Consistency of the Effects of Rate of Speech on Brain-damaged Adults' Comprehension of Information in Narrative Discourse

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A number of studies have demonstrated that slowing the rate at which single sentences are spoken facilitates aphasic listeners' comprehension of the sentences (Gordon, 1970; Parkhurst, 1970; Gardner, Albert, and Weintraub, 1975; Weidner and Johnson, 1976; Weidner and Lasky, 1976; Poeck and Pietron, 1981). In 1984, Linda Nicholas and I (Brookshire and Nicholas, 1984) reported that the facilitating effects of slow speaking rate on comprehension of Token Test type commands is not consistent across aphasic listeners, and is not consistent for a given aphasic listener across time. In 1982, Gail Pashek and I (Pashek and Brookshire, 1982) evaluated the effects of slow speech rate on aphasic listeners' comprehension of spoken paragraphs. We found that aphasic listeners correctly answered more questions about the content of paragraphs when paragraphs were spoken at slow rate (120 wpm) than when paragraphs were spoken at a normal rate (150 wpm). The questions we asked subjects primarily assessed their comprehension of details from the paragraphs -- few questions sampled their comprehension of main ideas. We made no attempt to assess the consistency of the effects of slow speech rate across individual aphasic listeners, or for those individuals across time.

The experiment that I will report here today was designed to examine: (1) the effects of slowed speech rate on brain-damaged listeners' comprehension of directly stated and implied main ideas and details from spoken stories, and (2) the consistency of these effects, both across subjects, and within each subject across time.

SUBJECTS

Subjects were 21 brain-damaged adults who were at least one month post-onset of a single thromboembolic brain lesion, and seven age-matched non-brain-damaged control subjects. Fourteen of the brain-damaged subjects had left hemisphere brain damage and aphasia. The remaining seven had right hemisphere brain damage and were not aphasic. The 14 aphasic subjects consisted of five subjects exhibiting nonfluent aphasia, two exhibiting fluent aphasia, and seven exhibiting mixed aphasia. These classifications were made by two judges, who examined speech and language test results, listened to a sample of spontaneous speech for each subject, and assigned each subject to one of the three categories. Subjects for whom the judges did not agree on a classification were not included in the experiment. The 14 aphasic subjects were also subdivided into two groups based on percentiles for the auditory comprehension subtests of the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1983). The High Comprehension Group consisted of subjects with auditory subtest percentiles from 83 to 96 (mean = 91), and the Low Comprehension Group consisted of subjects with auditory subtest percentiles from 60 to 79 (mean = 70). Characteristics of brain-damaged subjects are summarized in Table 1.

Table 1. Descriptive information for brain-damaged subjects.

Subject	Age	Educ.	Time Post Onset (Months)	Type of Aphasia	BDAE Severity	BDAE Auditory (percentile)
High Aph						
1.	63	12	127	FL	5	96
2.	51	14	111	NF	3	96
3.	51	12	85	NF	3	93
4.	64	13	61	MX	5	93
5.	59	9	18	MX	5	90
6.	74	12	2	FL	5	84
7.	59	20	78	NF	1	83
$\bar{X}$	60.1	13.1	68.9	--	3.9	90.7
Low Aph						
1.	61	14	3	MX	4	79
2.	70	8	12	NF	1	78
3.	65	16	27	MX	5	71
4.	46	16	13	NF	2	69
5.	63	11	33	MX	3	69
6.	61	12	48	MX	3	67
7.	71	12	5	MX	2	60
$\bar{X}$	62.4	12.7	20.1	--	2.9	70.4
Rt CVA						
1.	69	12	1			
2.	62	12	3			
3.	66	9	2			
4.	66	12	2			
5.	64	8	66			
6.	62	12	20			
7.	60	12	51			
$\bar{X}$	64.1	11.0	20.7			

STIMULUS MATERIALS

Twelve narrative stories were written. Each story contained 13 or 14 sentences and 190 to 210 words. All stories were between fifth and sixth grade reading level as determined by the Dale-Chall Readability Formula (Dale and Chall, 1948). Listening difficulty ranged from 3.5 to 5.3 as determined by the Easy Listening Formula (Fang, 1966). With the Easy Listening Formula, larger numbers mean more difficulty in comprehension. A score of 12 is the maximum level at which materials will be easily comprehended by average American listeners. Consequently, our stories, with scores of 3 to 5, would be considered easy to comprehend, based on the Easy Listening Formula.

Eight yes-no questions were written for each story. Four questions for each story tested main ideas and four tested details. Half of the main idea questions and half of the detail questions tested information that was stated

in the stories. The other half of the questions for each story required listeners to draw inferences from information that was presented in the story. In order to establish the validity of main idea and detail questions, as well as to establish the validity of "stated" and "inferential" questions, we asked 10 persons (speech and language pathologists or graduate students in speech and language pathology) to read each of the 12 stories and to answer the questions that followed each story. We also asked them to decide whether each question tested a main idea or a detail, and whether the information that each question asked for had been directly stated in the story or required that an inference be constructed from information in the story. Seven of the ten judges had to agree on each question's main idea - detail classification and stated - implied classification in order for the question to be used in the experiment. Questions that did not meet these criteria were revised or re-written until seven of the ten judges agreed on its classification. The stories were then tape-recorded by a male speaker at two speech rates -- Slow Rate (110-130 wpm), and Fast Rate (190-210 wpm) with normal stress and intonation. Questions for each story were recorded following the story at a slow speech rate (90-130 wpm).

METHOD

Before their participation in the experiment, each brain-damaged subject was tested with the yes-no question auditory comprehension subtest from the Western Aphasia Battery (WAB; Kertesz, 1982). In order to be certain that subjects had comprehension adequate for the yes-no questions in the experiment, and to insure that subjects had reliable yes-no responses, no subject who made more than three errors on the 20 items in the subtest was included in the experiment.

In the experiment proper, subjects were tested individually in a single-wall audiometric room. Two training stories and their accompanying questions were played at the beginning of the session to familiarize them with the task and to establish a comfortable listening level forthe experimental stories. One of the training stories was presented at Slow Rate and the other was presented at Fast Rate. Then the ten experimental stories and their questions were played. Five stories were presented at Slow Rate and five were presented at Fast Rate. The order of stories and the speech rates within stories were randomly determined for each subject.

Subjects responded to questions for each story by saying "yes" or "no." Each brain-damaged subject was tested with the same stories in the same conditions on two occasions, no less than two weeks and no more than three weeks apart. Non-brain-damaged subjects were tested only once.

RESULTS

Several analyses of variance were carried out (Table 2). Because the response variability of the non-brain-damaged group was not homogeneous with that of the brain-damaged groups, the non-brain-damaged group was not included in the analyses of variance. The following interpretations of results are based upon the results of these analyses.

(1) SALIENCE had strong effects on comprehension (Figure 1). Questions which sampled MAIN IDEAS were answered correctly significantly more often than questions that sampled DETAILS, for all three subject groups, in both sessions. (2) DIRECTNESS affected comprehension of details in both sessions (Figure 2). Directly stated details were comprehended significantly better than indirectly

Table 2. Summary of analyses of variance results.

WITHIN MAIN IDEAS

Variables: Groups, Rate, Directness

Session 1		Session 2
Groups		Groups
* Rate		Rate
Directness		Directness
* G X R	HA: Fast≈Slow	
	RH: Fast≈Slow	
	LA: Fast<Slow	

WITHIN DETAILS

Variables: Groups, Rate, Directness

Session 1		Session 2	
* Groups	HA RH LA	Groups	
* Rate	Fast < Slow	Rate	
* Directness	Stated > Implied	* Directness	Stated > Implied

WITH MAIN IDEAS AND DETAILS COMBINED

Variables: Groups, Salience

Session 1		Session 2	
* Groups	HA RH LA	* Groups	HA RH LA
* Salience	M Idea > Detail	* Salience	M Idea > Detail

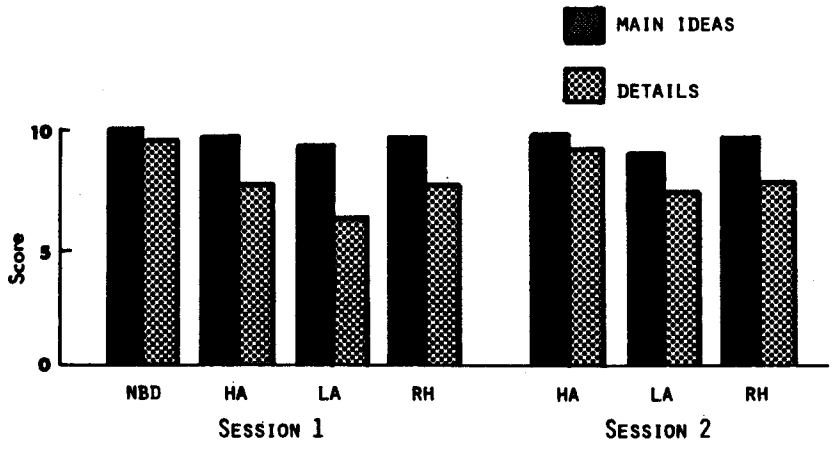

Figure 1. Effects of salience (main idea vs. detail) on performance of high comprehension aphasic, low comprehension aphasic, right-hemisphere-damaged, and non-brain-damaged subjects.

stated details in both sessions. Directness did not affect comprehension of main ideas in either session. (3) RATE had a significant effect on comprehension of details only in Session 1 (Figure 3). All groups answered more detail questions correctly in Session 1 when paragraphs were spoken at slow rate than when they were spoken at fast rate. Rate affected comprehension of main ideas only for Low Aphasic subjects, and only in Session 1. (4) GROUP MEMBERSHIP nad its strongest effects on comprehension of details. The three brain-damaged groups did not differ in their comprehension of main ideas in either session. However, Low Aphasic subjects' comprehension of details was significantly worse than that of High Aphasic or Right Hemisphere damaged subjects in both sessions, with the greatest difference in Session 1 (Figure 3).

In order to evaluate the consistency with which changes in speech rate affected aphasic subjects' performance, we calculated, for each group, the number of subjects showing differences in performance from Fast Rate to Slow Rate for Sessions 1 and 2 combined (Table 3). This table presents the number of subjects who showed differences from Fast Rate to Slow Rate according to whether information was main ideas or details, and whether it was directly stated or implied. In order to evaluate the significance of the differences shown, binomial probabilities were calculated. Cases in which significantly more subjects exhibited a change in performance from fast to slow rate than would be expected by chance are marked by asterisks. As you can see, Low Aphasic subjects demonstrated significant rate effects across three of the four question types, and Right Hemisphere damaged subjects demonstrated significant rate effects within implied details. The High Aphasic group showed no significant effects of rate for any of the four question types. Note, however, that in most cases in which rate effects were significant for a group, some subjects within the group demonstrate no rate effect and usually a few change in a direction opposite to that of the group.

Table 3. Number of subjects showing differences from fast to slow rate for stated (ST) and implied (IM) main ideas (MI) and details (DT) for sessions one and two combined. (n = 14 per condition per subject group.) (+ = improved, - = deteriorated, and nc = no change from fast to slow rate.)

	MI-ST			MI-IM			DT-ST			DT-IM		
	+	-	nc	+	-	nc	+	-	nc	+	-	nc
High Aph	2	1	11	2	2	10	6	1	7	3	7	4
Low Aph	8	1	5*	9	1	4*	11	3	0*	7	6	1
Rt CVA	3	0	11	1	4	9	5	6	3	10	1	3*

* = $p < .05$

DISCUSSION

The results of this experiment are consistent with many of our previous findings regarding aphasic persons' comprehension of spoken discourse. One of the strongest effects was that of SALIENCE. All subjects, non-brain-damaged as well as brain-damaged, consistently comprehended main ideas better than they comprehended details. We have observed this effect in two of our previous studies of aphasic listeners' comprehension of discourse (Wegner, Brookshire, and Nicholas, 1984; Brookshire and Nicholas, 1984). In the present experiment, we found that right-hemisphere-damaged subjects also comprehend main ideas

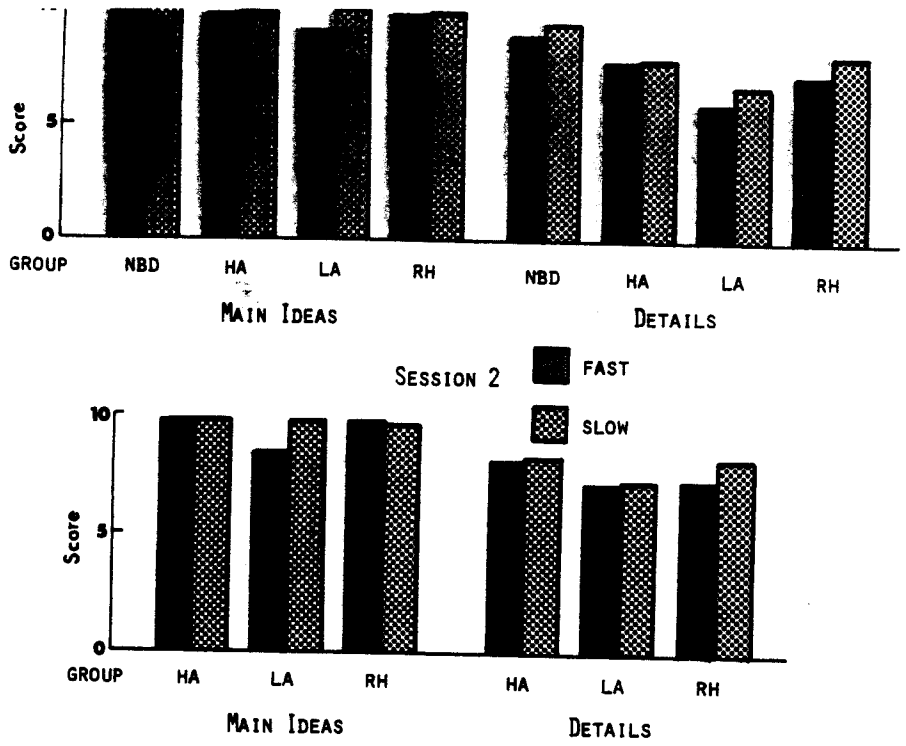

Figure 2. Effects of rate (fast vs. slow) on performance of non-brain-damaged, high comprehension aphasic, low comprehension aphasic, and right-hemisphere-damaged subjects.

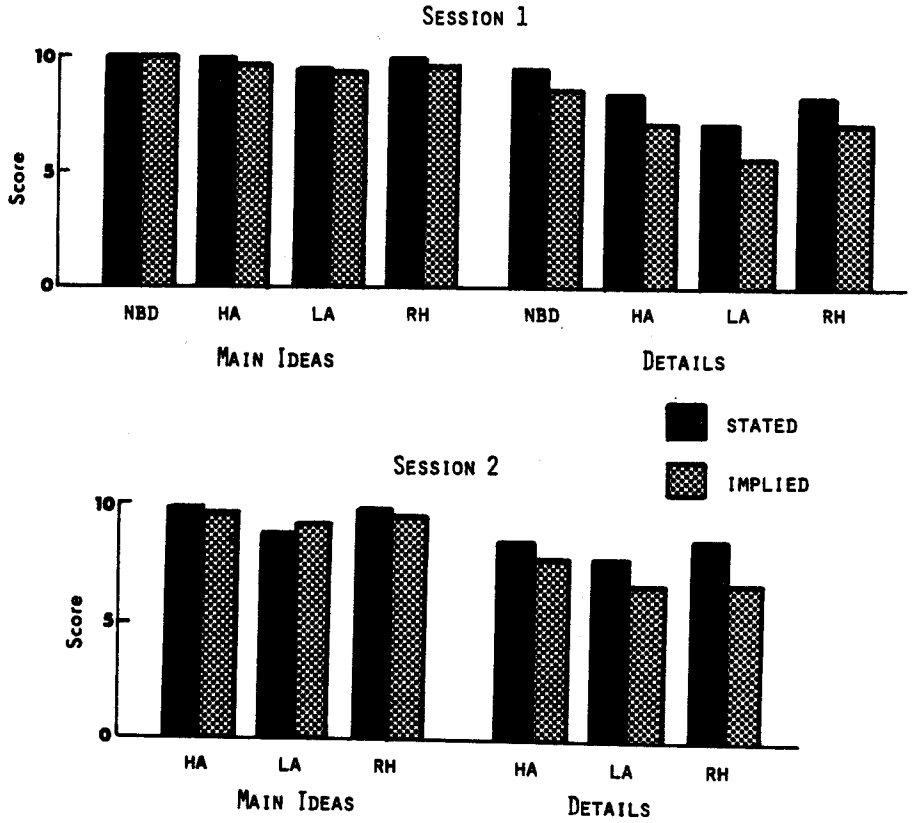

Figure 3. Effects of directness (stated vs. implied) on performance of non-brain-damaged, high comprehension aphasic, low comprehension aphasic, and right-hemisphere-damaged subjects.

better than they comprehend details. Because one must be sensitive to the hierarchical arrangement of information within discourse (discourse structure) in order to give preferential treatment to main ideas, this suggests that patients with right hemisphere damage are sensitive to the structure of discourse, and can be expected to remember important information better than they remember unimportant information. In this experiment, as in previous experiments, aphasic subjects' performance on main ideas was nearly indistinguishable from that of non-brain-damaged listeners (and of subjects with right hemisphere damage).

In this experiment, as in our previous work, we found that the effects of experimental variables on comprehension of information from discourse tends to be localized to comprehension of details -- comprehension of main ideas tends to be unaffected by many experimental manipulations -- probably because errors on main ideas are infrequent. DIRECTNESS affected subjects' comprehension of details, but not main ideas -- it did not appear to matter whether main ideas were directly or indirectly stated, but indirectly stated details generated more errors than directly stated ones in both sessions.

The effects of RATE were less strong and consistent than the effects of either salience or directness. Once again, the effects were limited to details, except for Low Aphasic subjects, whose comprehension of main ideas in Session 1 was better with slow rate than with fast rate. However, the effects of rate on comprehension of details were seen only in Session 1. By Session 2, they had disappeared. The undependability and transitory nature of the effects of rate were also illustrated by the performance of individual subjects. Even when a group showed significant rate effects, it was always the case that some members of the group showed no rate effects, or even effects opposite to that for the group.

The performance of aphasic GROUPS in this experiment was similar to the performance of aphasic groups in our previous experiments. In every analysis in which group differences were found, it was the case that the Low Aphasic group's performance was significantly worse than that of any of the other groups. In our previous work, we found that aphasic listeners did not differ significantly from non-brain-damaged listeners or from listeners with right CVAs in comprehension of main ideas. Only in comprehension of details did aphasic and nonaphasic subjects differ appreciably.

The performance of right hemisphere damaged subjects in this experiment deserves mention. In every analysis, right hemisphere damaged subjects clustered with high aphasic and normal control subjects. This result is similar to that in our 1984 experiment (Brookshire and Nicholas, 1984), in which right-hemisphere-damaged subjects, normal control subjects, and aphasic subjects (with mild comprehension deficits) performed equivalently. However, inspection of Figures 1, 2, and 3 suggest that right-hemisphere-damaged subjects did not appear to profit, in Session 2, from their experience in Session 1 in the same way that other groups did. In almost all cases subject groups improved their performance from Session 1 to Session 2. This was not true for right-hemisphere-damaged subjects, who performed essentially the same on all measures in Session 2 as they had in Session 1.

Now I'll say a few words about the clinical significance of our results. We demonstrated significant effects of salience, directness, and rate, in at least some conditions. I have addressed the meaningfulness of the rate effects already -- they are not strong, even when they are statistically significant, and they are not dependable either within subjects from session to session or across subjects. Let me emphasize that the undependability of rate effects is not the result of inadequacies in design or execution -- our

procedures were, I believe, adequate to detect a consistent rate effect, if it were there.

We also demonstrated a significant effect of directness, at least for details. However, the magnitude of the differences in performance between stated and implied details was quite small -- approximately 1 to 1.5 errors in ten responses. One could legitimately question the clinical importance of such small differences, and their importance in daily-life communication activities.

The effects of salience are, I think, both robust and clinically significant. Differences between main ideas and details generally were in the 2-3 errors per ten responses range. The magnitude of this difference is large enough, I think, to make it clinically significant. The importance of one's ability to deduce and remember main ideas from discourse also makes this difference a pragmatically interesting one.

The somewhat ephemeral nature of the effects of rate and directness, at least in this experiment, are illustrative of what happens when one studies comprehension of sentences in discourse rather than studying comprehension of isolated sentences. One is likely to find that variables that have relatively strong effects on comprehension of isolated sentences often will have only weak effects on comprehension of sentences in discourse. Whether there are variables that weakly affect comprehension of isolated sentences but strongly affect comprehension of sentences in discourse remains to be seen.

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Q: A couple of years ago you demonstrated to us that rate can affect comprehension in aphasic patients. More specifically, that inter-word pauses were more influential than intra- or within-word pauses. Would you describe again how you altered rate in your study and whether or not using intra- vs. inter-word pauses might have given you a more significant effect on sentences in discourse context?

A: We debated on how we were going to do these studies and the decision was made what we would do is simply talk slower because that's what people naturally do in the outside world. I haven't analyzed the differences between my fast rate and slow rate but my strong suspicion is that it's primarily made up of pause time. The most pause time accumulates at clause boundaries and sentence boundaries. There is prolongation of vowels that takes place when one gets down to a really slow rate such as 100 words per minute. Now, with regard to interword vs. intraword pauses, the only study I know of is one by Sheehan and Aseltine. They had an interpolated pause condition in which they claimed that they put 20 miliseconds of pause time after every phoneme in a short story. They had another condition which they called accumulated pause time, in which they totaled up all the time that would have been put within the word and put it at the end of the word. I think they also had a normal rate condition. Anyway, what they reported was when you put pauses within a word at what they claimed were phoneme boundaries, aphasic patients got marveously better than when you put all the time at the end of the word. Tony Salvatore and I read the article and didn't believe it, so we got from Sheehan and Aseltine a copy of one of their tapes. Eventually we ran some aphasic people and got results which clearly contradicted Sheehan and Aseltine's. Aphasic people could not understand the sentences in interpolated silence condition. They were much better when you put the time at the end of the words.

I think there is probably a difference between single sentences and discourse, in terms of your options about how you slow rate, because in discourse you have boundaries between sentences at which to insert pauses to slow the rate. You don't have that freedom in single sentences. I think probably that is an important difference. Although even in single sentences my impression is that the best place to put pauses is at clause boundaries. If you interrupt the clause with a pause, performance isn't as good as if you put the pause at the end of the clause.

By the way, there is something on the handout that didn't get mentioned. I think it is interesting information. We asked the same judges who decided whether our questions tested main ideas or details which were stated or implied to look at the questions for the paragraphs in the Boston Diagnostic Aphasia Examination auditory comprehension subtest. On the bottom of page 3 you'll see the results of the judgments on those questions. Seven of the eight tested main ideas, As our study showed, that level of information doesn't really distinguish much among the groups of brain-damaged or among non-brain-damaged and brain-damaged subjects. So you have really only one question in the BDAE that's looking at details.

Boston Diagnostic Aphasia Examination Paragraph Comprehension Questions

Question #:		
	1. Main Idea - Stated	5. Main Idea - Stated
	2. Detail - Stated	6. Main Idea - Implied
	3. Main Idea - Implied	7. Main Idea - Implied
	4. Main Idea - Implied	8. Main Idea - Stated

Q: Do you have any intuitions about what's happening when rate does have its positive effect--psychophysiologically, psychologically, or whatever?

A: Well, I can't speak with enough clarity to make any difference to this group. One can always fall back on buzz words like "processing time." We all know that aphasic people are slower on the uptake when messages come in and if you give them more time they are better at it. It's the same phenomenon as the paragraph from the Minnesota test (that even normal subjects miss parts of). At 210 words per minute you would have great difficulty. But if I gave it to you at 110 words per minute you would probably get it all. It is a matter of information handling. Over and over again we find that aphasic people look like nonaphasic people across conditions, they're just slower.

Q: It seems like much of the information in comprehension is contained in the transitions between phonemes. I wondered if you had considered this manner of slow rate?

A: One of the problems is that when you change transitions you mess up the acoustic characteristics of speech. If you look at the literature on rate effects you find that sometimes people find that slowing rate helps comprehension and in some cases people find that slowing rate makes comprehension worse. In almost every case one will find no effects or negative effects when people changed the normal acoustic characteristics of speech. Almost without exception one finds that enhancement of comprehension occurs only when people put pauses between words or between clauses and leave the acoustic characteristics alone.