Title

The Interaction of Semantic and Phonological Processing

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 18(0)

Authors

Tyler, Lorraine K.

Voice, J. Kate

Moss, Helen E.

Publication Date

1996

Peer reviewed

The Interaction of Semantic and Phonological Processing

Lorraine K. Tyler[1]
J. Kate Voice[2]
Centre for Speech and Language
Department of Psychology
Birkbeck College
Malet Street
London WC1E 7HX
Tel: (44) 171 631 6589
fax: (44) 171 631 6312

[1] ubjta39@ccs.bbk.ac.uk
[2] ubjta70@ccs.bbk.ac.uk

&
Helen E. Moss
Department of Psychology
Glasgow University,
Glasgow

helen@psy.gla.ac.uk

Abstract

Models of spoken word recognition vary in the ways in which they capture the relationship between speech input and meaning. Modular accounts prohibit a word's meaning from affecting the computation of its form-based representation, whereas interactive models allow semantic activation to affect phonological processing. To test these competing hypotheses we manipulated word familiarity and imageability, using auditory lexical decision and repetition tasks. Responses to high imageability words were significantly faster than to low imageability words. Response latencies were also analysed as a function of cohort variables; cohort size and frequency of cohort members. High and low imageable words were divided into 2 sets: (a) large cohorts with many high frequency competitors, (b) small cohorts with few high frequency competitors. Analyses showed that there was only a significant imageability effect for the words which were members of large cohorts. These data suggest that when the mapping from phonology to semantics is difficult (when a spoken word activates a large cohort consisting of many high frequency competitors), semantic information can help the discrimination process. Because highly imageable words are "semantically richer" and/or more context-independent, they provide more activation to phonology than do low imageability words. Thus, these data provide strong support for interactive models of spoken word recognition.

Introduction

Models of spoken word recognition vary in the ways in which they capture the relationship between phonology and semantics. Accounts assuming a modular structure, with the speech input passing through a series of stages until the meaning of the word is accessed (e.g. Forster, 1979), share the view that the speech input is initially mapped onto a level of form representation. Only when this process is completed can meaning be accessed; the meaning of a word cannot affect the computation of its form-based representation. In contrast, interactive models of word recognition (e.g. McClelland & Elman, 1986) assume feedback between different levels of processing. Although there is no extant interactive model which captures the entire process of spoken word recognition, from analysing the speech input to accessing meaning, we can extrapolate from existing models which capture part of the word recognition process. In TRACE, for example, the speech input is initially mapped onto a featural level of representation, then onto a phoneme level and finally onto a word level (McClelland & Elman, 1986). Interaction is achieved by feedforward and feedback between levels. If this model was extended beyond the word-form level to semantics, and assuming the same structure, semantic information would feed back to the word-form level. Thus, this kind of model would predict that the computation of a word's form could be affected by its meaning.

Experimental investigations of the relationship between form and meaning have often exploited imageability[1] (see Balota, Ferraro & Connor, 1991 for a review). The imageability of a word is the degree to which its referent can be perceived through the senses; for example, *table* is highly imageable whereas *hope* is low in imageability. The empirical issue is whether a purely semantic variable - imageability - can affect phonological processing. If it does,

[1] We use the terms imageability and concreteness interchangeably here

this might result in high imageability words being recognised more easily than low imageability words; this would be evidence that meaning variables affect word identification.

However, testing this claim crucially requires a task which taps into the early stages of word recognition; a task which reflects the automatic activation of phonological and semantic information during the process of recognising a spoken word. There are two primary candidates: word naming and lexical decision (cf Balota et al, 1991). Naming is generally considered to tap early activation processes, whereas lexical decision may include a post-access decision stage, making it less suitable for probing early word recognition processes.

Although few studies have directly explored the relationship between phonology and meaning, a number of experiments have focussed on a related issue - whether meaning has an early influence on word recognition. These experiments typically involve subjects making lexical decisions to written words of varying degrees of imageability. Some, although not all, have reported an advantage for highly imageable words in lexical decision (e.g. Rubenstein, Garfield & Millikan, 1970; de Groot, 1989; Schwanenflugel, Harnishfeger & Stowe, 1988), but it is difficult to argue on the basis of LD data alone for the early influence of semantics, given the possibility that LD latencies may involve post-access phenomena.

A more direct test of the relationship between phonology and meaning involves subjects naming written words. Semantic effects in word naming are even more elusive, with studies showing either very small (deGroot, 1989) or no effects of imageability (Brown & Watson, 1987). Recently, however, Strain, Patterson & Seidenberg (1995) have reported an imageability effect for low frequency exception words with naming, arguing that when the orthographic to phonological mapping is slow, inefficient or error prone, meaning plays a larger role in word naming.

The semantics/phonology interaction is most directly studied by investigating imageability effects in spoken word recognition. This avoids any problems with the orthography-phonology mapping. The question we ask in the studies reported here is whether imageability affects the computation of a phonological representation during the processing of a spoken word. If it does, this is evidence for a highly interactive word recognition system.

Experiments

In this research we manipulate imageability and use two tasks - word repetition and auditory lexical decision - in order to probe the effect of semantics on phonology. Using LD allows a direct comparison with research in the visual domain looking at imageability effects, and repetition is considered to be a more direct reflection of the automatic activation of phonological information without accompanying post-access processes (Balota et al, 1991).

Auditory lexical decision

In this study, subjects heard a mixed list of words and non-words and made a lexical decision to each item. The set was comprised of 46 high imageability words (imageability and concreteness ratings>540) and 46 low imageability words (<400), which were further grouped into 2 equal-sized familiarity bands; high familiarity (familiarity rating >550) and low familiarity (<420). High and low imageability words within the same familiarity band were matched as closely as possible in terms of frequency and familiarity, number of syllables, number of phonemes and phoneme onset (Table 1). Familiarity and imageability ratings were from the MRC database (Coltheart, 1981); frequencies were calculated using the LOB norms (Johansson & Hofland, 1989). We could not perfectly match the frequencies of the two sets of high frequency words, but the higher frequency of the low imageability words is a conservative solution since it should increase the probability of faster responses to low imageability words, thus loading the dice against our pedicted outcome. The words, all of which were 1-2 syllable nouns, were pseudo-randomly mixed with an equal number of non-words.

Familiarity	High		Low	
Imageability	Low	High	Low	High
Mean concreteness	314	600	314	594
Mean imageability	351	600	331	571
Mean familiarity	578	588	353	373
Mean frequency	222	90	6	2
Mean No. syllables	1.5	1.5	1.8	1.6
Mean No. phonemes	4.4	4.2	4.7	4.6

Table 1: Statistics of the high and low imageability words.

The results given below are for 14 subjects, all native speakers of British English. An ANOVA showed a main effect of imageability ($F^1[1,13]=53.18$, $p<.001$; $F^2[1,84]=5.49$, $p<.02$), with LD latencies being faster to high (817 ms) compared to low imageability words (854ms). Highly familiar words (798 ms) were also identified significantly faster than low familiarity words (877 ms). Imageability did not interact with familiarity.

	Familiarity	
Imageability	High	Low
Low	829	881
High	769	872
Difference	60	9

Table 2: Lexical decision latencies (ms).

Repetition

The same real words were then run in a repetition study, with subjects repeating each word as rapidly as possible. Repetition latencies for 12 subjects were significantly faster for high imageability (397 ms) compared to low imageability (442 ms) words ($F^1[1,11]=10.63$, $p<.001$; $F^2[1,84]=5.43$, $p<.02$). Once again, there was a significant effect of familiarity (high: 396 ms; low:441 ms) and no interactions.

	Familiarity	
Imageability	High	Low
Low	424	456
High	371	428
Difference	53	28

Table 3: Repetition latencies (ms).

Cohort analyses

Because we were dealing with spoken rather than written words, we also analysed repetition and lexical decision latencies as a function of cohort variables which may affect the recognition of spoken words; cohort size and frequency of cohort competitors. Cohorts were defined as those words sharing the initial consonant-vowel or consonant-vowel cluster. We also measured the frequency of the target word in relation to the frequency of its cohort competitors [frequency of target/total frequency of cohort members x 100]. High and low imageable words were divided into 2 sets according to whether they were members of large cohorts with many high frequency competitors or small cohorts with few high frequency competitors. (Table 4).

Imageability	High		Low	
Cohort size	Large	Small	Large	Small
Mean concreteness	587	597	317	311
Mean cohort size	236	22	280	40
Mean % cohort*	3.5	22	6	22

*the smaller the value, the greater the competition

Table 4: Cohort variables.

We included the cohort variable in further ANOVAs and found that there was only a significant imageability effect for the words which were members of large cohorts. These results are shown in Tables 5 & 6.

	Cohort size	
Imageability	Large	Small
Low	898	812
High	794	829
Difference	104*	-17

* F^1 & F^2 significant at the .05 level or beyond

Table 5: Lexical decision latencies (ms).

	Cohort size	
Imageability	Large	Small
Low	438	438
High	367	423
Difference	71*	15

* F^1 & F^2 significant at the .05 level or beyond

Table 6: Repetition latencies (ms).

Discussion

Our results are compatible with interactionist models in which: (a) there is parallel activation of multiple candidates initiated by the speech input, and (b) where phonological and semantic representations interact with each other. This includes hierarchically structured models in which there is continuous feedback and feedforward throughout the system, as well as interactionist models in which there is no hierarchical structure, such as that of Gaskell & Marslen-Wilson, 1995. In their model, phonological and semantic representations reside at the same level in the system, and are simultaneously co-activated by the speech input.

Our data suggest that when a spoken word activates a large cohort consisting of many high frequency competitors the mapping from phonology to semantics becomes more difficult; highly activated words compete with the less highly activated target word. Although there is continuous interaction between phonology and semantics for all words, irrespective of imageability, semantic information has a larger role to play as the discrimination process becomes more difficult. Highly imageable words provide more activation to phonology than do low imageability words. This may be because they are "semantically richer" in that they have more and varied semantic representations, as Plaut & Shallice (1993) have suggested, or because their representations are more context-independent.

Our data, and the account we provide of them, is consistent with the recent findings of Strain et al (1995). In a word naming task in which subjects were asked to name regular and exception words varying in imageability and familiarity, they only found an advantage for high imageability low frequency exception words. Strain et al (1995) argue that semantic representations have their greatest influence when the mapping from orthography to phonology is most difficult. Similarly, we argue that as it becomes more difficult to discriminate between a word and its competitors (when cohort members increase in number and frequency), semantics becomes increasingly influential. In general, these data are incompatible with models which assume a strict separation between phonological and semantic levels, and instead provide strong support for interactive models of spoken word recognition.

References

Balota, D., Ferraro, R., & Connor, L. (1991) On the early influence of meaning in word recognition: A review of the literature. In: P. Schwanenflugel (Ed.) *The Psychology of Word Meanings*. LEA: Hillsdale.

Brown, G.D. & Watson, F. L. (1987) First in, last out: Word learning age and spoken word frequency as predictors of word familiarity and word naming latency. *Memory and Cognition*, 15, 208-216.

Coltheart, M. (1981) The MRC psycholinguistic database. *Quarterly Journal of Experimental Psychology*, 33a, 497-505.

deGroot, A.M.B. (1989) Representational aspects of word imageability and word frequency as assessed through word associations. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 15, 824-845.

McClelland, J. & Elman, J. (1986) The TRACE model of speech perception. In McClelland, J.L. & Rumelhart, D. (Eds) *Parallel distributed processing: Explorations in the microstructure of cognition.* Cambridge, Mass: Bradford Books.

Forster, K. (1979) Levels of processing and the structure of the language processor. In W.E. Cooper & E. Walker (Eds) *Sentence processing: Psychological studies presented to Merrill Garrett*, Hillsdale, NJ: LEA

Gaskell, G. & Marslen-Wilson, W.D. (1995) Modelling the perception of spoken words. *Proceedings of the 17th Annual Cognitive Science Conference,* Hillsdale, NJ: Erlbaum.

Johansson, S. & Hofland, K. (1989) *Frequency analysis of English vocabulary and grammar.* Oxford: Oxford University Press.

Rubenstein, H. Garfield, L. & Millikan, J. (1970) Homographic entries in the internal lexicon. *Journal of Verbal Learning and Verbal Behaviour,* 9, 487-494.

Schwanenflugel, P. Harnishfeger, K. & Stowe, R. (1988) Context availability and lexical decisions for abstract and concrete words. *Journal of Memory and Language*, 27, 499-520.

Strain, E., Patterson, K.E & Seidenberg, M. (1995) Semantic effects in single word naming. *Journal of Experimental Psychology: Learning, Memory & Cognition.*