EXTENDING FORMANT TRANSITIONS MAY NOT IMPROVE APHASICS' PERCEPTION OF STOP CONSONANT PLACE OF ARTICULATION*

Karen Riedel+ and Michael Studdert-Kennedy++

Abstract. Synthetic speech stimuli were used to investigate whether aphasics' ability to perceive stop consonant place of articulation was enhanced by the extension of initial formant transitions in CV syllables. Phoneme identification and discrimination tests were administered to twelve aphasic patients, five fluent and seven nonfluent. There were no significant differences in performance due to the extended transitions, and no systematic pattern of performance due to aphasia type. In both groups, discrimination was generally high and significantly better than identification, demonstrating that auditory capacity was retained, while phonetic perception was impaired; this result is consistent with repeated demonstrations that auditory and phonetic processes may be dissociated in normal listeners. Moreover, significant rank order correlations between performances on the Token Test and on both perceptual tasks suggest that impairment on these tests may reflect a general cognitive rather than a language-specific deficit.

Some researchers have attributed speech comprehension deficits in aphasia to a defect in the processing of acoustic information in the speech signal. Tallal and Newcombe (1978) proposed a connection between nonverbal auditory processes, phonetic perception, and spoken language comprehension. They hypothesized that aphasics have a primary defect in temporal analysis affecting their ability to process rapidly changing acoustic cues. They suggested that this defect is responsible not only for failure to perceive specific phonemes, but also for a variety of other temporal processing problems.

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compromising aphasics’ ability to understand speech. The present study tests
this hypothesis on a group of post-CVA aphasics.

Tallal and Newcombe trained a group of 10 missile-wounded, left-brain-
damaged subjects to identify, with a button press, contrasting pairs of 3-
formant synthetic syllables, differing in the direction of their second
formant transitions. The syllables were to be identified as either /ba/ or
/da/. One pair of syllables had short (40 ms) transitions on all formants,
the other had extended (80 ms) transitions. Training continued to a criterion
of 20 correct out of 24 consecutive responses or until 48 trials had been
given. Only 4 of their 10 subjects reached criterion on the syllables with
short formant transitions, but 7 out of 10 reached criterion on the syllables
with extended formant transitions. The six subjects who had difficulty on the
short transition syllables also made the greatest number of errors on a
nonverbal sequencing task, in which they had to specify the order of two
tones, presented with very brief (from 8 to 305 ms) intervals between them.
Impairment on the latter task correlated highly with impairment on the Token
Test (DeRenzi & Vignolo, 1962). Given these findings, Tallal and Newcombe
inferred a causal chain from impairment in judgments of rapidly presented
nonverbal sequences to impairment in the perception of phonetic contrasts,
signaled by rapid formant transitions, to impairment in language comprehen-
sion.

We should note an ambiguity in the interpretation of the improvement in
aphasics’ place of articulation judgments, attributed by Tallal and Newcombe
to transition extension. Research with normal listeners has demonstrated that
identifications of syllable-initial stop consonants shift in manner from stop
to glide when formant transitions are extended (Liberman, Delattre, Gerstman,
& Cooper, 1956; Miller & Liberman, 1979). For example, an increase in the
duration of bilabial transitions from 30 to 60 ms shifts judgments from
predominantly /b/ to predominantly /w/: The boundary between the two manner
classes averages 40 ms. Was it then the extension of formant transitions per-
se that improved aphasics’ performance or was it the shift to a different
phonetic contrast? This ambiguity would not have arisen if Tallal and
Newcombe had blocked the manner shift by confining formant transition exten-
sion to those formants (F2 and F3) that carry place of articulation informa-
tion, while leaving the formant that carries manner information (F1) un-
changed.

Other experimenters have used synthetic speech to examine the speech
perception abilities of aphasics (e.g., Basso, Casati, & Vignolo, 1977;
Blumstein, Cooper, Zurif, & Caramazza, 1977; Kellar, 1979). This research,
limited to studies of voice-onset-time (VOT) perception, has indicated that
aphasics of both major diagnostic categories, nonfluent (Broca’s) and fluent
(Wernicke’s) have unusual difficulty in reliably assigning stimuli from a VOT
continuum to one of two classes. However, some aphasics who perform poorly on
this phoneme identification task perform almost normally when asked to judge
whether paired stimuli from the VOT continuum are the same or different. This
finding shows that in aphasia, the discrimination of acoustic parameters may
be functionally separable from phoneme identification. Moreover, these stud-
ies and others (e.g., Auerbach, Naeser, & Mazurski, 1981) have found little
evidence of a direct connection between disorders of phonetic perception and
reduced general comprehension of speech.
The goals of the present study were therefore: (1) to look for an improvement, similar to that reported by Tallal and Newcombe, in aphasics' identification and discrimination of stop consonant place of articulation, both when all three syllable-initial formant transitions were extended and when only F2 and F3 transitions were extended, and (2) to assess the relation between aphasics' performances on these tasks and their language comprehension, as measured by the Token Test.

METHOD

Test Materials

Three pairs of syllables were synthesized on the Haskins Laboratories parallel resonance synthesizer. The pairs differed from each other only in the formant patterns used to render /ba/ vs. /da/. The stimulus patterns for pairs 1 and 2 were modeled after those used by Tallal and Newcombe and described by Tallal and Piercy (1974, 1975).1 All stimulus patterns began with 13 ms of prevoicing and were followed by a three-formant pattern. Values are listed in Table 1. The durations of all three formant transitions were 30 ms in the first pair and 82 ms in the second pair. The third pair was identical to pair 2 except that formant transition extension was confined to those formants (F2 and F3) that carry most of the place of articulation information, while the formant that carries manner information (F1) was left unchanged. Formant transitions for all pairs were followed by a steady state portion sufficient to produce an overall stimulus duration of 250 ms.

Table 1

Onset and ending values of the three pairs of formant transition patterns used for identification and discrimination

<table>
<thead>
<tr>
<th></th>
<th>/b/</th>
<th>/d/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Onset</td>
<td>Ending</td>
</tr>
<tr>
<td>F1</td>
<td>202</td>
<td>688</td>
</tr>
<tr>
<td>F2</td>
<td>848</td>
<td>1077</td>
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<tr>
<td>F3</td>
<td>2193</td>
<td>2527</td>
</tr>
</tbody>
</table>
Subjects

Twelve adult aphasic out-patients of the Institute of Rehabilitation Medicine, New York University Medical Center, New York City, were tested. Subjects were limited to individuals who had sustained a left hemisphere CVA, were native English speakers, and had no history of neurological impairment before the onset of aphasia. All were screened for normal peripheral hearing through the speech frequencies. The mean length of time post-onset was 3.2 years (range 1 to 6 years). Their mean age was 55 years (range 36 to 66 years). A wide range of aphasia severity was reflected in the group, from mild to severe speech/language disturbance. Subjects were categorized into two types, fluent and nonfluent, on the basis of clinical examination and an analysis of speech characteristics (Goodglass & Kaplan, 1972). Auditory comprehension impairment was assessed with the Token Test (Spreen & Benton, 1977).

General Procedure

Subjects were tested individually in an IAC soundproofed chamber. The tape recorded stimuli were played on a Wollensak 1520 tape recorder and presented free field at a comfortable loudness level.

IDENTIFICATION TESTS

These tests were designed to answer the following questions:

1. Does extension of initial stop consonant formant transitions contribute to improved phoneme identification in aphasic subjects (a) when all three formant transitions are extended and/or (b) when formant transition extension is confined to F2 and F3?

2. Is any improvement produced by extending the formant transitions of stop-vowel syllables confined to a specific subtype of aphasia?

3. Is phoneme identification performance associated with performance on the Token Test?

Identification Procedure

Subjects were told that they would hear computer-generated syllables that sounded like "ba" or "da." Sample syllables (four /ba/ and four /da/) were presented. The identification task, which consisted of marking the correct syllable on a prepared answer sheet, was demonstrated by the experimenter. To familiarize subjects with the task, twelve practice items were then presented. These were followed by a 24 item (12 tokens of each syllable) randomized phoneme identification test, with 4 seconds between items.

Each identification test was followed by two discrimination tests (described below). The entire set of identification and discrimination tests was then repeated in reverse order. Testing was accomplished in 2 to 3 one half-hour sessions.
Results

The first four data columns of Table 2 present the individual and mean percent correct for the two aphasic groups. No differences in accuracy of phoneme identification were found among the synthetic pairs. Wilcoxon Matched Pairs tests (for 1 vs. 2, 2 vs. 3, and 1 vs. the average of 2 and 3), carried out on subjects whose score on pair 1 was less than 100% (N=9) and on subjects whose score on pair 1 was less than 90% (N=6) yielded no significant differences.

Type of aphasia also had no significant effect on performance of the identification tests. Certain individuals in both groups were prone to errors in identification, but others, specifically the milder aphasics, encountered no difficulty.

Table 2 (rightmost column) lists individual Token Test scores. A significant rank order correlation between identification scores and Token Test performance was found, r = .83, p < .01.

DISCRIMINATION TESTS

These tests were designed to answer the following questions:

1. Is aphasics' discrimination of stop-vowel syllables improved (a) when all three formant transitions are extended and/or (b) when formant transition extension is confined to F2 and F3?

2. Does reducing the inter-stimulus interval (ISI) between syllables affect discrimination performance?

3. Is there a difference between aphasics' ability to identify syllables and their ability to make same-different judgments about them?

4. Is there a correlation between phoneme discrimination and Token Test performance?

Subjects

Eleven of the subjects who were tested on identification were also tested on discrimination. One aphasic failed to understand task demands even after repeated trials and therefore was eliminated from discrimination testing.

Discrimination Procedure

The stimuli were identical to those of Experiment 1. Two same-different discrimination tests for each of the three pairs were constructed. The two tests differed only in the interstimulus interval (ISI), which was 500 ms for discrimination test 1 and 50 ms for discrimination test 2. There were 4 sec between items.

Subjects were informed that they would hear the two syllables, presented previously in the identification test, in pairs, and were instructed to decide whether the two stimuli were the same or different. Four demonstration pairs
### Table 2

Percent correct on identification and discrimination of synthetic syllable pairs and on Token Test

<table>
<thead>
<tr>
<th>Subject</th>
<th>Identification Test*</th>
<th>Discrimination Test*</th>
<th>Token Test</th>
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<tr>
<td></td>
<td>ISI</td>
<td>ISI</td>
<td></td>
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<tr>
<td></td>
<td>500 ms</td>
<td>50 ms</td>
<td></td>
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<tr>
<td></td>
<td>1 2 3 Mean</td>
<td>1 2 3 Mean</td>
<td>1 2 3 Mean</td>
</tr>
<tr>
<td>Group:</td>
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<td>Fluent</td>
<td>Non- Fluent</td>
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<table>
<thead>
<tr>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>Mean</th>
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<td>76</td>
<td>83</td>
<td>83</td>
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<td>3</td>
<td>Mean</td>
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<td>79</td>
<td>84</td>
<td>82</td>
<td>94</td>
</tr>
</tbody>
</table>

*1 = syllables with 30 ms transitions on all formants

*2 = syllables with 82 ms transitions on all formants

*3 = syllables with 30 ms transitions on F1, 82 ms on F2 or F3
were presented and the experimenter indicated the appropriate response on a
prepared answer sheet. Two answer sheets were available for use depending on
individual need. The primary answer sheet contained the letters S for "same"
and D for "different." If, after one practice set was administered, this
response form was deemed too difficult for the subject, a second sheet was
provided on which simple symbols were drawn to convey the concept of "same"
two circles) and "different" (a circle and a square). A practice set of
eight items was presented, followed by the 20 item discrimination test.

Results

Table 2 (columns 5–12) lists individual and mean percent correct for the
two groups of aphasics. None of the appropriate Wilcoxon Matched Pairs tests
showed significant improvement in discrimination of /ba/ and /da/ as a
function of formant transition extension. Differences due to ISI were also
not significant. Finally, although aphasic groups are too small for us to
generalize from their data, there was no consistent or reliable pattern
associated with aphasia type, other than a non-significant tendency in the
fluent group for series 3 (F2 and F3 transitions only lengthened) to result in
higher discrimination scores.

Regardless of the length of the ISI or the duration of the initial
formant transition, aphasics performed significantly better on discrimination
tests than on identification tests. Only one out of seven aphasics with Token
Test scores below 80% reached 80% correct on the three identification tests,
whereas all aphasics reached that criterion on at least two discrimination
tests. Wilcoxon Matched Pairs tests between subjects' mean identification
scores and mean discrimination scores across all stimulus pairs (see Table 2)
for each ISI (eliminating subject 5 who did no discrimination tests, and
subject 6 whose scores were 100% on every test) give W = 10 (N = 10, p < .05)
for ISI = 500 ms, and W = 4 (N = 9, one tie, p < .02) for ISI = 50 ms. Again,
as with the identification tests, there was a significant rank order correla-
tion between perceptual performance and Token Test score (r = .86, p < .01).

DISCUSSION

To support the hypothesis that the basic impairment underlying speech
comprehension deficits in aphasia is a failure to analyze rapidly changing
acoustic events, studies should demonstrate, at least, that identification
improves when spectral changes occur more slowly and/or that performance
deteriorates when test syllables to be discriminated are presented at a
sufficiently rapid rate. Furthermore, if rate of spectral change is the
crucial factor in aphasics' phonological performance, their ability to identi-
fy should be no worse than their ability to discriminate.

The present study yields no evidence to support the hypothesis. Aphasics'
identification performance did not benefit from the extension of the
initial formant transitions conveying place of articulation information. The
results from pairs 1 and 2, the two pairs in which stimulus patterns were
closely modeled after Tallal and Pierce (1974, 1975), in no way replicate the
findings reported in Tallal and Newcombe (1978).
It is noteworthy that pair 2 stimulus patterns (all three formant transitions extended) elicited a variety of identifications from aphasics. The lack of uniformity in labels given these stimulus patterns was corroborated by informal judgments from normal listeners (cf. Liberman et al., 1956; Miller & Liberman, 1979). Reported identifications included, in addition to /ba/-/da/, the labels /wa/-/lai, /bwa/-/dla/, /wa/-/da/ and /ra/-/ya/. Tallal and Newcombe do not report how subjects identified their stimuli, but if, as seems likely, similar shifts in judged manner class occurred, the improved performance of three of their ten subjects with lengthened transitions could, as we remarked in the introduction, have reflected either facilitation of auditory processing for stop consonants, as they assert, or shifts in the manner class of the phonetic segments specified by the extended formant transitions.

In any event, since stimulus patterns for pairs 1 and 2 were, as far as possible, identical to those used by Tallal and Newcombe, the difference in study outcome must be due to other variables, such as the precise experimental procedure, or the nature of the study population. Whatever the source of the difference, the present results are consistent with those of Blumstein, Tartter, Nigro, and Statlender (in press), who also found that formant transition extension had no effect on aphasics' ability to identify or discriminate place of articulation. Auerbach et al. (1981) found that benefit from extending formant transitions was confined to subjects who manifested a "word deafness" component in their speech comprehension impairment. None of the subjects tested here presented this rare unimodal deficit.

Stimulus patterns for pair 3 (extension confined to F2 and F3) were identified as /ba/ and /da/ by all subjects. Nevertheless, except for three fluent aphasics for whom correct syllable discrimination increased, improved stop consonant synthesis had no effect on performance; and these three demonstrated no consistent superiority in identification of the improved patterns, as would be required to justify the claims of Tallal and Newcombe.

The results also offer no support for the notion that aphasics with comprehension deficits discriminate poorly when the interval between stimuli to be discriminated is sharply reduced. Differences between discrimination scores when test syllables were separated by 50 ms vs. 500 ms were small and no trends could be discerned either for the group as a whole or for individual subjects. It was not unusual for a subject to show an increment on the 500 ms over the 50 ms task on one test series, no differences on the second, and a decrement on the third.

The difference in the effect of reduced ISI between the present study and that of Tallal and Newcombe is probably due to task differences. Tallal and Newcombe asked that subjects indicate the order in which two tones occurred, a task calling for both identification and ordering of the tones. The present study simply required that subjects discriminate between two syllables, clearly a less demanding task. Nonetheless, if aphasic deficit does indeed reflect a failure in the processing of rapidly presented acoustic events, the simpler task of the present study should also have reflected this failure at reduced values of ISI.
Performance deficits were not confined to, nor more severe in, one diagnostic group rather than another. Neither group was more sensitive than the other to a reduction in ISI in the discrimination tests, and both fluent and nonfluent aphasics with comprehension deficits demonstrated better discrimination than identification.

This last finding is perhaps the most striking result of the whole study since it runs directly counter to the notion, implicit in Tallal and Newcombe's hypothesis, that phonetic perception is merely an auditory process. A dissociation between discrimination and identification has been reported by others for a different phonetic contrast, voiceless unaspirated vs. voiceless aspirated English stops, signaled by variations in VOT (Blumstein et al., 1977; Kellar, 1979). Moreover, such a dissociation is precisely what we would expect from repeated demonstrations that auditory and phonetic processes may be dissociated in normal listeners (e.g., Mann & Liberman, in press; Studdert-Kennedy, 1983).

Finally, the high correlation between perceptual task performance and Token Test scores is consistent with the results of Tallal and Newcombe, but inconsistent with other investigations in which synthetic stimuli have been used to explore the connection between phonetic deficits and speech comprehension impairment in aphasia (Basso et al., 1977; Blumstein et al., 1977). Identification and discrimination deficits were confined to individuals with substantially reduced Token Test scores, i.e., scores under 80%. Individuals with high or normal Token Test scores obtained near perfect scores on all nine perceptual tests, and no aphasic with a substantially reduced Token Test score ever outperformed aphasics with little or no comprehension impairment.

Although these correlations match those reported by Tallal and Newcombe, the interpretation of the correlations must be different, since the present study found no evidence to support the temporal deficit hypothesis. As far as the identification task goes, we may note that both identification and the Token Test require subjects to perform without the advantage of the semantic context provided in naturalistic situations to support identification. Identifications of contrasting stimuli (two CV syllables, two shape or color names) tend to be labile and over time often become increasingly confused. However, this account will not explain the correlation between discrimination and Token Test performances, so that we must look for other similarities in the cognitive requirements of the tasks. We may note that both the perceptual tests and the Token Test are extremely artificial and require consistent levels of attention over relatively long periods of time. Of course, it is also possible that the tests share no common factor: The several tests may all be sensitive indices of aphasia, but for different unrelated reasons.

REFERENCES


**FOOTNOTE**

Tallal and Piercy (1974, p. 86) provide a table of F2 and F3 transition patterns for their two stimuli representing /ba/ and /da/. However, they report in a footnote to a later paper (Tallal & Piercy, 1975) that the description in their first paper was incorrect. They provide spectrograms of the corrected syllables without listing the actual formant values. Table 1 values are estimated from these spectrograms.