

Modality Effects in Immediate Recall of Verbal and Non-verbal Information

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Immediate serial recall performance was compared for sound-producing objects represented by (1) their spoken name, (2) their typical sound, (3) their written name or (4) their picture. Recency was largest for the spoken lists, intermediate for the sounds, and almost non-existent for print and pictures. Experiment 2 used a speech or auditory non-speech suffix to investigate the nature of the recency effects. A spoken suffix interfered with recency of spoken material, but not with that of non-speech sounds; an auditory non-speech suffix did not interfere with speech or with non-speech. Taken together, these two experiments highlight the special status of spoken input as well as that of auditory information.

INTRODUCTION

Questions regarding memory and representation often focus on matters of content and address such issues as *what* is remembered, *how* it is remembered or what is the format of memory representations. Questions on format thus point not so much to an abstract content than to a

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sensory modality of input like, for example, hearing or seeing. Critical issues include whether the sensory input modality is represented and what aspects of processing and memory it determines. The dependence of memory for abstract content on the sensory modality of presentation is probably a complex one, with interactions going in both directions. Crucial to the importance of format for memory is the modality effect. In immediate serial recall, substantial recency effects are found with auditory, but not with written, material. Originally, the advantage of auditory material was attributed to "pre-categorical acoustic storage" (PAS), which was supposed to retain auditory speech in a literal auditory-based code for a couple of seconds (Crowder & Morton, 1969). The advantage of auditory over visual material was called the "modality effect". In retrospect, the term has turned out to be somewhat misleading because further research has shown that it may not be the auditory modality *per se* which is superior, but rather whether the material is coded as speech or not. One critical finding was that lipread material was remembered the same way as speech. Substantial recency effects were found with lipread material (Campbell & Dodd, 1980; Spoehr & Corin, 1978). In the absence of any common sensory feature between audition and lipreading, the similarity in memory performance appears to derive from the fact that the two types of stimuli both convey speech rather than auditory information.

Strong and complementary evidence for the role of speech processing in obtaining recency has come from studies that examined the selective impact of different kinds of suffixes on recency. Adding a supposedly irrelevant item after the last item of a heard list (i.e. a stimulus suffix) had the effect of overruling the advantage of the last item. Originally, the suffix effect was seen as a strictly auditory phenomenon. However, it appeared that it was related more to speech processes, because lipread information could interfere with auditory recency (Spoehr & Corin, 1978). Studies comparing various input modalities for linguistic information added supporting convergent evidence to the notion long defended by Liberman that speech is special (for a history and overview of this position, see Liberman, 1995) and that speech is handled by dedicated processing resources, a view made popular by the notion of a speech module (Fodor, 1983).

Based on these lipreading studies, the focus of the explanation shifted from the input modality (auditory or non-auditory) to content (speech or non-speech). Yet the situation is considerably more complex than originally envisaged. The issue of the "what" versus the "how" of representations cannot be settled by arguments based on the fact that speech processing and its corresponding memory code is exclusively a matter of abstract, a-modal representations. De Gelder and Vroomen (1992, 1994)

identified a series of puzzling results. One persistent observation is that the recency advantage of lipread lists is smaller than that of auditory speech, notwithstanding the basic speech-related similarities between the two. If memory depended exclusively on an abstract code, this would be difficult to explain. It has been argued that the extra advantage of auditory recall over lipreading is an indication of an auditory code that is used together with an abstract speech code (Crowder, 1983; Penney, 1989). It would appear that the abstract representation view is not the last word. Data from suffix effects contrasting auditory and lipread suffixes suggest that in addition to the fact that the information is speech, what also matters is the input format, because an auditory speech suffix has a small effect on lipread lists when compared with heard lists, and a lipread suffix has little effect on auditory lists (de Gelder & Vroomen, 1992).

Another argument that challenges the speech-specific notion of recency effects arose out of studies that showed that auditory non-speech stimuli such as musical tones (Greene & Samuel, 1986) and naturalistic sounds (Rowe & Rowe, 1976) could lead to recency as well as to suffix effects. The explanation favoured by Greene and Samuel (1986) is that of a coding process that is not speech-specific, but one that is automatically applied to speech. This coding process may or may not be applied to non-speech depending on the context. However, one can question whether this argument should be taken as firm evidence against the notion of a speech-specific store. For instance, it may be that there are two separate stores, one for auditory non-speech and one for speech. These stores may be similar in their surface characteristics, but in terms of underlying processing mechanisms they may be completely separate and behavioural similarities may not license inferences about underlying shared processing mechanisms. Moreover, one should be cautious when treating recency and suffix effects of speech and non-speech sounds in the same way. In terms of absolute amount of recall, recency of the final serial position of speech is usually larger than that of non-speech sounds (cf. Greene & Samuel, 1986; Rowe & Rowe, 1976). If one wants to attribute recency of speech and non-speech sounds to a common source, one should account for this difference, but this has yet to be done. Second, Rowe and Rowe (1976) observed that a speech suffix interfered with spoken lists more than with auditory non-speech lists. The reverse was the case for a non-speech suffix. Unfortunately, Rowe and Rowe did not include a non-suffix control condition, but their results certainly suggest that speech and non-speech are coded differently. Finally, auditory speech and non-speech stimuli not only differ in whether they are speech or not, but also in the way in which memory processes operate on them. In a model such as Baddeley's

(1990), speech input has an advantage because it automatically enters the phonological store, whereas non-speech input requires phonological recoding. This advantage is unrelated to the presentation format *per se*, but it is relevant to a model like Baddeley's, although as noted recently by Crowder (1993), issues of perception, coding and immediate memory are notoriously difficult to disentangle.

To summarise, the issue of the recency advantage of spoken lists is a complex one, because it involves auditory format (which speech shares with all auditory input) as well as linguistic content (which speech shares with lipread input, but not with pictures and sounds). Furthermore, in a comparison of speech and non-speech, one must bear in mind the impact of automatic activation of a phonological code, as is the case in speech, versus elaborative phonological recoding which takes time and resources when the input is non-speech. The experiments presented here were set up so that different facets of the contrast could be explored jointly. The four presentation formats compared here took into account the similarities as well as the differences between speech and non-speech input. Speech input is similar to environmental sounds in the sense that they are acoustic, whereas written input and pictures are both visual. On the other hand, speech as well as written input concern verbal information. Sounds and pictures, if they are able to be remembered in a verbal format, require phonological recoding which, unlike written input, may be less automatic and more time-consuming.

Given this focus on the format of memory representations, we were concerned to exclude the input of content and semantic variability in the material. The choice of the same objects represented in different formats offers the best possible guarantee for bias-free comparisons of the impact of different modalities. Experiment 1 compared serial recall of speech and non-speech sounds with written words and pictures. Speech stimuli should have larger recency effects than visually presented items (i.e. the modality effect) and non-speech sounds may have larger recency effects than visually presented items.

EXPERIMENT 1

Experiment 1 compared serial recall of items that were either spoken, written or represented by environmental sounds or pictures. To allow for a proper comparison, the objects in these four modalities were the same in all conditions, thus effectively excluding differences in familiarity or other differences stemming from semantic content, frequency of occurrence, and so on.

Methods

Subjects. Altogether, 193 students participated in the experiment so as to fulfil course requirements.

Stimuli. The memory list consisted of eight items that were presented in quasi-random order. The items were presented in four different formats: (1) their spoken name, (2) their typical sound, (3) their written name or (4) their picture (line drawing). The same Dutch items were used in all four formats: *auto* (car), *eend* (duck), *trein* (train), *hond* (dog), *applaus* (applause), *stappen* (steps), *politie* (police) and *bel* (bell). For the spoken presentation, the items were spoken in isolation by a male speaker of Dutch. The items were then digitized with a sound editor and played back on digital audiotape. The environmental sounds were taken from a commercially available recording containing sounds especially made for sound studios. As for the spoken items, the sounds were digitized and recorded on digital audiotape. For the written condition, items were presented in print (white background and black lettering) on a computer monitor. The pictures were drawn by a semi-professional artist. They were scanned and, like the written words, presented on the monitor. All items were presented at a rate of one every 1.5 sec. The four presentation formats were thus equated for total presentation time.

Design and Procedure. Each item appeared in each list. Across lists within each condition, each item appeared twice in each serial position. There were thus 16 experimental trials for each presentation format. The format of the lists was blocked, and the order of the blocks was completely counterbalanced across subjects. Before testing began, the subjects were familiarised with the sounds and the pictures of the items. There were 12 practice trials, 3 for each condition. One warm-up trial preceded the experimental blocks. The subjects were tested in groups of 10–12. The auditory items were presented over two loudspeakers for the whole group; the visual items were presented to each subject via their own computer screen.

Each trial began with a warning signal. After presentation of each memory list, the subjects were asked to write down the list in the order shown on a prepared sheet. They were given 15 sec for this and were required to work from left to right. They were encouraged to guess if they were unsure, but they were allowed to leave blank spaces.

Results

An item was scored as correct only when reported in the correct serial position. The serial position curves for the four presentation formats are

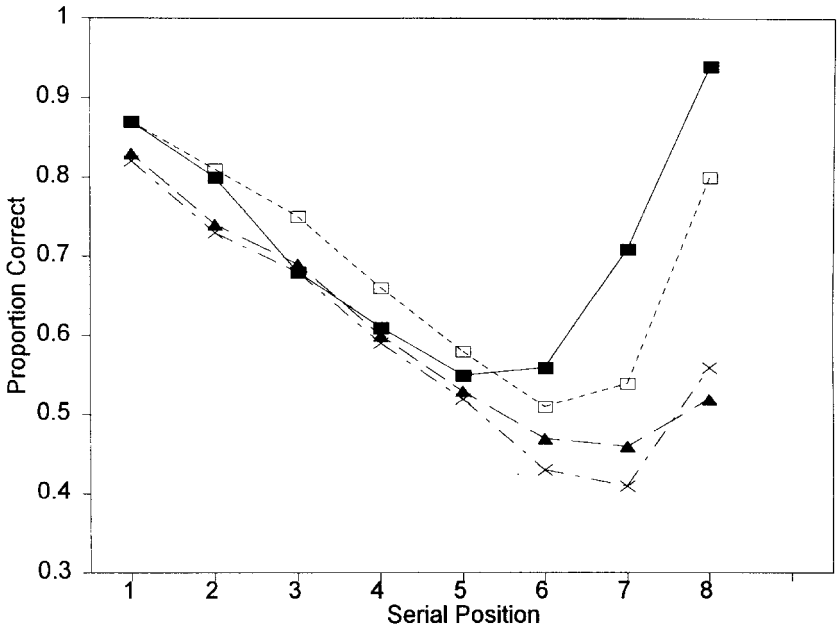


FIG. 1. Serial position curves for the four presentation formats in Experiment 1. ■, Spoken material; □, non-speech sound; ▲, written material; ×, line drawing.

shown in Fig. 1. As can be seen, recency effects were largest for spoken material, intermediate for sounds, and almost absent for printed words and pictures.

An analysis of variance (ANOVA) was performed on the proportion of correct responses, with serial position and presentation format as within-subjects variables. There were main effects of format of the list [$F(3,576) = 63.40$, $MSe = 904.6$, $P < 0.001$] and serial position [$F(7,1344) = 297.01$, $MSe = 413.7$, $P < 0.001$]. The interaction between format of the list and serial position was also significant [$F(21,4032) = 64.61$, $MSe = 151.3$, $P < 0.001$]. The percentage of correct responses on the final serial position was taken as a measure of the theoretically important recency effect. An ANOVA on the recency scores with format of the list as a within-subjects factor was highly significant [$F(3,576) = 297.7$, $MSe = 262.0$, $P < 0.001$]. Planned comparisons indicated that the recency effect of spoken material was larger than that of sounds, written material and drawings; recency of sounds was larger than that of written words and pictures (all $P < 0.001$); and there was no difference in recency between the written material and pictures.

Discussion

Experiment 1 provides a clear picture of the effect of presentation format on recall. Recency of spoken lists was largest, recency of non-speech sounds was intermediate, and there were no significant recency effects for visually presented lists (written words or pictures). Pre-recency recall appears entirely insensitive to the modality used.

The most striking finding in Experiment 1 is that the recency effect for environmental sounds was intermediate between that of speech and that of visually presented material. Sounds share with spoken lists the auditory aspect, but, unlike speech, the phonological code is not part of the presentation format. The fact that environmental sounds occupy this intermediate position appears to favour those views that seek an auditory explanation of recency or a combination of the auditory format and a linguistic content code. Various featural accounts (e.g. Broadbent & Broadbent, 1981; Campbell, Garwood, & Rosen, 1988; Nairne, 1988, 1990) appear at first sight to be able to handle this difference. Featural accounts of recency effects propose that the representation of a memory item consists of a bundle of features. The exact composition of this bundle of features varies as a function of the content of the items as well as the presentation modality. Besides a generic advantage for auditorily presented material (speech and non-speech sounds alike), there appears to be a speech-specific advantage for spoken material.

Based on the above, spoken words would appear to have two sets of features, one set related to the auditory format and another related to a speech-based code. Environmental sounds only have the auditory features and lack the features resulting from speech coding; visual material, like written words or drawings, are neither encoded in an auditory format nor in a speech-like code. The distinction between an auditory and a speech-like code may account for the classical modality effect (speech versus written presentation), in the sense that spoken, but not written, material has the additional advantage of an auditory and speech-like code during list recall. It also explains why sounds have an advantage over written material and drawings because sounds are maintained in an auditory code. Finally, spoken lists have larger recency effects than sounds because spoken lists are represented in an auditory as well as a speech code, whereas non-speech sounds rely on an auditory code.

There is, however, another way of explaining the differences between speech and non-speech. It could also be argued that speech is exclusively encoded in a speech-like code, whereas non-speech is exclusively encoded in a separate auditory code. In this case, there is no need to appeal to a general auditory code which is shared by both speech and non-speech material. The recency advantage of speech over auditory non-speech

could derive from the specific linguistic format of immediate memory, or it could be related to more detailed and fine-grained coding and maximum item discriminability. If this is the case, and if indeed no correspondences exist between speech and non-speech coding, then speech suffixes should not interfere with non-speech sounds and vice versa. Such an absence of crossover effects was observed by Rowe and Rowe (1976). They found that a speech suffix interfered with recency more than a non-speech suffix in spoken lists, while the reverse was the case for non-speech sounds. However, Rowe and Rowe did not include a no-suffix control condition, thus it is not clear whether a spoken suffix had any effect at all on non-speech sounds and vice versa. To clarify the issue of the codes underlying recency effects, we conducted another experiment in which speech and non-speech lists were followed by no suffix, a speech suffix or a non-speech suffix. If there is no interference by a spoken suffix on non-speech lists and vice versa, this would provide evidence of separate processing mechanisms of auditory speech and non-speech.

EXPERIMENT 2

Experiment 2 examined suffix effects by comparing recall of spoken words and of sounds that were or were not followed by a suffix. The suffix was either the spoken word "stop" or a "buzz" sound. If there is a general auditory code in which speech and non-speech sounds are encoded, speech and non-speech suffixes might have an effect on speech and non-speech lists. No such crossover suffix effects should emerge if speech is represented solely in a speech-like code and non-speech solely in an auditory non-speech code.

Methods

Subjects. Eighteen subjects were tested and paid a small sum for their participation. None had participated in Experiment 1.

Stimuli. The same items were used as in Experiment 1. The lists consisted of spoken words or sounds. Each list was followed by (1) no suffix, (2) the spoken word "stop", or (3) a "buzz" sound. Thus there were six different conditions. The suffix was presented in rhythm with item presentation. All other stimulus attributes were as in Experiment 1.

Design and Procedure. Across lists within each condition, each item appeared only once in each serial position. There were thus eight experimental trials for each condition. The presentation format of the lists

(spoken or sound) was blocked, and the suffix condition appeared randomly within each block. The order of the blocks was counterbalanced across subjects. Before testing began, the subjects were acquainted with the sounds of the items and suffixes. Six practice trials were allowed. A warm-up trial preceded the experimental blocks.

The subjects were tested individually. Their instructions were the same as in Experiment 1, except that they were told to ignore the suffix that followed at the end of the list.

Results

The serial position curves for the two presentation formats and the three suffix conditions are presented in Fig. 2 (spoken lists) and Fig. 3 (sounds). As in Experiment 1, recency of the spoken words was greater than that of sounds. The "stop" suffix interfered with recency of spoken material but not with recency of sounds; the "buzz" suffix had no effect at all.

An ANOVA was performed on the proportion of correct responses with presentation format of the list, suffix and serial position as within-subjects variables. There was a main effect of serial position

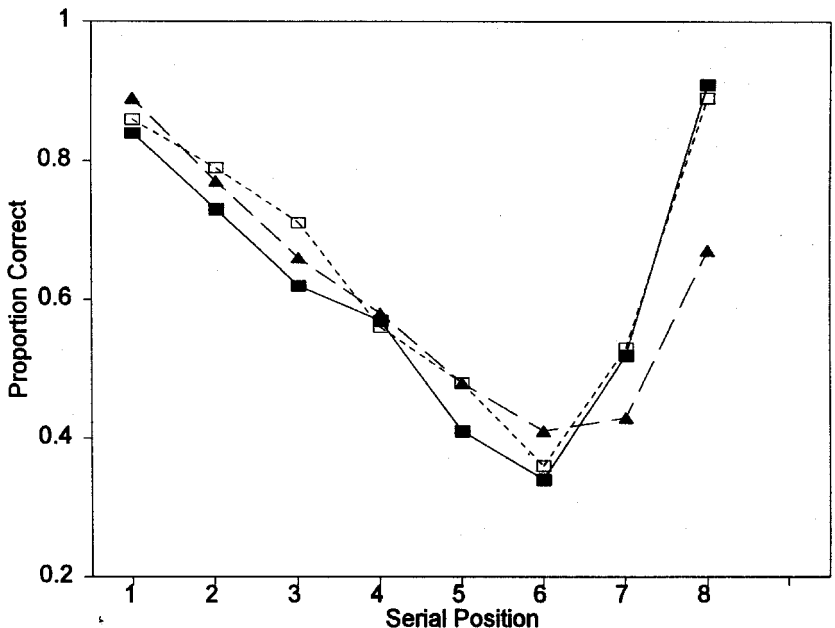


FIG. 2. Serial position curves for spoken lists in Experiment 2. ■, No suffix; □, "buzz" sound; ▲, spoken "stop".

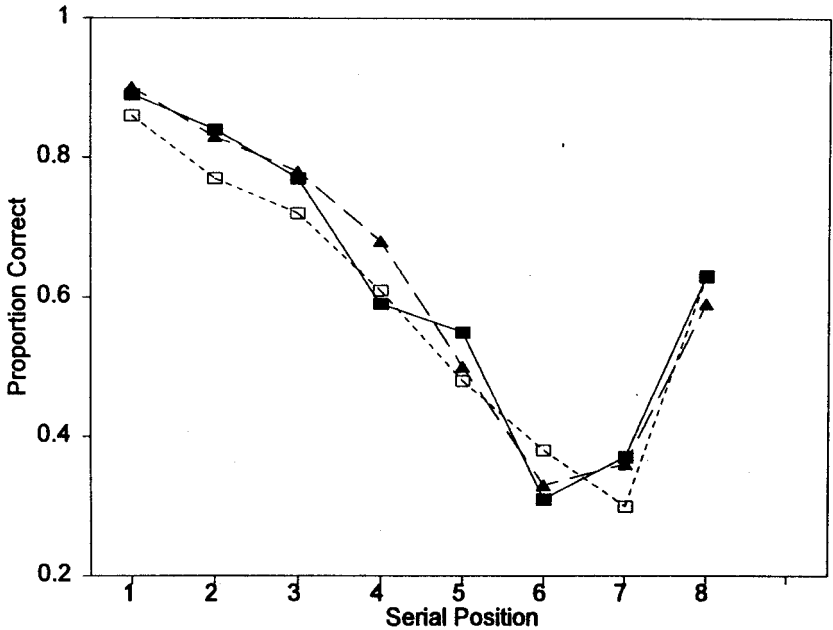


FIG. 3. Serial position curves for non-speech sounds in Experiment 2. ■, No suffix; □, "buzz" sound; ▲, spoken "stop".

[$F(7,119) = 44.67$, $MSe = 0.08$, $P < 0.001$] and there were significant interactions between format of the list and serial position [$F(7,119) = 11.5$, $MSe = 0.03$, $P < 0.001$] and between suffix and serial position [$F(14,238) = 2.59$, $P < 0.002$]. The second-order interaction between presentation format of the list, suffix and serial position was also significant [$F(14,238) = 2.17$, $P < 0.01$]. The ANOVA on the recency effect, as defined in Experiment 1, indicated that spoken lists had larger recency effects than sounds [$F(1,17) = 24.6$, $MSe = 0.05$, $P < 0.001$]. The overall effect of a suffix on the recency effect was significant [$F(2,34) = 14.27$, $MSe = 0.02$, $P < 0.001$], as was the interaction between presentation format of the list and suffix [$F(2,34) = 8.16$, $MSe = 0.01$, $P < 0.001$]. Separate ANOVAs on the recency effects of spoken lists and sounds indicated that the suffix effect was significant for spoken lists [$F(2,34) = 37.62$, $MSe = 0.01$, $P < 0.001$] but not for sounds ($F < 1$). Planned comparisons on recency effects of the spoken lists indicated that the "stop" condition had a smaller recency effect than the buzz or no-suffix condition (all $P < 0.001$), whereas the buzz and no-suffix condition did not differ. Planned comparisons on recency effects of the sound lists showed that there were no significant differences.

Discussion

The main aim of Experiment 2 was to examine whether speech and non-speech suffixes have a crossover interference effect. Such an effect would suggest that there is some commonality in the representation of auditory speech and non-speech. However, no such effect was observed. A speech suffix had a large impact on recency of spoken lists, but the same suffix had no effect on non-speech sounds. This was surprising, since the spoken word "stop" clearly has an auditory component. If this auditory speech component were shared with non-speech sounds, one would have expected an interference effect of "stop".

One might argue, as one of the reviewers of this paper did, that the sound frequencies of the "stop" suffix were too different from the non-speech items. This might have prevented a crossover interference effect. At the heart of this suggestion is the idea that there is a similar frequency-coded acoustic representation for both speech and non-speech, and that other tokens of "stop", which are more similar in terms of frequency to the non-speech items, may well have produced a crossover suffix effect. From an acoustic point of view, both the speech and non-speech suffixes covered a wide range of audible frequencies, so there is no reason to expect such a difference. Of course, one cannot rule out completely that there were more complex time-varying differences between the buzz sound and spoken "stop" that were relevant. However, what constitutes the acoustic basis of speech is still poorly understood. For example, the acoustics of sine-wave speech (Remez, Rubin, Pisoni, & Carrell, 1981) are very different from regular speech, yet the sounds are perceived as speech. Unfortunately, we are not in a position to decide whether frequency differences *per se* account for the present results. However, there is evidence from previous studies to support this. The frequency account bears some resemblance to a proposal made by Crowder in 1983. At that time, Crowder conjectured that the recency effect in serial recall is based on a frequency-coded auditory representation. Since data on lipreading have become available, Crowder and others have rejected the frequency-based account (e.g. Crowder & Surprenant, 1995). One of the most convincing arguments against the frequency-based account is that a lipread suffix (with no sound whatsoever) affects recall of spoken lists (de Gelder & Vroomen, 1992), whereas a non-speech sound (with acoustics) does not affect recall of spoken lists (Experiment 2). It is therefore unlikely that similarity, defined in acoustic terms such as frequency, is at the basis of our results.

Instead, we would argue that our findings indicate that there is *no* commonality in the representation of auditory speech and non-speech materials. This implies that the physical/acoustic aspects that speech and

non-speech have in common are coded in separate representations. We must therefore consider whether the recency effect of auditory non-speech has a basis different from that of speech. The similar behaviours of auditory speech and non-speech lists may thus have a different origin and require another explanation. The “buzz” suffix is somewhat more difficult to interpret because it had neither an effect on speech nor on non-speech sounds. The “buzz” suffix was thus not potent. However, as shown by Rowe and Rowe (1976), a non-speech suffix interferes more with non-speech sounds than with speech. Taken together, these results suggest that the recency effect of speech is based on a speech-based code and recency of non-speech sounds is based on an auditory code.

GENERAL DISCUSSION

Two experiments were undertaken to examine the impact of modality on serial recall and to clarify the importance of an auditory versus a speech-based code in memory. With this in mind, spoken presentation was contrasted with written presentation, but also with sound lists sharing the auditory but not the speech component. Picture lists completed the comparison because they neither had an auditory nor a speech-based format. Experiment 1 showed a clear spoken-word advantage combined with a relative advantage of sounds over the two visual presentations. Experiment 2 showed that the similarity in recency between spoken words and environmental sounds has its own specific basis rather than being based on a common auditory component.

The observed modality-specific suffix effects are difficult to combine with a dual-coding approach to speech information. If there is an auditory code in addition to the speech code, then the “stop” suffix should have had an effect on the non-speech list and the “buzz” suffix an effect on the speech list. However, our results are more in line with the notion that the content or domain of the input, rather than the sensory format, determines recency. The present results, like those of other studies (Crowder & Surprenant, 1995; de Gelder & Vroomen, 1992, 1994, 1995; Morton, Marcus, & Ottley, 1981), support the notion that speech is special. These results underscore the importance of a level of modular processing as opposed to modalities or sensory areas.

This view contrasts with traditional two-stage, serially ordered models, where the assumption is that auditory speech and non-speech signals are initially encoded by general auditory processing mechanisms, but that only sounds are then classified as speech and further processed by the speech processing mechanism. On a traditional account, there is first auditory processing in echoic memory and pre-categorical storage, which

is then followed by speech coding. The dual-coding view (auditory speech is coded once as sound and once as speech) maintains the principle of auditory as well as linguistic processing of speech. Presumably, no other processing is required for non-speech sounds. Indeed, the notion that there is serial coding does not fit the present findings well. If only speech and not non-speech sounds require more elaborate processing, one would expect a speech suffix to interfere with non-speech sounds, as the auditory component of the speech signal should overwrite the pre-categorical representation of non-speech sounds. This is clearly not the case. The motor theory of speech perception (Liberman & Mattingly, 1985) may help here. Motor theory adopts the notion that speech takes precedence over acoustics. This was introduced to explain why speech is heard as a phonetic event and not as an acoustic plus phonetic event, as in duplex perception. The proposal is that speech takes precedence over acoustics so that it pre-empts the acoustic processor. Therefore, only acoustic material that cannot be interpreted as speech is referred to acoustic encoding. Thus speech is encoded in a speech-like code and not in an auditory code, and non-speech sounds are encoded exclusively in an auditory code.

If suffix effects point to speech specificity and to a specialised speech processing structure, how can one then explain the further observation that environmental sounds still have recency in contrast with non-auditory presentations? One answer is that in the auditory non-speech case this is due to an echoic memory, whereas with spoken words it is due to the operation of a component of a special speech processor. An advantage of appealing to two different mechanisms to explain behaviours that appear similar is that it might accommodate the differences in performance between, for example, recency and suffix effects observed with piano notes (Greene & Samuel, 1986).

A number of authors have noted that recency effects are still poorly understood and that this might be related to the relative independence of recency effects from short-term memory processes (Baddeley & Hitch, 1993; Crowder, 1993). In line with this view, the present results suggest some comments and speculations. Specifically, recency for speech points to the existence of a specialised processor that is more a part of the speech processing architecture than a component of short-term memory *per se*. At the same time, the specific recency observed for auditory information may point to a mechanism that is part of auditory perception and which serves a specific function, for example orientation in time and space, as suggested by Baddeley and Hitch (1993). The similar behaviour of the two recency mechanisms would thus have a different basis, a view that has been obscured by the traditional notion of recency in relation to memory.

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