

Abstractness, Allomorphy, and Lexical Architecture

William Marslen-Wilson

MRC Cognition and Brain Sciences Unit, Cambridge, UK

Xiaolin Zhou

Centre for Speech and Language, University of Cambridge, UK

Two intra-modal immediate repetition priming experiments ask whether speech inputs can link directly to abstract underlying representations, or whether access is mediated via intervening “access representations” of each word’s surface phonetic form. Experiment 1 showed that auditory-auditory priming between morphologically related derived/stem pairs (such as *excitement/excite*) was not affected by allomorphic variation in the phonetic form of the stem in prime and target (as in *sanity/sane*). Experiment 2 showed that interference effects between suffixed primes and targets sharing the same stem (as in *excitement/excitable*) were also unaffected by stem variation (as in *sanity/sanely*). These results, which cannot be attributed to either semantic or phonological factors, are problematic for mediated access theories and point to direct access from speech to abstract representations at the level of the lexical entry.

INTRODUCTION

We take as a starting-point for a theory of the mental lexicon the distinction between the *lexical entry*—the core representation of a word’s abstract syntactic, semantic, and phonological properties—and the

Requests for reprints should be addressed to Dr William Marslen-Wilson, MRC Cognition and Brain Sciences Unit, 15 Chaucer Rd, Cambridge CB2 2EF, UK; Email: william.marslen-wilson@mrc-cbu.cam.ac.uk

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modality-specific procedures required to access these representations from the sensory input (Marslen-Wilson, Tyler, Waksler, & Older, 1994). We focus in this paper on access procedures in the auditory domain, and ask whether lexical access from speech requires the postulation of modality-specific *access representations* of each word's surface phonetic form (a phonological "access lexicon"), or whether the speech input can be mapped directly onto *abstract* underlying representations at the level of the lexical entry.

The problem of abstractness in lexical access is posed most directly by the phenomena of phonological and allomorphic variation—we focus here on these phenomena in English, but they are a salient feature of languages worldwide. These are processes whereby the surface form of a word—the phonetic shape actually produced by a speaker—varies as a function of the phonological and morphological environment in which a particular word (or morpheme) finds itself. In previous research we initially focused on processes of phonological variation in morphologically simple words, looking at assimilatory processes, where the properties of one segment are affected by the properties of a following segment. These include vowel nasalisation, where an oral vowel is nasalised when it is followed by a nasal consonant, as in the English words *ban* or *hang* (Lahiri & Marslen-Wilson, 1991), and place assimilation, where a syllable-final consonant can take on the place of articulation of a following segment, as in alternations such as "sweep boy" and "sweek girl", where underlying *sweet* is articulated either as [swip] or [swik], depending on whether it is followed by a labial or a velar consonant (Gaskell & Marslen-Wilson, 1993; 1996; Marslen-Wilson, Nix, & Gaskell, 1995).

The problem for a theory of lexical access is to explain how phonologically variant forms of this type could nevertheless be treated by the perceptual system as acceptable tokens of the words from which they were derived. In earlier research, we have argued for a primarily representational account where surface variations such as [swik] or [swip] could map directly onto an abstract underlying lexical representation which was *underspecified* for the feature dimension that was varying. Thus, for example, the word-final /t/ in *sweet* is assumed to be unspecified for place of articulation, meaning that surface [k] or [p] do not create mismatch with the underlying specifications of the lexical form in question. This also means that no intermediate processing step is required, where surface [swik] maps onto an access representation of /swik/, which subsequently connects to the lexical entry for {sweet}.¹

¹ We will use curly brackets {...} to denote abstract morphemic representations at the level of the lexical entry.

In subsequent research (Marslen-Wilson et al., 1994) we have proposed the same kind of analysis to explain how listeners represent and perceive cases of regular *allomorphic* variation (i.e. where phonological changes in the form of a stem are morphologically triggered). These are cases where the phonetic realisation of a stem morpheme, such as *sane* or *decide*, is changed when it is followed by certain derivational morphemes, as in forms like *sanity* or *decision*. In cross-modal repetition priming experiments we found that phonologically divergent prime/target pairs, such as *sanity/sane* primed each other just as effectively as pairs like *happiness/happy*, where prime and target are phonologically much more similar (Marslen-Wilson et al., 1994). To explain this we again proposed a representational account, where phonetically divergent surface forms of the same stem could map directly onto an abstract phonological representation at the level of the lexical entry.

One way of capturing this is in conventional symbolic terms,² where the underlying representation of the morpheme {sane} would be something like /sÆn/, with the capitalised vowel symbol (Æ) denoting a vowel segment unspecified for tenseness (Myers, 1987).³ In the appropriate environment this vowel is realised as either [ey] or [æ], as in the surface forms [seyn] and [sænltl]. The crucial point, from the perceptual side, is that because the lexical representation is underspecified for this particular feature, both surface forms will match to it (as illustrated in Fig. 1). Underlying [sÆn] will match equally well to surface [seyn] and to surface [sæn]. There is no need, therefore, to postulate an intermediate access representation to deal with surface allomorphy of this type. We will refer to this as the *single direct access* account.

We should stress that representational accounts of this type can only apply to *regular* phonological alternations, triggered by specific morphological changes. The tense/lax alternation in the stem vowel of pairs like [seyn] and [sænltl] is a case in point. Vowel laxing is a general phonological process in English, which is triggered here by the change in syllable structure caused by the addition of a derivational suffix to a stem. Irregular morphophonological alternations cannot be captured in this way. In English inflectional morphology, for example, the irregular past tense, as in pairs like *buy/bought* and *give/gave*, cannot plausibly be analysed in terms of a single abstract underlying representation from which both stem and past tense form can be derived. Here, it seems, we do need to postulate

² The use of a specific linguistic notation to represent the single direct access approach, as in Fig. 1, should not be interpreted as a commitment to the literal psychological reality of this notation.

³ The alternation here between [ey] and [æ] is typically characterised as a variation in the tense/lax vowel feature.

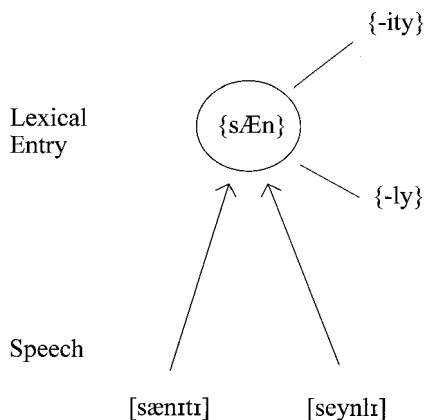


FIG. 1. A Single Direct Access model of lexical access from speech (see text).

stored representations of the allomorphic forms (Marslen-Wilson & Tyler, 1998).

The single direct access model needs to be distinguished from at least two further views. The first of these, also a direct access model, is a major linguistic alternative to the type of analysis we proposed above, where allomorphic forms are traced back to a single abstract underlying form. This view argues instead for multiple underlying forms, on the grounds that a number of languages seem to allow word-formation rules to access derived allomorphs before phonological rules could have derived these allomorphs from an underlying representation (e.g. Lieber, 1982; Marantz, 1982; Spencer, 1988). This would mean that derived allomorphs, as well as possible basic forms, must be listed in the lexicon. These representations are again quite abstract, and will undergo various phonological processes in the process of realising the complex surface form. Relating this to a theory of lexical access, this would lead to the *multiple direct access* arrangement sketched in Fig. 2, where allomorphic forms do not map directly onto a single underlying representation, but rather onto separate representations of the base form and its allomorphic variants. These listed allomorphic stems can be assumed to be located at the level of the lexical entry, so that again no additional access representation of surface form is required.

Both the views we have discussed so far have in common the assumption that lexical access is based on direct access of abstract underlying forms. This contrasts with the third type of view we will consider, which assumes that stored representations of the surface forms of words are the first step in the access process. This view has been the default in essentially all modern psychological theories of lexical representation and access. The

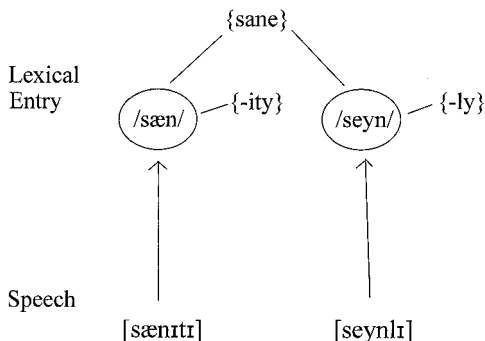


FIG. 2. A Multiple Direct Access model of lexical access from speech (see text).

influential early model proposed by Forster (1976), for example, distinguished modality-specific access files from a lexical master file. These access files, bins of word-forms ordered according to frequency, provide an access code which allows the perceiver to contact the appropriate master file, where lexical content is represented. The logogen model (Morton, 1969), especially in its later extensions in the context of cognitive neuropsychology, made a rigorous distinction between an auditory input lexicon and other aspects of lexical representation.

A more recent formulation, influenced both by neuropsychological and normal data, is the Augmented Addressed Morphology (AAM) model, where a modality-specific input lexicon mediates between the sensory input and a central system of lexical entries (for a review see Burani & Laudanna, 1992). The AAM assumes that a morphologically complex input string activates both whole-word representations and the individual morphemes (roots and affixes) that make up a word. Known words can be accessed by either route, with word and morpheme frequency swinging the balance one way or the other (Burani & Laudanna, 1992). However, when a form involves allomorphic variation, as in words like *concezione* ("conception"), from the root *concep-ire* ("to conceive"), it is assumed that access is only possible either through the whole-word route, or via a representation of the surface stem (*concezion-*). Similarly, Caramazza, Laudanna, and Romani (1988) argue for separate representation in the input lexicon of irregular verb stems. The alternate stem *cors-*, for example, as in forms like *cors-ero* ("they ran"), is listed for the verb *correre* ("to run") together with its regular stem *corr-*.⁴ These are all access

⁴ See Orsolini and Marslen-Wilson (1997) for a discussion of the extensive sub-regularities in these Italian second conjugation irregular forms.

representations in the sense intended here, as modality-specific reflections of the surface form of words.

Similar assumptions are made in the Morphological Race Model (MRM) and its descendants (Baayen, Dijkstra, & Schreuder, 1997; Frauenfelder & Schreuder, 1992; Schreuder & Baayen, 1995). The MRM has in common with the AAM the same intermediate access representations, where the full form of a morphologically complex word is represented together with units corresponding to its constituent morphemes. Again, access can be made either through whole-word or decompositional routes, and the winning route will depend on factors such as frequency, predictability, and transparency. Unlike the AAM, however, these models assume an interactive activation computational architecture, allowing feedback of activation between levels.

For all such *mediated access* models, whether or not they explicitly discuss the problem of allomorphic variation, the solution they offer is through separate access representations for each allomorphic surface form. Forms like *sane* and *sanity* must have separate representations in the phonological access lexicon. These will then connect to representations at higher levels in ways which will differ according to different assumptions about the properties of these representations. We illustrate here (Fig. 3) one model of this type, based on the models of Dutch (Schreuder & Baayen, 1995) rather than Italian (Burani & Laudanna, 1992), as being typologically closer to English, the object of our enquiries here. Here the

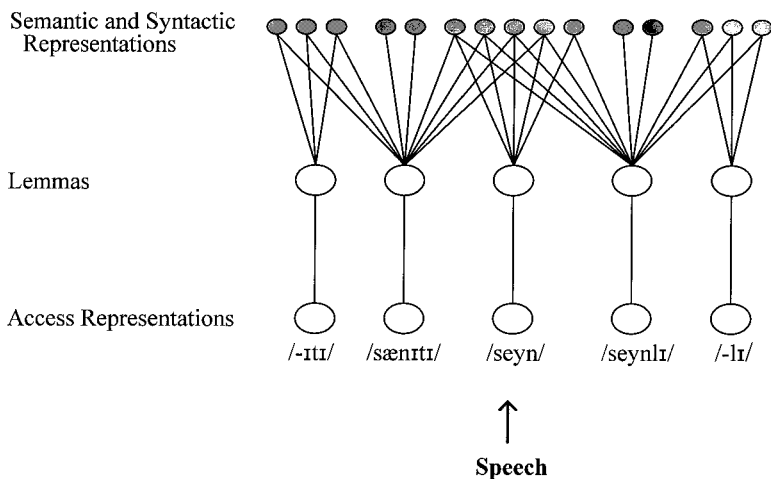


FIG. 3. A Mediated Access Model of lexical access from speech (the Morphological Race Model), illustrating access routes for allomorphic (*sanity*) and nonallomorphic (*sanely*) complex forms.

allomorphic form *sanity* is represented as a full form in the access representation, connects to a separate node at the lemma level,⁵ and is related to the morphemes {sane} and {-ity} at the level of syntactic and semantic lexical representation (Baayen et al., 1997).

Experimental Issues

The initial evidence for morphemically organised abstract representations came from the cross-modal repetition priming studies we summarised earlier, where auditorily presented prime words were found to prime lexical decision responses to morphologically related visual target words, irrespective of the degree of phonological overlap between them (Marslen-Wilson et al., 1994). But these results are only preliminary. To make the argument that auditory inputs do indeed project directly onto abstract underlying representations, and to distinguish among different access models, we need to re-examine these effects in an intra-modal auditory-auditory version of the task, where an auditory prime is followed by an auditory target.

There are a number of reasons for this. The first is that although the cross-modal results are compatible with a direct mapping account, they are also consistent with other interpretations. In particular, as priming in this task falls at the level of the lexical entry, we cannot exclude the possibility that inputs in different modalities can access this level via modality-specific access representations, in either or both input domains.

The second reason is that the single direct access hypothesis requires that allomorphic variation should have no effect in intra-modal, auditory-auditory immediate repetition priming, whereas the other two hypotheses do not. If allomorphic forms relate directly to a single underlying abstract representation at the level of the lexical entry, as indicated in Fig. 1, and do so without involvement of any mediating representation of their surface phonetic form, then they should prime as effectively as derived forms whose stems do not show the same allomorphic variation. Any diminution of the effect will be evidence against a strong form of this hypothesis. If, on the other hand, full priming is obtained, this can still be accommodated by the multiple direct access hypothesis (Fig. 2), but is more problematic for mediated access models. In the AAM, for example, repetition priming in lexical decision tasks is argued to depend on repeated activation of related structures in the modality-specific input lexicon (Caramazza et al., 1988; Laudanna, Badecker, & Caramazza, 1989; Laudanna & Burani, 1985). This

⁵ The level labelled “lemma” in more recent versions of the MRM (e.g. Baayen et al., 1997) is the same as the level labelled “concept” in Schreuder and Baayen (1995).

predicts that allomorphic items should show either no or significantly reduced priming, depending on the degree of feedback from higher levels.

The third reason is that the existing data on priming between auditorily presented allomorphic forms is not only sparse, but inconclusive and hard to interpret. In a long-term delayed repetition task, using an identification-in-noise paradigm, Kempley and Morton (1982) found strong effects of allomorphic variation, with no priming between pairs like *wove/weave*, but strong priming between pairs like *bulged/bulgeor faces/face*, where there is no variation in the surface form of the stem. In contrast, Fowler, Napps, and Feldman (1986) found strong priming in a more conventional delayed repetition auditory-auditory task, with allomorphic primes such as *invasion* being almost as effective as stem forms (*invade*) in facilitating lexical decisions to a subsequent affixed target (*invader*), though not as effective as identity primes. It is possible that these differences reflect the different proportions of irregular inflected (as opposed to derivational) past tense forms used as primes or targets in the two studies, as our own studies show that pairs of this type (*creep/crept*, *bought/buy*, etc.) do not prime well even in cross-modal immediate repetition tasks (Marslen-Wilson, Hare, & Older, 1993; Marslen-Wilson, Hare, Older, & Ford, 1995). More generally, these studies are hard to interpret because they did not explicitly control for the kinds of allomorphic processes involved, nor for the semantic transparency of the complex forms, a variable which we have shown to be crucial in determining priming effects between morphologically related words in English (Marslen-Wilson et al., 1994).

The first experiment reported here, therefore, takes the same set of contrasts as we used in our initial cross-modal experiments (Marslen-Wilson et al., 1994) and asks whether we find parallel effects in the intra-modal, auditory-auditory task. In a second experiment, we probe more specifically the predictions of competing access models, exploiting suffix-suffix interference effects in the auditory domain.

EXPERIMENT 1

The evidence for direct access of abstract representations in the cross-modal task comes from experiments where we co-varied the phonological and the morphological relationship between the prime and the target. We follow the same strategy here, contrasting three conditions where prime and target are morphologically related but vary in phonological similarity, with a fourth condition where prime and target are morphologically unrelated but phonologically very similar (see Table 1).

In Condition 1, with pairs like *dancer/dance* and *arrangement/arrange*, the auditory prime (always a derived suffixed word) is morphologically related to the auditory target (always a free stem), and the relationship

TABLE 1
Properties of Stimuli in Experiment 1

<i>Condition</i>	<i>Prime</i>	<i>Target</i>	<i>Rel</i>
1 [+ m, + s, + p]	<i>friendly</i>	<i>friend</i>	7.7
2 [+ m, + s, - p]	<i>elusive</i>	<i>elude</i>	7.6
3 [+ m, + s, - p]	<i>sanity</i>	<i>sane</i>	7.5
4 [- m, - s, + p]	<i>tinsel</i>	<i>tin</i>	1.5

Rel, semantic relatedness between primes and targets; m, morphological; s, semantic; p, phonological.

between the two is phonologically transparent. As in the earlier experiment, morphological relatedness is defined on linguistic and historical grounds (for details, see Marslen-Wilson et al., 1994, p. 7). In addition, we checked in pre-tests that the prime-target pairs were synchronically semantically transparent. We refer to this type of prime-target relation as [+ Morph, + Phon, + Sem].

We contrast priming in this condition with priming in two further conditions where prime and target are still morphologically and semantically related, but where differing types of stem allomorphy make the relationship between prime and target less phonologically transparent. In Condition 2 the change is mainly in the final consonant of the stem, as in the /d/→/s/ alternation found in pairs like *defensive/defend* or *elusive/elude* or the palatalisation found in pairs like *rotation/rotate* or *attraction/attract*. In Condition 3, the change is primarily in the final vowel of the stem, as in pairs like *sanity/sane* or *derivative/derive*, though often involving the final consonant as well, as in *decision/decide* or *allegation/allege*. We define the stimuli in both these classes as [+ Morph, - Phon, + Sem].

In the earlier research with contrasts of this kind (Marslen-Wilson et al., 1994, Experiment 1), we found significant priming in all three of these [+ Morph, + Sem] conditions, with no significant difference in the amount of priming across conditions. Allomorphic pairs like *tension/tense* or *division/divide* primed just as well as phonologically transparent pairs like *dancer/dance*. As we noted earlier, direct access models predict the same outcome in auditory-auditory priming. Indirect access theories, where access (and priming) are mediated via separate access representations of allomorphic forms, predict reduced or no priming in Conditions 2 and 3.

The unknown factor here, however, is the degree to which purely phonological or phonetic factors control performance in the intra-modal task, over and above any effects due to the presence or absence of modality specific access representations. This is another area where the recent literature does not give a clear picture. Perhaps the most relevant

research is a study by Emmorey (1989) which examined auditory-auditory immediate repetition priming for pairs of words that varied in morphological and phonological relatedness. Emmorey found significant priming between morphologically related prefixed pairs, such as *submit/permit*, but also found facilitation between purely phonologically related pairs such as *tango/cargo* and *rabid/morbid*. These results, in fact, were one reason why we avoided intra-modal tasks in our original research on morphological representation. On the other hand, phonological priming research, using morphologically and semantically unrelated pairs that match from word-onset, rather than at word-offset as in the Emmorey (1989) experiments, tends to find inhibitory effects between primes and targets that are clearly phonologically related, and facilitatory effects for pairs where the phonological relation is reduced or less explicit (e.g. Goldinger, Luce, Pisoni, & Macario, 1992; Radeau, Morais, & Segui, 1995; Slowiaczek & Hamburger, 1992; but see Radeau, Morais, & Dewier, 1989).

To re-evaluate these effects in the current experimental context, and to provide a baseline for interpreting the results in the three [+Morph] conditions, we include a fourth, phonological control condition (Condition 4 in Table 1). This uses prime/target pairs that are phonologically related but morphologically and semantically unrelated, as in *planet/planor* and *tinsel/tin*. These do not prime at all in cross-modal tasks (Marslen-Wilson et al., 1994), and it is important to determine how far they prime under auditory-auditory testing conditions. The least favourable outcome will be if priming in this condition is as strong as in the [+Morph] conditions, as this will make it difficult to separate morphological effects from those based just on phonological overlap between prime and target. In contrast, on a strong interpretation of the direct access hypothesis, and on the assumption that repetition priming is most effective when it involves repeated access to the same lexical entry, priming should be significantly reduced or nonexistent in this condition.

Method

Materials. These were based on the stimulus set constructed for the parallel cross-modal study reported as experiment 1 of Marslen-Wilson et al. (1994), modified as necessary to remove problematic items from the original set, and to make some of the nonword targets more appropriate for auditory presentation.⁶

We selected 120 prime-target pairs, falling into the four conditions outlined in Table 1. Ninety of the pairs, forming Conditions 1, 2, and 3,

⁶ Copies of the materials for Experiments 1 and 2 are available from the authors.

consisted of a derivationally suffixed form and its associated free stem, matched across conditions for frequency, number of syllables, and grammatical category. In Condition 1, the prime-target pairs were phonologically transparent. The stem had the same phonetic form in isolation and as part of the derived word (e.g. *delightful-delight*). In Conditions 2 and 3 the stem had a different phonetic form in isolation than in the derived word. In Condition 2, the allomorphy chiefly involved the final consonant of the stem, as in *tension-tense* and in Condition 3 the final vowel of the stem, as in *serenity-serene*. A further 30 pairs, in Condition 4, consisted of words that were not morphologically related but which overlapped phonetically (e.g. *tinsel-tin*).

For each of the 120 prime words, we selected a control (or baseline) word which matched the prime in frequency, number of syllables, and form-class. Frequency was computed on the principle that inflectional variants of the same stem should be counted together (e.g. *jump, jumps, jumped*) but that derivational variants should not. None of the control items were either morphologically, semantically, or phonologically related to the targets.

Fillers: The filler materials were constructed so as to (a) significantly dilute the proportion of related items encountered by the subject in the experiment as a whole, and (b) to obscure the regularities in the test items. To this end we constructed 180 additional filler pairs, falling into three categories:

1. Thirty fillers consisted of word/nonword pairs, such as *donkey-donk*, in which the target was fully contained within the prime. A further 30 fillers consisted of word/nonword pairs in which there was a partial overlap between the prime and the nonword target (e.g. *forgery-forticle*). These two sets of fillers ensured that not all prime-target pairs which overlapped phonetically had real words as targets.
2. Thirty fillers consisted of morphologically and phonologically unrelated word/word pairs (e.g. *penniless-edge; lucky-accept*). We included these items to increase the percentage of unrelated word pairs in the stimulus set.
3. To balance the number of word and nonword targets, 90 additional word/nonword pairs were constructed with no phonological relationship between prime and target (e.g. *volunteer-soad; vinegar-bline*).

This gave a total of 150 word/word pairs and 150 word/nonword pairs. Morphologically related pairs made up 15% of the stimuli encountered by the subjects. The fillers and test items were pseudo-randomly distributed throughout the list, with the same order of test and filler items in each of the two versions. Each version contained a total of 360 pairs—40 practise

pairs which were followed by 20 warm-up pairs and the 300 test and filler pairs.

Design and Procedure. The test items were divided into two versions. These were balanced so that all the targets appeared once in each version, half preceded by the prime and half preceded by the control word.

The primes and targets were recorded by a female native speaker of English onto DAT tape. They were then stored on a computer at a sampling rate of 22 kHz, and played out binaurally to the listeners over headphones, under the control of VMASTR experimental software.⁷ The interval between prime and target was set at 150 msec, and there was a 2500 msec interval between trials. The listener's task was to press one response key if the target was a real word and another if it was a nonword, with instruction to respond as quickly and accurately as possible. Response times were measured from the onset of the target-word.

There were two breaks in the test session; one after the practise sequence, and one halfway through the main test sequence. The entire session lasted about 40 minutes.

Participants. We tested 35 native speakers of British English from the Centre for Speech and Language subject pool. Participants were paid for their attendance.

Results and Discussion

Data from five participants were discarded because of high error rates (above 15%), leaving 15 participants per version. Two prime-target pairs in Condition 4 were also deleted from analyses because they attracted error rates of over 45%. The mean reaction times and response error rates for the remaining data are given in Table 2. The priming effects are plotted across conditions in Fig. 4, which also includes the results for the parallel set of stimuli run under cross-modal conditions (Marslen-Wilson et al., 1994).

Figure 4 makes clear that the pattern of priming is very similar to what we found earlier in the cross-modal experiments, although the priming effects are generally larger and more stable in the auditory-auditory task. In two-way analyses conducted on participant and item data, with the two-level factor Prime Type and the four-level factor Condition, there were significant main effects of Condition [Min $F(3,157) = 3.27, P < .05$] and of Prime Type [Min $F(1,127) = 46.98, P < .001$], and an interaction

⁷ VMASTR was kindly made available to us by Ken and Jonathan Forster of the University of Arizona, Tucson.

TABLE 2
Mean Lexical Decision Times and Error Rates in Experiment 1

Condition	Test	Control	Difference
1 [+ m, + s, + p] (friendly/friend)	725 (0.4)	813 (1.3)	88**
2 [+ m, + s, - p] (elusive/elude)	770 (0.9)	849 (3.1)	79**
3 [+ m, + s, - p] (sanity/sane)	760 (1.8)	847 (4.9)	87**
4 [- m, - s, + p] (tinsel/tin)	819 (6.9)	840 (7.6)	21

Note: Error rates in parentheses; m, morphological; s, semantic; p, phonological.

** $P < .05$ in both subject and item tests.

between them [$\text{Min } F(3,175) = 3.05, P < .05$]. This interaction reflects the finding that there was strongly significant priming in all three [+Morph] conditions,⁸ but greatly reduced and nonsignificant priming in Condition 4 [$F_1(1,29) = 2.76, P < .1; F_2(1,27) = 1.455, P < .1; \text{Min } F < 1$]. The analysis of errors revealed no significant overall effects or differences between conditions.

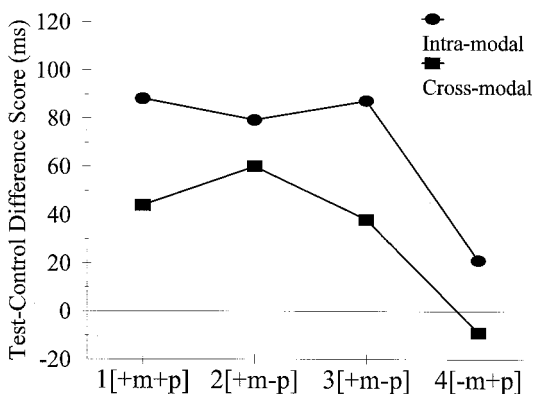


FIG. 4. Priming effects in intra-modal (auditory-auditory) and cross-modal (auditory-visual) tasks, as a function of morphological and phonological relatedness between prime and target (see Table 1). Conditions 1-3 are morphologically related (+m) but vary in phonological relatedness ($\pm p$); Condition 4 is phonologically but not morphologically related ($-m+p$).

⁸Separate analyses for each [+Morph] condition gave the following outcomes. For Condition 1 [$\text{Min } F(1,50) = 19.41, P < .001$; for Condition 2 [$\text{Min } F(1,48) = 19.76, P < .001$; for Condition 3 [$\text{Min } F(1,52) = 30.84, P < .001$].

The importance of these results is that they show that variation in phonological similarity between primes and targets plays essentially the same role in an auditory-auditory priming task as it does in the cross-modal situation. When primes and targets are morphologically (and semantically) related, they prime equally well across the three [+Morph] conditions, despite considerable variations in phonological transparency. In contrast, when primes and targets are phonologically but not morphologically related, there is no significant priming.

This outcome is consistent with a strong form of the single direct access model, where allomorphic surface forms project directly onto an abstract underlying representation, and where repetition priming is most effective when it reflects repeated activation of the same lexical component—in this case, the underlying morpheme shared by prime and target. It is also consistent with a multiple direct access view, so long as priming is again assumed to reflect the state of the common underlying element to which both the base form and the allomorphic form connect (see Fig. 2).

It is clearly inconsistent, however, with mediated access models such as the AAM, in which access and priming are assumed to reflect processes at the level of a modality specific input lexicon. Caramazza et al. (1988) specifically predict, for example, that allomorphic forms like *cors-ero* (“they ran”) should not prime words like *corr-eranno* (“they will run”) because the representations in the input lexicon of the regular and the allomorphic stems (*corr-* and *cors-*) are assumed to be wholly independent. This is a prediction that we have not confirmed for Italian prime-target pairs (Orsolini & Marslen-Wilson, 1994, 1997), and which now seems to fail for English as well.

The only way the AAM could predict the current results is if repetition priming was assumed to be mediated at higher levels of the system. The AAM includes a semantic level into which the modality-specific input lexicon feeds, and it must be possible for repetition priming to be mediated at this level—if only to explain earlier research showing priming between cross-modally presented primes and targets. These results demonstrate that there is a primable level of lexical representation at which inputs from the two modalities converge. On the further assumption that semantically transparent derived forms and their stems share overlapping representations at this level of the system, then repeated activation of these representations could be responsible for priming both cross-modally and intra-modally.

The predictions of the MRM (Baayen et al., 1997; Schreuder & Baayen, 1995) are less straightforward, partly because the model has not made such strong claims for the locus of repetition-priming effects, and partly because of the complexities introduced by the interactive activation architecture of the model, allowing feedback between levels. Nonetheless, we believe that

the MRM, like the AAM, can only fully account for the results of Experiment 1 by assuming that repetition priming is mediated at the syntactic and semantic representation level of the model.

To see this, consider the model as laid out in Fig. 3. When the nonallomorphic complex form is heard (*sanely* in Fig. 3), this will activate the access representations of *sanely*, *sane*, and *-ly*, and their associated lemmas and overlapping syntactic and semantic representations. The activation feedback mechanism in this model will allow activation to then flow back from the semantic and syntactic levels to the lemma and access representations that became active in the recognition process. This combination of bottom-up and top-down activation can explain faster responses to *sane* as a subsequent priming target. When the allomorphic form *sanity* is heard, this will activate the access representations and lemmas for *sanity* and *-ity*, and their corresponding syntactic and semantic representations. These will overlap to a considerable extent with the representation of *sane*, generating top-down feedback that should activate lemma and access representations for *sane*, and therefore also allowing for priming of *sane* as a target word.

There are two reasons, however, for expecting priming to be significantly reduced here. The first is that there is no direct bottom-up activation of *sane* by the prime word, in contrast to the *sanely/sane* case. At the short time delays involved in immediate repetition priming, we would expect this to increase residual activation of the target word, at both access and lemma levels, relative to the *sanity/sane* case. The second is that the MRM assumes that the amount of feedback to the access representations is proportional to the activation levels of the access representations involved. The less they are activated initially, the less they receive positive feedback.⁹ This predicts that access and lemma representations of *sane* should receive less feedback when *sanity* is heard, as *sanity* should not activate *sane* strongly in the first place.

This means that, whatever the source of activation of a target stem in cases where the prime is allomorphic, the stem should be less activated than when the prime is nonallomorphic, and therefore priming should be reduced. This holds true whether we assume repetition priming is mediated at access or lemma representations levels of the system. But what we find is that priming is equally strong across all [+ Morph, + Sem] conditions, irrespective of phonological variation in the form of the stem. The only escape route for the model seems to be to assume that priming is mediated at the semantic and syntactic levels of the model. So long as

⁹ The purpose of this is to allow the system to learn to process opaque forms correctly, so that, for example, *depart* and *-ment* do not continue to be strongly activated when *department* is heard.

allomorphic and nonallomorphic primes are equivalent in semantic transparency, they will activate the representations of their shared stems to the same degree, and lead to equivalent amounts of priming when the stem is subsequently heard or seen.

This puts us in a position where the mediated access models become hard to distinguish from direct access models, but at the cost of weakening the mediated access models to the point where their modality-specific input lexicons and whole-word access representations seem to have few consequences for lexical access in the auditory domain. There is nothing about the pattern of priming so far which justifies the additional representational and processing apparatus associated with mediated rather than direct access.

In Experiment 2, we turn to a second set of phenomena, which not only give us a different perspective on the performance of direct and mediated access models but also allow us to distinguish single and multiple direct access models. We will also examine the possibility that the effects so far are not really morphological effects at all but reflect semantic priming between related words.

EXPERIMENT 2

A prominent feature of our earlier research using the cross-modal paradigm was the phenomenon of “suffix-suffix interference”. This was the finding that two suffixed forms transparently derived from the same stem, as in pairs like *excitable/excitement*, do not prime each other, even though they are strongly semantically related, and despite the facilitatory effects of sharing the same underlying stem (Marslen-Wilson et al., 1994). We explained this in terms of competitive interference between suffixes attached to the same stem. When a particular combination of stem and suffix is heard, as in {excite} + {ment}, this seems to inhibit temporarily the combination of this stem with any other derivational suffix. Thus, when a related suffixed form (such as *excitable*) immediately follows, processing and recognition of this form will be slowed.

In the current experiment, we propose to use the suffix-suffix interference effect as an index of the architectural properties of underlying representations. We argue that the effect is specifically due to competition between suffixes locally attached to the same underlying stem morpheme. On the single direct access model, this is true for allomorphic and nonallomorphic stems alike. As Fig. 1 indicates, both {-ly} and {-ity} attach to the underlying morpheme {sane}, despite the allomorphy in the phonetic expression of these forms. This predicts that we should find reduced priming for pairs like *sanely/sanity* just as we did for transparent pairs like *excitement/excitable*. As either *sanely* or *sanity* is heard, this will activate

the underlying morpheme {sane} and the derivational suffixes attached to it. The subsequent choice of one of these suffixes will inhibit later processing of other derived suffixed forms sharing the same stem, irrespective of their surface allomorphy.

The multiple direct access model does not make this prediction. The rationale for this model is to provide separate underlying base forms to explain allomorphy in morphological combination. Thus, as in Fig. 2, the suffixes {-ly} and {-ity} combine with different underlying stems (/seyn/ and /sæn/, respectively). Because these stems belong to separate cohorts, only one of them should be activated as either *sanely* or *sanity* is heard, so that there is no basis for competition between the suffixes attached to them, nor for subsequent inhibitory effects. In contrast, when phonologically transparent pairs are heard, as in *excitement/excitable*, the same situation holds as for the direct access model, and interference effects should be obtained.

Turning to mediated access models, the issue here, first, is whether they offer an account at all of suffix-suffix interference effects, and, second, whether this account explicitly implicates whole-word representations in the modality-specific access lexicon. Focusing on the MRM (Baayen et al., 1997; Schreuder & Baayen, 1995), this offers two potential explanations. The first of these, based on interference in the initial processing of the target word, predicts differences between allomorphic and nonallomorphic pairs.

Figure 5 gives the layout of an MRM-type model for a nonallomorphic pair like *madly/madness*. When the prime *madly* is heard, this will activate

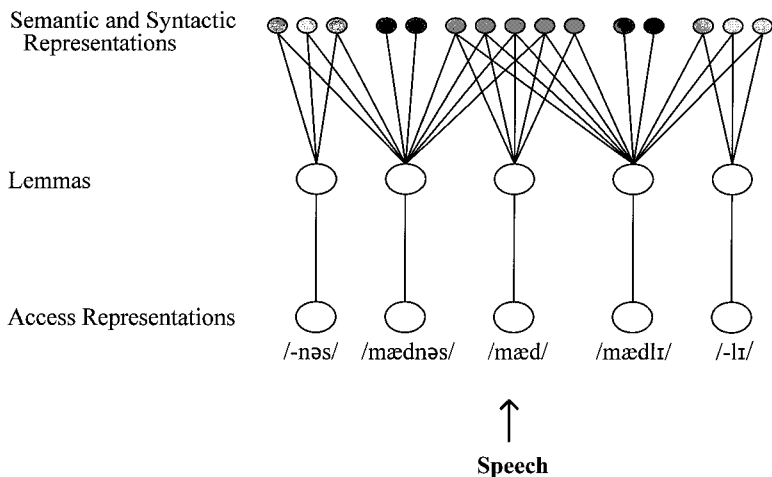


FIG. 5. Mediated access from speech (the Morphological Race Model): Access routes for two nonallomorphic forms (*madly*, *madness*).

the access and lemma representations for both complex forms, though a combination of bottom-up and top-down effects, but with the activation level of *madly*, the form actually heard, remaining higher than that of other related forms. This should generate cohort-based interference when the target *madness* is then heard, counteracting any residual facilitation of the same form. If there were any lateral inhibition in the model, acting between competing items at each level, this would strengthen any such effects. In contrast, when an allomorphic pair such as *sanity/sanely* is heard, this interference should be greatly reduced (see Fig. 3). Even if the prime word *sanity* remains highly activated, this is unlikely to interfere significantly with the processing of the target *sanely*, because the cohorts involved will separate as soon as the first vowel is heard.

This account depends on the existence of whole-word access representations, and competition between them as the target word is processed. The alternative account offered by the MRM (Schreuder & Baayen, 1995) depends on interference effects at the semantic and syntactic levels.¹⁰ In the full MRM model, the syntactic category of each stem is reset when it combines with certain affixes (e.g. the syntactic categorisation of *mad* as an adjective is inhibited when it combines with the suffix *-ness* to form the abstract noun *madness*). When *madly* is then encountered, the affix *-ly* is looking for an adjective to combine with to form an adverb. Because the subcategorisation of *mad* as an adjective has just been cancelled, this slows down the combination process for *madly*, resulting in the interference effect. Equivalent processes should apply for allomorphic stems (such as the *sanely/sanity* pair illustrated in Fig. 3), bringing the predictions of a mediated access model into line with those of the single direct access model. But the cost, again, is that the extra machinery postulated by the mediated access model is playing no role in determining the behaviour of the system. It is only if we find a difference between allomorphic and nonallomorphic pairs that we can argue for mediated access in favour of direct access.

The final point that is addressed by the use of suffix-suffix pairs is the potential role of semantic factors in the explanation of priming between morphologically related derived forms and their stems. Pairs like *sanity/sane* and *happiness/happy*, as used in Conditions 1–3 of Experiment 1, are closely semantically related, whereas pairs like *tinsel/tin* or *planet/plan* are not. From these data alone, therefore, we cannot safely conclude that the effects are morphologically mediated, or that they reflect abstractness in phonological representation at the level of the lexical entry. Phonologically unrelated but semantically related pairs, like *idea/notion* or *cello/guitar*,

¹⁰ We thank Harald Baayen and Rob Schreuder for useful pointers to this prediction of the MRM (personal communication, 19 December, 1995).

have been shown to prime in previous cross-modal and auditory intra-modal experiments (Marslen-Wilson et al., 1994; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995), and it is possible that this is the basis of the contrasts here.

The relevance of the suffix-suffix pairs is that these are also highly semantically related. The finding in earlier cross-modal studies that suffix-suffix pairs did not prime, despite their semantic relatedness, was evidence that the priming effects could not simply be reduced to semantic factors. If we find a similar drop-off in priming here, for suffix-suffix pairs presented in the intra-modal auditory-auditory task, this will again be an argument against a purely semantic interpretation of the results.

To evaluate these sets of issues, we constructed the six contrasts listed in Table 3. These contain the crucial comparisons, in Conditions 3 and 4, between the nonallomorphic (e.g. *abruptly/abruptness*) and allomorphic (e.g. *sincerely/sincerity*) derived/derived pairs. These are labelled [+ Morph, + Sem, + Phon], and [+ Morph, + Sem, - Phon], respectively. The other four conditions provide the additional tests we need to be able to interpret the results for the two main conditions.

Condition 1 repeats the corresponding condition in Experiment 1, with transparently related [+ Morph, + Sem, + Phon] derived/stem pairs, such as *attractive/attract*, whereas Condition 2 presents similar stimuli but in reversed, stem/derived order, as in *calm/calmness*. This is to check that priming does occur for derived targets, as long as they are primed by their stems and not by other derived forms sharing the same stem. Conditions 5 and 6 estimate the possible effects of phonological overlap *per se*, for two types of prime-target relation. Condition 5 examines priming effects for semantically unrelated derived/derived pairs, such as *treatment/treaty*, and Condition 6 tests derived/stem pairs, such as *apartment/apart*. To ensure parallelism between these stimuli and those in Conditions 1–4, these are also morphologically related pairs, being historically derived from the

TABLE 3
Properties of Stimuli in Experiment 2

<i>Condition</i>	<i>Type</i>	<i>Prime</i>	<i>Target</i>	<i>Rel</i>
1 [+ m, + s, + p]	derived-stem	<i>bravely</i>	<i>brave</i>	7.5
2 [+ m, + s, + p]	stem-derived	<i>calm</i>	<i>calmness</i>	7.6
3 [+ m, + s, + p]	derived-derived	<i>madly</i>	<i>madness</i>	7.4
4 [+ m, + s, - p]	derived-derived	<i>decisive</i>	<i>decision</i>	7.4
5 [+ m, - s, + p]	derived-derived	<i>witty</i>	<i>witness</i>	2.1
6 [+ m, - s, + p]	derived-stem	<i>apartment</i>	<i>apart</i>	2.2

Rel, semantic relatedness; m, morphological; s, semantic; p, phonological.

same stems. This type of [+ Morph, – Sem, + Phon] materials did not show priming in the earlier cross-modal research (Marslen-Wilson et al., 1994), which we interpreted as evidence that semantically opaque complex forms are not stored in morphologically decomposed form. On this basis, there is no reason for a [+ Morph, – Sem] pair like *apartment/apart* to behave any differently from a [– Morph, – Sem] pair like *tinsel/tin*, where prime and target have no historical morphological relationship. The methodological advantage, however, of using the historically related pairs is that it ensures that the phonological relationship between prime and target is closely matched to the [+ Morph] test pairs in conditions 1–4.

Method

Materials. There were 24 prime-target pairs in each of the six conditions outlined in Table 3, giving a total of 144 test pairs. The choice of stimuli was based on previously established criteria for morphological and phonological relatedness, as defined in Marslen-Wilson et al. (1994), and as used in Experiment 1. For derived-derived pairs, both members of the pair were required to have a recognisable affix, and when this was removed, the resulting stems were required to be etymologically identical in their mode of entry into the language. The test-pairs in each condition were selected from a larger group of potential stimuli on the basis of a semantic relatedness pre-test, where participants were asked to judge the relatedness of pairs of words on a 9-point scale, ranging from *very unrelated* (1) to *very related* (9).

Condition 1 used the same stimuli as Condition 1 in Experiment 1, presented in the same derived/stem order. Condition 2 used a new set of stimuli, also of high semantic relatedness, with primes and targets presented in the reversed, stem/derived order. In both conditions, the relationship between prime and target was phonologically transparent, with no allomorphy in the form of the stems. In the derived/derived Conditions 3 and 4, both primes and targets were suffixed forms derivationally related to the same stem, pre-tested in three ways for semantic relatedness. Three tests were necessary because we had to consider three different relations—the semantic transparency of the relationship between each derived form and its stem (testing *madly/mad* and *madness/mad* separately), and the transparency of the relationship between the two complex forms themselves (i.e. testing *madly/madness*). All pairs used were judged to be highly related in all three tests. Mean relatedness between the derived forms and their stems was 7.6 in Condition 3 and 7.8 in Condition 4, and mean relatedness between the complex forms themselves was, respectively, 6.9 and 6.7 in the two conditions. We give the overall average of the three tests in Table 3.

These two conditions varied in their phonological properties. In Condition 3 the relationship between prime and target was phonologically transparent, as in *madly/madness*. In Condition 4, the stems exhibited allomorphy, as in pairs like *vainly/vanity*. The phonological alternations were similar to those in Condition 3 in Experiment 1, and always involved changes in the vowel of the stem, sometimes accompanied by consonant changes, as in *precision/precisely*.

The word pairs in Conditions 5 and 6 were also morphologically related, being historically derived from the same stems, but they were no longer semantically related. In Condition 5 we used derived/derived pairs, as in *witty-witness*, and in Condition 6 we used derived stem pairs, as in *university/universe*. In all cases the relationship between prime and target was phonologically transparent.

Each prime/target set was paired with a control prime matched for number of syllables, word frequency, and morphological status. If the test primes were derived forms, the matched control primes were also complex forms; and if the test primes were stems, the control primes were also stems as well. None of the control primes were morphologically, semantically, or phonologically related to their targets.

Fillers: Three types of filler pairs were selected, along the lines described for Experiment 1.

1. For 18 filler word/nonword pairs, the primes were pseudo-suffixed words with the target being the pseudo-stem (as in *calendar/calend*). For a further 18 word/nonword pairs, the primes were real suffixed words with targets derived from these by the construction of allomorphic pseudo-stems, to which real suffixes were added (as in pairs like *destroy/distrish*). In a third group of 36 word/nonword pairs, the primes were again real suffixed words, with targets derived from these primes by adding real suffixes to pseudo-stems constructed by deleting or changing final consonants in the real stems (as in *blankly/blanism*). The effect of these 72 fillers was to ensure that phonetic overlap between prime and target could not by itself be a reliable cue to wordhood.
2. Seventy fillers consisted of morphologically and phonologically unrelated word/word pairs, to increase the percentage of unrelated word pairs in the stimulus sequence. Half of these pairs had suffixed primes and half had suffixed targets.
3. An additional 150 word/nonword pairs were constructed, to bring into approximate balance the overall number of word and nonword targets the listeners heard. These stimuli were mainly morphologically simple.

This gave a total of 214 word/word pairs and 222 word/nonword pairs. Morphologically related pairs made up 16.5% (72/436) of the stimuli heard in each version of the experiment. Fillers and test items were pseudo-randomly distributed through the list, with the same order of test and filler items in each version. Each version consisted of 476 pairs, consisting of 40 practise pairs, followed by the 436 pairs in the main test sequence.

Design and Procedure. These followed the same pattern as for Experiment 1, with materials recorded by a female native speaker of English, and played back with an ISI of 150 msec and 2500 msec between trials. The listeners' task was again to carry out a lexical decision response to the second word of each pair, responding as quickly and accurately as possible. Response times were measured, as before, from the onset of the target-word.

Participants. We tested 22 native speakers of British English, recruited from the subject pool of the Centre for Speech and Language, and paid for their services.

Results and Discussion

Four participants had to be discarded because of high error rates (above 15%) and slow, variable responses, leaving nine subjects in each test version. Two items were discarded from Condition 6, because of high error rates (above 45%). The mean reaction times and error rates for the remaining data are given in Table 4.

An analysis of errors revealed no significant overall effects. Turning to the reaction-time data, the results are straightforward, and as predicted by the single direct access model. In two-way analyses conducted on the participant and item data, with the two-level factor Prime Type and the six-level factor Condition, we found significant main effects of Condition [$\text{Min } F(5,172) = 4.61, P < .001$] and of Prime Type [$\text{Min } F(1,81) = 7.19, P < .01$], and a marginally significant interaction between them [$F(1,85) = 2.43, P = .04$; $F(2,136) = 2.03, P = .08$; but $\text{Min } F(5,216) = 1.10, P < .20$]. This reflected the significant effects for Condition 1 [$\text{Min } F(1,39) = 6.84, P < .05$] and Condition 2 [$\text{Min } F(1,38) = 4.10, P < .05$], and the absence of any priming effects for Conditions 3–6, with $\text{Min } F' < 1$ throughout, and no significant effects in any individual item or participant analyses. Conditions 1 and 2 do not differ significantly from each other, but they do differ significantly from the other four conditions ($P < .005$).

This means that for the crucial [+Morph, +Sem] derived/derived conditions we obtain the suffix-suffix interference effect not only for the non-allophonic pairs in Condition 3, but also for the allophonic pairs in

TABLE 4
Mean Lexical Decision Times and Error Rates in Experiment 2

<i>Condition</i>	<i>Type</i>	<i>Test</i>	<i>Control</i>	<i>Difference</i>
1 [+ m, + s, + p] (bravely/brave)	derived-stem	762 (1.4)	816 (4.2)	54**
2 [+ m, + s, + p] (calm/calmness)	stem-derived	792 (3.2)	831 (3.2)	39**
3 [+ m, + s, + p] (madly/madness)	derived-derived	850 (0.5)	852 (2.8)	2
4 [+ m, + s, - p] (decisive/decision)	derived-derived	865 (1.4)	879 (1.9)	14
5 [+ m, - s, + p] (witty/witness)	derived-derived	855 (4.2)	855 (2.3)	0
6 [+ m, - s, + p] (apartment/apart)	derived-stem	773 (4.5)	791 (6.6)	18

Note: Error rates in parentheses; m, morphological; s, semantic; p, phonological.

** $P < .05$ in both subject and item tests.

Condition 4. In contrast, there is strong priming between comparable [+ Morph, + Sem] derived/stem and stem/derived pairs in Conditions 1 and 2. The [+ Morph, - Sem] phonological control pairs in Conditions 5 and 6 show no significant priming, consistent with the results in Experiment 1 and with the earlier cross-modal research.

We also looked in more detail at possible semantic relatedness effects. For Conditions 1–4, there were no significant correlations between amount of priming and semantic relatedness ($r = .12, P > .20$). Taking the derived/derived conditions by themselves, and splitting the items in Conditions 3 and 4 into higher and lower relatedness groups, the effects are if anything in the wrong direction. Average priming for the higher relatedness group was - 8 msec, and 11 msec for the lower relatedness group. This confirms the results in earlier experiments (Marslen-Wilson et al., 1994), showing that semantic transparency in the relationship between a morphologically complex prime and its target is a necessary but not sufficient condition to ensure priming.

GENERAL DISCUSSION

The purpose of this research was to find out how auditory inputs are mapped onto central representations in the mental lexicon, asking whether we could find support for a direct access model, where speech input is

projected directly onto these representations without the mediation of intervening access representations of surface phonetic form. We investigated these issues in two experiments using morphological priming techniques. Before discussing the implications for direct and mediated access models, we need to analyse the possible role of phonological and semantic factors in these experiments.

Phonological Priming

In our original experiments on morphology and lexical structure (Marslen-Wilson et al., 1994), we used cross-modal priming to avoid interference from low-level intra-modal effects, given Emmorey's (1989) finding of priming between pairs like *tango* and *cargo* in auditory-auditory repetition. As it turns out, using a similar task, we find no significant effects of phonological overlap between otherwise unrelated primes and targets. In Experiment 1, these were pairs like *tinsel/tin* or *walrus/wall*, where the target word was transparently contained within the prime. In Experiment 2, the phonological control conditions were constructed from historically [+Morph] pairs like *treatment/treaty* and *university/universe*, allowing the phonological similarities between primes and targets to exactly match those in the parallel test conditions.

The absence of significant phonological priming means that we cannot attribute the presence (or absence) of priming in other conditions simply to the phonological relationship between primes and targets. It also means that priming in this task does not reflect either the repeated use of shared pre-lexical speech analysis procedures or repeated access of pre-lexical modality-specific representations of the speech input. Nor, it appears, is simple match between speech input and lexical form sufficient to produce priming. The word *tin*, for example, is fully contained in the prime *tinsel*, as is the word *depart* in the prime *department*. On generally accepted views of sequential access as the speech input is heard (e.g. Marslen-Wilson & Welsh, 1978; McClelland & Elman, 1986), this should mean at least transient activation of the embedded word as the prime is heard. The fact that no significant priming is obtained suggests that the initial activation of these embedded forms becomes rapidly superseded by the interpretation consistent with the complete form—that *tin* is the first syllable of *tinsel*, and that *depart* is not the morpheme {depart} but part of the unrelated word *department*.¹¹

¹¹ It is also likely that prosodic cues will help the early separation of initial syllables that are words on their own from syllables embedded in longer words (Davis, Marslen-Wilson, & Gaskell, 1997).

It remains to be explained why our results diverge from Emmorey's (1989), and why we do not find priming effects of the type reported by Goldinger et al. (1992) and Slowiaczek and Hamburger (1992) for partially overlapping phonological primes. Where Emmorey (1989) is concerned, there are methodological differences which could have led to different outcomes. In particular, Emmorey (1989) does not seem to have included phonologically related nonword foils, such as *donkey/donk* or *blankly/blanism*. This may have made it easier for listeners to develop response strategies based on phonological similarities between prime and target.

Goldinger et al. (1992) and Slowiaczek and Hamburger (1992) report complex patterns of priming, varying according to task, length of ISI, and nature of the overlap between prime and target. Under the testing conditions most similar to our own, but using very different stimulus materials, Goldinger et al. (1992) found inhibitory priming between pairs like *bull/beer*, sharing initial segments only. This is similar to results reported by Radeau et al. (1995) for pairs of words sharing initial phonemes, although the effect was stronger in speech shadowing than in lexical decision. Slowiaczek and Hamburger (1992), in contrast, found facilitatory priming between stimulus pairs sharing initial segments (as in *smoke/still*), with inhibitory effects appearing as the amount of overlap increased to three segments (as in *stiff/still*). For identity priming (*still/still*), they found a nonsignificant trend towards facilitatory effects. A related pattern is reported by Radeau et al. (1989), with facilitatory effects emerging in identity priming conditions, and signs of inhibition for partially overlapping primes and targets.

Overall, it seems hard to find facilitatory effects between phonologically related primes and targets unless prime and target are also lexically related, or unless there is opportunity for bias effects to operate. It is likely, in fact, that the nonsignificant facilitatory trend we observed in Experiment 1 and in Condition 6 of Experiment 2 (the control conditions where the target was fully contained in the prime) did not reflect phonological priming at all, but rather residual lexical effects (cf. Radeau et al., 1995). This is consistent with the absence of even a trend towards facilitation in Condition 5 of Experiment 2, where pairs like *witty/witness* show no priming at all. The target item *witness* is only partially matched by the prime word *witty*, providing no basis for subsequent facilitatory effects. In contrast, for cases like *tinsel/tin*, the target word *tin* is fully matched by the prime *tinsel*, and this may lead to residual priming. More generally, these conclusions are consistent with the view that priming in this task, just as in the cross-modal version, is based primarily on repeated access to abstract morphemic or lexical representations, and that purely phonological effects play only a transient and minor role in determining the degree and direction of priming.

Semantic Priming

The second issue we have to consider is how far priming effects between morphologically related items can be explained in terms of the semantic relations between prime/target pairs. This is particularly a problem for research in English, because morphological decomposition in the English mental lexicon seems to depend on the semantic transparency of the complex form. We found in earlier research (Marslen-Wilson et al., 1994) that only semantically transparent forms (like *punishment* or *happiness*) are stored in decomposed form, sharing their stem with other complex forms (such as *punishable*, *happily*, etc.). We related this to decisions made during language acquisition, where a semantically opaque form, such as *department*, will not be stored in decomposed form ({depart} + {ment}) because this gives the wrong semantics. Instead, such [- Sem] forms are assumed to be stored as separate, single units. These semantic dependencies make it all the more important to show whether or not morphological effects in English are separable from semantic effects.¹²

Fortunately, an increasing amount of evidence along these lines is now accumulating. The first type of evidence is the demonstration that semantic relatedness between morphologically related prime/target pairs does not by itself guarantee priming. This is the case for the derived/derived suffixed pairs tested in Experiment 2, and for similar materials tested earlier in a cross-modal format (Marslen-Wilson et al., 1994). A comparable dissociation has been obtained for English inflectional morphology, where we find that pairs like *gave/give* or *built/build* with irregular past tense forms as primes and their stems as targets, fail to show reliable priming (Marslen-Wilson et al., 1993, 1995), whereas regular past tenses and their stems, as in *jumped/jump*, prime strongly. All these pairs are strongly semantically related, and should prime equally well on a semantic interpretation of morphological priming.

A second type of evidence is that semantic and morphological priming have markedly different time-courses, with semantic priming being more short-lived (e.g. Henderson, Wallis, & Knight, 1984). We have recently confirmed this in auditory-auditory delayed repetition priming experiments (Marslen-Wilson, Ford, & Zhou, 1997; Marslen-Wilson, Zhou, & Ford, 1996b). At short delays (one intervening item), priming is equally strong for morphologically related (*excitement/excite*) and semantically related items (*cello/violin*), at 39 and 31 msec, respectively. At longer delays (eight intervening items), morphological priming is undiminished

¹² For other languages, such as Hebrew, it has proved more straightforward to demonstrate the independence of morphological and semantic factors (e.g. Frost, Forster, & Deutsch, 1997).

(at 30 msec) but semantic priming has disappeared (at 1 msec). This clearly points to different representational substrates for the two types of priming.

A final type of evidence, which also complicates any purely semantic story, is our recent demonstration of reliable cross-modal priming between productive derivational affixes (Marslen-Wilson, Ford, Older, & Zhou, 1996a). Pairs like *darkness/toughness* and *devalue/defrost* show significant priming, on the order of 40 msec, although control pairs like *darkness/harness* or *devalue/devious* do not. Affixes like {-ness} and {de-} do not have clearly definable semantic identities. They are fundamentally morphological entities, functioning in productive linguistic processes of word formation, and it is hard to see how priming between them can be accounted for in anything other than morphological terms.

In addition to this accumulating evidence, a more general problem with a semantic account of priming for morphologically related items is that this leads to implausible claims about lexical organisation. A semantic account tries to assimilate priming between forms like *happiness* and *happy* to priming between any pair of semantically related but independently represented items (e.g., pairs like *idea* and *notion*). This requires not only that *happiness* and all its morphological relatives (*happily*, *unhappy*, *unhappily*, etc.) are separately represented from *happy* as individual word-forms, but also that each form has its own copy of the semantic and syntactic properties of the stem in question. The close relationship between these two semantic representations would then produce priming, in the same way as priming between otherwise unrelated pairs like *idea* and *notion*, or *rich* and *wealthy*. But this requires cumbersome and uneconomical assumptions about representation, it fails to capture the fact that some words are morphologically as well as semantically related, and it provides no account of the ways in which morphological and semantic priming differ in their properties. We believe it is much more straightforward to assume that pairs like *happiness* and *happy* show priming because they are both linked to the same underlying morpheme in the lexical entry—and indeed, that derived/derived pairs like *happiness* and *happily* fail to show priming for the same reason, because in their case the linkage to the same underlying morpheme generates competition as well as facilitation.

Direct and Mediated Access

Given the foregoing discussion, we will assume that the priming between morphologically related pairs in Experiments 1 and 2, is indeed morphological in nature, involving repeated access to morphemic elements shared by prime and target words. Throughout, the pattern of results has

followed the predictions of a single direct access model (see Fig. 1), where the speech input is projected directly onto morphemic representations at the level of the lexical entry, and where these representations are phonologically abstract in ways which make them appropriate targets for allomorphic versions of the same underlying stem. This accounts both for the maintenance of strong priming across variations in stem allomorphy in Experiment 1, and for the maintenance of suffix-suffix interference in Experiment 2 across both nonallomorphic and allomorphic pairs. We now have to consider how far the same results can be accommodated either by a different type of direct access model, or by some form of mediated access model.

The multiple direct access model seems to be ruled out by the results of Experiment 2. This is a model where stem allomorphy is captured underlyingly by separate representations of the base form and its variants—for example, /seyn/ and /sæn/ for the morpheme {sane}, as illustrated in Fig. 2. This arrangement can explain the results of Experiment 1, as both transparent and allomorphic forms will be able to project directly onto the lexical entry, via these separate representations. It does not predict, however, the presence of suffix-suffix interference effects for allomorphic (*sanely/sanity*) pairs in Experiment 2. We explain this effect in terms of competition between simultaneously activated suffixes attached to the same underlying stem. In the multiple direct access model, this competition should not arise for allomorphic pairs, as the suffixes involved are attached to different stems, and only one of these stems will be activated by the incoming speech. When the string [seyɪnɪ] is heard, this will project onto underlying /seyn/, to which the affix *-ly* attaches, but not onto underlying /sæn/, to which *-ity* attaches. There would be no reason, then, for any interference with the subsequent processing of *sanity*.

Turning to mediated access models, the results of the two experiments rule out any version of these models where allomorphic forms are separately represented in an auditory access lexicon, and where repetition priming is assumed to be mediated at this level of the system. Such models predict (Caramazza et al., 1988) that allomorphic variants of the same stem should not prime each other, and provide no basis for suffix-suffix interference effects, especially between allomorphic forms. We argued earlier that the MRM model (Baayen et al., 1995; Schreuder & Baayen, 1995), despite the presence of extensive feedback between levels, seemed unable to explain the results of Experiment 1 unless priming effects were allocated to deeper layers of the model, where syntactic and semantic representations are shared by related forms. The same seems to hold true for the suffix-suffix interference effects in Experiment 2, where again there is no evidence to implicate whole word representations in a modality-specific access lexicon.

As we noted earlier, the MRM appears to offer two possible ways of explaining suffix-suffix interference effects. Given the layout in Fig. 4, where there are separate access and lemma representations for non-allomorphic forms like *madly* and *madness*, it can explain interference effects in terms of cohort-based competition at the access and lemma levels. But this predicts reduced interference for allomorphic pairs, which are not cohort competitors to the same extent.

The alternative view, involving the resetting of stem syntactic categories, may be able to account for the results, but only at the cost of assuming an access process where whole word access and lemma representations, even for allomorphic forms, do not play an identifiable role in lexical access. This is the view where inhibitory links between incompatible syntactic category nodes lead to interference when two suffixed items with different syntactic categories follow each other. When the complex form *madness* is heard, the noun-forming affix *-ness* is assumed to inhibit the categorisation of *mad* as an adjective, slowing down the later combination of *mad* with *-ly*, which requires an adjective as its stem. Similarly for allomorphic pairs, where the processing of the prime *sanity* leads to inhibition of the adjectival category node for *sane* by the noun-forming affix *-ity*, slowing down subsequent processing of *sanely*.

This is a plausible enough account, where the interference effect is related to changes in the status of stems rather than to changes in the status of affixes, and it deserves further investigation. But the problem in the current context, both for a mediated access model and for morphological race models in general, is that it makes these models indistinguishable from a direct access model. Suffix-suffix interference effects are explained at the same level of the system in each case, and the underlying representation and processing of semantically transparent allomorphic and nonallomorphic forms is effectively the same as in the direct access model. The form *sanity* is processed as the combination of *sane* + *ity* in the same way that *madness* is processed as the combination of *mad* + *-ness*, without any recourse to whole-word access or lemma representations for either type of word. Indeed, if such representations were involved, then the MRM and its relatives could not predict the results of either experiment.

This means that we are justified in rejecting mediated access models of lexical access from the speech signal. The type of abstract access model we proposed in Marslen-Wilson et al. (1994), building on earlier proposals by Lahiri and Marslen-Wilson (1991), successfully predicted the results of both experiments, suggesting that the speech input is projected relatively directly onto highly abstract underlying representations. This is consistent with the view, long argued for (e.g. Marslen-Wilson, 1973), that the speech input is immediately and continuously interpreted as it is heard. It is also consistent with a highly combinatorial view of lexical access and speech

comprehension (Marslen-Wilson et al., 1996a), where the processing representation of morphologically complex words is computed, on the fly, as the word is heard.

It is also, however, compatible with the view that there are significant modality differences in lexical access. In our own work, using parallel materials to those described here in visual-visual priming tasks, we find suggestive evidence that lexical access from orthographic form may well involve intermediate access representations (Marslen-Wilson, et al., 1996b). This is compatible with the growing evidence from other work on visual word-recognition for at least some storage of regular inflected forms (e.g. Baayen et al., 1997). It is possible, in fact, that the entire debate about lexical access for morphologically complex words, and the role of whole-word as opposed to decomposed representations, has been clouded by a historical failure to keep separate, theoretically and experimentally, access from speech as opposed to access from text.

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