of this model is illustrated in Figure 1. This is a connectionist model with sets of processing units representing orthographic, phonological, and semantic information. Importantly, the orthographic and phonological components of the model (but not the semantic component) are “composed of a hierarchy of units ranging from graphemes (e.g., C, A, and T) and phonemes (e.g., /k/, /æ/, and /t/) up to whole words. Activation passes up this hierarchy as well as between O and P units at the same level.” (p. 206).

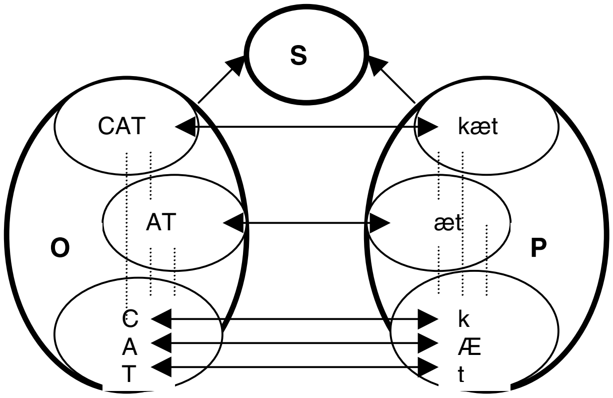

Figure 1: As depicted in Taft & van Graan (1998), a model of word recognition with sets of units representing orthography (O), phonology (P), and semantics (S).

Taft and van Graan (1998) argued that, when processing printed words, there is automatic activation of the phonological component of the model. Certainly, there has been controversy about the role that phonology plays in visual word recognition (e.g., Davelaar, Coltheart, Besner & Jonasson, 1978; Jared & Seidenberg, 1991; Pugh, Rexer, & Katz, 1994, etc.). While Taft and van Graan found evidence that phonology did not mediate access to word meaning, they concluded that there was evidence for activation of phonology. That evidence came from studies involving homophone stimuli (e.g., MAID-MADE) (e.g., Jared & Seidenberg, 1991; Van Orden, 1987, etc.).

In several studies, researchers have investigated whether homophones create confusion when presented without context, in a lexical decision task (LDT) (e.g., M. Coltheart, Davelaar, Johnasson, & Besner, 1977; Rubenstein, Lewis, and Rubenstein, 1971). Recently, Pexman et al., (2001) reported longer decision latencies for homophones than for nonhomophonic control words in LDT, particularly for low frequency homophones with higher frequency homophone mates. Those homophone effects were larger with pseudohomophone foils than with pseudoword foils. Pexman et al. concluded that homophone effects in LDT were robust, and argued for automatic activation of phonology in visual word recognition.

Pexman et al. (2001) offered an account of homophone effects in LDT that was similar in many ways to the notion of orthography-phonology-orthography rebound (Taft & van Graan, 1998). Pexman et al.'s account was based on the concept of feedback phonology. The notion that feedback activation from phonology to orthography might influence the process of word recognition was first explored by Stone, Vanhoy, and Van Orden (1997).

Stone et al. (1997) argued that the process of word recognition is best explained by a model that includes both feedforward and feedback connections (resonance) between orthographic and phonological units. As support for this claim, they reported feedback consistency effects in LDT. Feedback inconsistent words are words for which the body can be spelled in more that one way (e.g., /-ADE/ in FADE can be spelled /-AID/ or /-AYED/ as in PAID or SWAYED), whereas feedback consistent words are words for which the body can only be spelled one way (e.g., /-IMP/ in LIMP). Stone et al. observed slower lexical decision latencies for feedback inconsistent words than for feedback consistent words. Accordingly, they suggested that, when a feedback inconsistent word is processed in an LDT, the phonological representation can activate, via feedback connections, orthographic representations for several word bodies. These orthographic representations will compete with each other, and this competition will slow the recognition process. In a replication study, Zeigler, Montant, and Jacobs (1997) also reported feedback consistency effects, thus supporting the notion that feedback activation can influence word recognition performance.

Although much current research supports the feedback account, it should also be noted that Peereman, Content, and Bonin (1998) reported a failure to replicate feedback consistency effects with French stimuli in LDT. Peereman et al. suggested that whereas homophone effects in various tasks "can be interpreted as showing that lexical phonological codes reverberate to orthographic word forms, they do not imply interactions between orthographic codes and phonological codes at the sublexical level" and argued for a "restricted interactivity account in which interactions are limited to lexical processing levels" (p. 170).

Pexman et al.'s (2001) feedback account of homophone effects in LDT also involved interactivity at the lexical level, although did not deny the possibility of sublexical interaction. Pexman et al. suggested that, when the phonological representation of a member of the homophone pair is activated, it feeds back to the orthographic representations for both spellings of the word. Thus, while some of the feedback is directed towards the representation for the correct orthographic unit, some of it is also captured by activity in the orthographic representation of the incorrect homophone mate, thus creating competition and resulting in longer decision latencies for homophones. This account involves the assumption that LDT responses are made primarily on the basis of activation in the orthographic units (see Pexman & Lupker, 1999, and Pexman et al., 2001, for more detailed explanations of this assumption).

The Present Research

If it is the case that phonology feeds back to, and creates competition in, the orthographic units, then it becomes important to characterize and attempt to understand the exact nature of this orthographic competition. In previous research there have been several different suggestions about the nature of orthographic representations. As mentioned above, one suggestion is that feedback activation from phonology influences activation of whole word orthographic representations (Peereman et al., 1998; Pexman et al., 2001). There have also been suggestions about the sublexical orthographic representations that might be activated by feedback from phonology. These sublexical representations have been described as grapheme based (Zeigler et al., 1997) or syllabically based, with feedback to onset and rhyme units (Stone et al., 1997), however, both Ziegler et al. and Stone et al. acknowledged that other levels of orthographic representation could be activated via feedback. There is, in fact, a suggestion that several different grain-sizes of units are activated in the process of word recognition, such that feedback activation would influence both lexical and sublexical levels of orthographic representation (Taft & van Graan, 1998). The purpose of the present research was to investigate the grain-size of orthographic units activated by feedback from phonology. To do this, we investigated whether homophone effects are modulated by the type of orthographic overlap that exists between homophone mates. In previous investigations of homophone effects in LDT (e.g., Pexman et al., 2001; Pexman & Lupker, 1999; Rubenstein et al., 1971) homophone pairs have only been categorized by frequency. Yet homophone pairs vary widely in orthographic overlap; some homophone pairs differ only by a single internal grapheme (e.g., BERTH-BIRTH), while others differ by onset and also by word body (e.g., ATE-EIGHT). Our question for the present research was whether these sublexical differences in orthographic overlap lead to differences in the size of observed homophone effects. To this end, we created nine separate categories of homophones. Our aim was to divide homophones according to types of sublexical, orthographic overlap within homophone pairs (see Table 1), but our divisions between categories were also unavoidably influenced by the type of homophones that tend to occur in English. We restricted our analysis to low frequency homophones that have higher frequency mates since these were the homophones that produced the largest effects in Pexman et al. (2001).

In the following experiments we presented low frequency homophones from each homophone pair in the above homophone categories, along with sets of low frequency non-homophonic control words matched to the low frequency homophones. Our tasks were 3 LDTs, across which we manipulated the type of foils presented, to create task conditions that required less vs. more extensive processing. In Experiment 1A foils were consonant strings (e.g., PRNVR), in Experiment 1B foils were pseudowords (e.g., PRANE), and in Experiment 1C foils were pseudohomophones (e.g., BRANE). Pexman et al. (2001), and Pexman and Lupker (1999) have reported that when foils are more word like (e.g., pseudohomophones), homophone effects are larger. The explanation is that pseudohomophone foils create a difficult LDT, in which participants tend to process all of the stimuli more extensively. With more extensive processing, there is more opportunity for feedback activation to influence activation at the orthographic level and, hence, more competition and larger homophone effects. By using progressively more difficult LDTs, we hoped to capture homophone effects at several different "moments" of processing, allowing for more thorough contrasts between the homophone categories.

Method

Participants

The participants in these experiments were undergraduate students at the University of Calgary. There were 35 participants in Experiment 1A, 37 participants in Experiment 1B, and 41 participants in Experiment 1C.

Stimuli

Words The words used in this experiment were 95 homophones (mean frequency = 16.92 per million; Kucera & Francis, 1967) and 95 control words (mean frequency = 15.43) matched for frequency, onset, length and neighbourhood size (Coltheart, Davelaar, Jonasson, & Besner, 1977).

Foils Foil stimuli were required in all three parts of the experiment. There were 95 foils of each of the three types: consonant strings (Experiment 1A), pseudowords (Experiment 1B), and pseudohomophones (Experiment 1C).

Procedure

On each trial, a letter string was presented in the center of a 17-inch Sony Trinitron monitor controlled by a Macintosh G3 and presented using PsyScope (Cohen, MacWhinney, Flatt & Provost, 1993). Lexical decision responses were made by pressing either the left button (labelled NO) or the right button (labelled YES) on a PsyScope response box.

Experiment 1A – Results and Discussion

For this and each of the following experiments, mean decision latencies, mean error percentages, and homophone effect sizes for each category are presented in Table 1. In all analyses, data were analyzed with subjects (F1 or t1) and, separately, items (F2 or t2) treated as random factors.

To test the view that whole-word units are the important orthographic units for feedback activation, we conducted a 9 (homophone category type) X 2 (homophony) ANOVA to see if the effects of homophony varied by category. The overall homophone effect was significant in the latency analysis (F1(1, 34) = 6.73, p < .05, MSE = 3514.11; F2(1, 86) = 4.26, p < .05, MSE = 916.53), and in the error analysis (F1(1, 34) = 18.87, p < .001, MSE = 128.50; F2(1, 86) = 18.86, p < .001, MSE = 36.66). Thus, we confirmed the existence of homophone effects in LDT, replicating the results of Pexman et al. (2001), but here with a larger set of items and with consonant string foils. There was a main effect of category in the latency analysis (F1(8, 27) = 3.81, p < .01, MSE = 3422.01; F2(8, 86) = 2.37, p <.05, MSE = 1514.47) and in the error analysis (F1(8, 27) = 5.08, p < .01, MSE = 54.31; F2(8, 86) = 1.90, p = .07, MSE = 46.84). The interaction of category and homophony was not significant in the latency analysis (F1(8, 27) = 1.71, p = .13, MSE = 4446.21; F2(8, 86) = 1.47, p = .18, MSE = 916.53) but was significant in the error analysis by subjects (F1(8, 27) = 5.19, p < .01, MSE = 38.05; F2(8, 86) = 1.71, p = .11, MSE = 36.66). These effects indicate that the size of the homophone effects differed somewhat across the nine categories of homophones. Since this LDT involved consonant string foils, decisions could be made on the basis of relatively shallow processing.

As illustrated in Table 1, none of the homophone effects were significant in both latency and error analyses. Significant latency effects were observed for the Body Only and Onset and Body categories, and significant error effects were observed for the Single Vowel Only, Silent E or Word Internal Dipthong, /-s/ Morpheme, and Silent Onset and Body categories. In the case of the Single Vowel Only and Silent Onset and Body categories, error rates were relatively high for the homophones (15.0 % and 10.0 %, respectively). These error rates are surprisingly high for a LDT involving consonant string foils, and suggest that some of our participants may not have known some of these homophones (e.g., BERTH, WHOLLY, etc.). In the latency analyses for these categories, which include only correct responses, there were no differences between latencies for homophones and latencies for control words. Thus, the error effects in these categories may not really be indicative of orthographic competition. Hence, in the following experiments we draw conclusions only about homophone effects that are significant in both latency and error analyses.

Table 1: Homophone Effect Sizes

		Experiment 1A (consonant string foils)				Experiment 1B (pseudoword foils)				Experiment 1C (pseudohomophone foils)			
Homophone category	Example	RT	Error	RT effect	Error effect	RT	Error	RT effect	Error effect	RT	Error	RT effect	Error effect
Single vowel only	berth	541	15.0			642	28.1			742	33.9		
Control	blink	548	3.4	-7	+11.6* **	597	6.9	+45*	+21.2* **	692	10.5	+50*	+23.4* **
EA or EE grapheme only	deer	511	4.9			562	9.2			675	14.6		
Control	deed	512	3.6	-1	+1.3	551	6.7	+11	+2.5	621	4.7	+54*	+9.9*
Silent E	brake	531	4.9			589	10.2			698	14.9		
Control	bleed	505	2.3	+26	+2.6	539	5.2	+50* **	+5.0*	601	2.0	+97* **	+12.9*
Silent E or word internal dipthong	maid	522	7.0			581	11.6			682	15.4		
Control	mess	518	1.9	+4	+5.1*	522	1.5	+59* **	+10.1*	600	2.2	+82* **	+13.2* **
/-ed/ morpheme	guessed	537	4.3			576	4.8			693	5.6		
Control	glimpse	549	4.5	-12	-0.2	600	9.6	-24* **	-4.8*	682	8.4	+11	-2.8
/-s/ morpheme	presents	537	7.9			594	16.0			724	16.7		
Control	pleasant	537	2.9	0	+5.0*	578	6.5	+16	+9.5*	681	7.7	+43*	+9.0*
Body only	suite	534	3.7			577	7.4			684	8.2		
Control	shirt	518	1.8	+16**	+1.9	545	1.8	+32* **	+5.6* **	623	3.3	+61* **	+4.9*
Onset and body	kernel	558	7.1			619	15.9			726	19.1		
Control	kennel	516	3.9	+42* **	+3.2	560	5.4	+59*	+10.5*	633	4.0	+93* **	+15.1* **
Silent onset and body	wholly	540	10.0			599	17.7			709	24.1		
Control	wildly	532	5.0	+8	+5.0*	584	8.9	+15	+8.8*	669	8.3	+40	+15.8*
Foils		499	2.0			640	6.1			732	6.4		

*p < .05 by subjects, **p < .05 by items

Experiment 1B – Results and Discussion

In the 9 (homophone category type) X 2 (homophony) ANOVA, the overall homophone effect was significant in the latency analysis (F1(1, 36) = 43.01, p < .001, MSE = 3118.18; F2(1, 86) = 21.57, p < .001, MSE = 2966.35), and in the error analysis (F1(1, 36) = 75.17, p < .001, MSE = 139.16; F2(1, 86) = 18.09, p < .001, MSE = 150.30). The main effect of category was significant in the latency analysis (F1(8, 29) = 5.55, p < .001, MSE = 3147.14; F2(8, 86) = 2.52, p <.05, MSE = 6521.49) and in the error analysis (F1(8, 29) = 8.39, p < .001, MSE = 77.04; F2(8, 86) = 2.19, p < .05, MSE = 178.82). Importantly, the interaction of category and homophony was significant in the latency analysis (F1(8, 29) = 5.74, p < .001, MSE = 3007.84; F2(8, 86) = 2.34, p < .05, MSE = 2966.35) and was significant by subjects in the error analysis (F1(8, 29) = 11.69, p < .001, MSE = 74.91; F2(8, 86) = 1.80, p = .09, MSE = 150.30). These effects indicate that the size of the homophone effects differed across the nine categories of homophones. This result confirms that homophone effects vary by category and reveals that the source of homophone effects is not only competition from whole-word orthographic units. Thus, it is not the case that homophone effects arise whenever one phonological representation maps onto two orthographic representations. The magnitude of homophone effects seems to depend to some extent on competition between orthographic units that represent the sublexical structure of the homophones.

As illustrated in Table 1, homophone effects were observed in this experiment for 5 of the 9 types of homophones. The largest homophone effects seemed to arise in the categories of homophones that differ from their high frequency mates in onset structure (as long as the onset is articulated, since there was no effect in latencies for the Silent Onset and Body category), body structure, or by a single vowel grapheme (although not for the EA or EE Grapheme category).

Notably, the /-ed/ Morpheme homophones actually produced an effect in the reverse direction, while the /-s/ Morpheme homophones produced a null effect in the latency analysis. A tentative conclusion is that homophone effects do not arise for homophones that differ in morphological structure from their homophone mates (e.g., GUESSED-GUEST). Before interpreting this result any further, we examined effect sizes for all categories again in Experiment 1C.

Experiment 1C – Results and Discussion

As in Experiment 1B, the overall homophone effect was again significant in the latency analysis (F1(1, 40) = 77.58, p < .001, MSE = 9481.57; F2(1, 86) = 35.62, p < .001, MSE = 7658.91), and in the error analysis (F1(1, 40) = 170.92, p < .001, MSE = 138.34; F2(1, 86) = 27.68, p < .001, MSE = 212.49). There was a main effect of Category in the latency analysis (F1(8, 33) = 7.93, p < .001, MSE = 7307.81; F2(8, 86) = 2.24, p <.05, MSE = 13926.27) and in the error analysis (F1(8, 33) = 24.87, p < .001, MSE = 87.94; F2(8, 86) = 2.59, p < .05, MSE = 235.16). There was also an interaction of Category and Homophony that was significant by subjects in the latency analysis (F1(8, 33) = 2.74, p < .01, MSE = 7082.59; F2 < 1) and in the error analysis (F1(8, 33) = 13.20, p < .001, MSE = 87.14; F2 (8, 86) = 1.54, p = .16, MSE = 212.49). These effects indicate that the size of the homophone effects differed across the nine categories of homophones.

As in Experiment 1B, the greatest homophone effects in Experiment 1C were observed in the categories where homophone pairs differed by a vowel grapheme or by onset-body units. These effects affirm the notion that graphemes and onset-body units are important sources of competition for homophones. The implication is that these units receive feedback activation from phonology.

The /-ed/ Morpheme category demonstrated facilitation for homophones in Experiment 1B, yet, in Experiment 1C with pseudohomophone foils, we found that this facilitation disappeared and a null homophone effect was observed instead. This finding, along with the relatively small homophone effects observed for the /-s/ Morpheme category across foil conditions, suggests that homophone effects are not generally observed for pairs of homophones that have different morphological structure. There are two possible interpretations of these null homophone effects. One interpretation is that the orthographic representations for the two members of the homophone pairs are so *similar* that no competition arises. The second interpretation is that the orthographic representations for the two members of the homophone pairs are so *different* that no confusion or competition arises. We would tend to support the latter interpretation. If one ignored morphological structure, the homophones in the /-ed/ Morpheme category could be classified as Body Only homophones. Yet the Body Only homophones produced quite robust homophone effects compared to those produced by the /-ed/ Morpheme homophones. Therefore, the morphological structure of the /-ed/ homophones is an important factor in explaining the null (and sometimes facilitory) effects for that category. Homophones like GUESSED, that have different morphological characteristics than their homophone mates (GUEST), are apparently not confused with their homophone mates at the orthographic level. The extra morpheme /-ed/ seems to create an orthographic representation that is easily distinguished from the orthographic representation for the homophone mate.

As in Experiment 1B, the homophone effect for the Silent Onset and Body category in Experiment 1C was not significant in the latency analysis (although it was significant by subjects in the error analysis). Again, there are two possible interpretations for a null (or relatively small) homophone effect. One possible interpretation is that the representations for the words in these homophone pairs are so similar that minimal competition arises. That is, 'silent' letters may not have much bearing on the nature of orthographic representations for words like WHOLLY or KNOT. Hence KNOT may be encoded very much like NOT, with little competition arising. The second interpretation is that the representations for the words in these pairs are so different that minimal competition arises. That is, because the onsets and many of the bodies are orthographically different within the homophone pairs, KNOT may be easily distinguished from NOT, resulting in minimal competition. We tend to favour the first interpretation. The reason for this is that the homophone effect for the Onset and Body category is much larger than the homophone effect for the Silent Onset and Body category. The fact that the effect size is markedly smaller for the Silent Onset and Body category suggests that the silent onsets are not competing in the same way that the articulated onsets are, causing smaller (non-significant) homophone effects.

General Discussion

The purpose of the present research was to conduct a precise examination of the orthographic factors that modulate homophone effects, in order to determine the grain size of units activated by feedback activation from phonology.

The homophone effects observed in the experiments reported here provide support for the notion that phonology is activated in the process of visual word recognition and feeds back to units in orthography. We also observed differences in the extent to which different types of homophones produced homophone effects. Analysis of effect sizes for our homophone categories revealed that homophone effect sizes varied by sublexical orthographic overlap of homophone mates. Homophone effects were greatest when the members of homophone pairs differ by a single vowel grapheme, or by the word body, or by the word body and articulated onset, within one morpheme boundary. In terms of identifying precisely what the levels of sublexical representation are, the trends in our data *suggest* that the levels likely correspond to graphemes, and onsets and bodies. We acknowledge, however, that the ambiguities inherent in the orthography of English homophones (e.g., some of our homophones differed slightly on orthographic properties other than those defined by the category labels, many of our categories were "grapheme" categories since these are the most common type of English homophone pairs) prevent us from making stronger conclusions. Nonetheless, the cross-category differences in our homophone effects make it apparent that the feedback process does not reflect a mapping of phonology onto only whole word constituents at the orthographic level. This is not to say that lexical units are not also involved in the feedback process. According to the model depicted in Figure 1, activation at sublexical levels within the orthographic units feeds up to the lexical level. Presumably, activation at the lexical level must reach a certain point before a response is made. For homophones, responses seem to be delayed by competition at sublexical levels within the orthographic units. These delays are most obvious when an LDT is difficult (e.g., with pseudohomophone foils), because a higher threshold of activation is set and hence competition must be more fully resolved before a response is made.

These data provide support for a fully interactive model of word recognition, in which sublexical information is part of the orthographic and phonological components (e.g., Plaut et al., 1996; Taft & van Graan, 1998; Van Orden & Goldinger, 1994). The homophone effects reported in this paper suggest that there is bi-directional activation between the orthographic and phonological components of such a model, and that this activation is captured in several different grain-sizes of representation.

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