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Auditory Vigilance in Aphasic Individuals: Detecting Nonlinguistic Stimuli with Full or Divided Attention

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Previous research (LaPointe & Erickson, 1991) has shown that aphasic individuals have difficulty, relative to control subjects, in monitoring for spoken words while performing a secondary task. This finding may indicate that aphasics have fundamental deficits in attention or that their linguistic deficits are simply exacerbated by dividing attention. Twenty subjects, 10 nonfluent aphasic and 10 nonaphasic adults, listened to two 10-min series of nonlinguistic acoustic stimuli across conditions of focused and divided attention. Subjects tried to identify target sounds interspersed with nontarget sounds. As in prior research, aphasic subjects performed less accurately on the auditory vigilance task during the divided attention condition, relative to the undivided attention condition and to control subjects. The findings suggest that deficient cognitive processing, intertwined with linguistic deficit, may underlie auditory comprehension deficits in aphasia and may help explain performance variation within aphasic individuals across tasks. © 1996 Academic Press, Inc.

Traditional, language-based views of aphasia are founded on well-established linguistic principles and guide professionals toward an understanding of the disorder. However, traditional views of aphasia have proven inadequate for explanation of many behaviors, such as the variability of performance across tasks and environments which is common in aphasic syndromes (Tseng, McNeil, & Milenkovic, 1993). While some would cite these

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inadequacies as grounds for rejecting traditional models of aphasia altogether (Caramazza, 1988), others have suggested that cognitive processes, particularly attention and short-term memory processes, are vitally linked to the obvious linguistic deficits seen in aphasia (LaPointe & Erickson, 1991; McNeil & Kimelman, 1986; McNeil, Odell, & Tseng, 1991).

One important correlate of aphasia not readily explained by traditional views is the great variability of performance within and across aphasic individuals. A common and frustrating experience in clinical aphasiology is that patients' communicative abilities are often unstable across testing occasions and settings. McNeil et al. (1991) have suggested that such variability may stem from nonlinguistic cognitive variables. External and internal factors that create performance fluctuations across tasks are being identified with increasing frequency (Glosser, Weiner, & Kaplan, 1988; LaPointe & Erickson, 1991; McNeil et al., 1991). As a result, deficient cognitive processes have recently been proposed as integral components of aphasic impairment (Bowles, Erickson, & LaPointe, 1992; Chapey, 1994; McNeil, 1982; McNeil & Kimelman, 1986; Wepman, 1972). McNeil and Kimelman (1986), for example, emphasized that linguistic behavior is an extension of cognitive processes:

> As applied to models of aphasia, these models and theories of speech perception and language comprehension are all viewed as active and constructive. This implies that listeners are not simply receivers or receptacles of information, but are active creative gatherers of information. These active cognitive operations performed on this information, independent of the speech code or purely linguistic aspect of the information perceived or comprehended, is referred to as 'processing.' (p. 127)

Linguistic behavior may be considered a ''special case'' of general cognitive processing. Thus, a holistic view of aphasia should include deficient cognitive processes, such as accessing lexical memory, working memory operations, perceptual categorization, and attentional resource allocation. Inefficient allocation of attention has been cited as an especially important contributor to auditory comprehension deficits in aphasia (Bowles et al., 1992; McNeil & Kimelman, 1986; McNeil et al., 1991), but research has yet to clearly define the precise role of attention deficits in aphasia, or in normal linguistic processing.

Although numerous theories of attention exist (Lachman, Lachman, & Butterfield, 1979; Shiffrin & Schneider, 1977; see Shiffrin, 1988, for review), a general model based on resource allocation has been particularly useful for investigation of cognitive–linguistic interactions in brain-damaged subjects. Kahneman (1973) described attention as a system that allocates available processing resources from a limited pool, according to the needs of the system. When a person performs simultaneous tasks, the attentional system tries to optimally allocate its resources based on the total supply available, motivational criteria, and the relative demands of each task. *Competition* for limited attentional resources among stimuli or tasks is the central theme of resource allocation theory.

McNeil et al. (1991) recently proposed a resource allocation framework to explain decreased linguistic performance in brain-damaged populations. This approach has empirical support: Kewman, Yanus, and Kirsch (1988) found that brain-injured patients were more impaired in comprehension of spoken messages in the presence of competing speech, relative to control subjects. They attributed the aphasics' impairment to an inability to properly allocate attention. Campbell and McNeil (1985) examined speech comprehension in children with acquired language disorders, finding that manipulation of external factors, such as presentation rate, hindered their comprehension during a divided attention task, relative to normal children (see also Grady, Grimes, Patronas, Sunderland, Foster, & Rapoport, 1989). Arvedson and McNeil (1986) compared brain-damaged and control subjects in semantic-classification and lexical-decision tasks, under conditions of divided attention. Upon finding that brain-damaged subjects were far more sensitive to the divided-attention manipulation, Arvedson and McNeil concluded that ''a model of resource allocation provides a framework to motivate further research which may eventually have an impact on clinical assessment and treatment methods'' (p. 197).

Although evidence on the role of attention in aphasia is increasing, many questions remain. One ability that has received little focus until recently is ''auditory vigilance,'' the ability to continuously monitor auditory signals for relevant information. As the name implies, auditory vigilance requires focused attention for extended periods. LaPointe and Erickson (1991) found that aphasic subjects performed less accurately than control subjects on a linguistic auditory vigilance task (identifying a target word interspersed with nontarget words) during divided attention. A single auditory vigilance task, or focused attention, revealed no difference between groups. In a similar study, Bowles et al. (1992) reported group $\times$ task interactions with aphasic, right-hemisphere-damaged (RHD), and control subjects. The aphasics performed less accurately than either the RHD or the control subjects in the dual task. In general, aphasics and control subjects exhibit similar auditory vigilance abilities in conditions of focused attention. But when a competing task is introduced, aphasics' performance decreases significantly relative to that of matched subjects with no brain damage or a different etiology of brain damage.

A limitation of these previous auditory vigilance studies is that *linguistic* stimuli were used for targets. Therefore, it is difficult to know whether aphasics' vigilance deficit should be attributed only to attention allocation deficits, or partially to the linguistic processing deficits that typically define aphasia. The present study further investigated the nature of impaired auditory vigilance in aphasia. We assessed aphasics' ability to detect *nonlinguistic* auditory stimuli during focused and divided attention, to determine whether previously observed decrements in divided attention are specific to linguistic stimuli, or if they reflect a more fundamental disruption of resource allocation. Dissociating attention allocation from language processing may help clarify the nature of vigilance deficits in aphasia, the general nature of aphasia, and may carry implications for treatment.

METHOD

Subjects. Twenty volunteers represented two groups. The aphasic group consisted of seven males and three females, ranging in age from 62.5 to 83.5 years, with a mean age of 74.6 ($SD = 6.49$). Each subject had experienced a left-hemisphere thromboembolic cerebrovascular accident (CVA), as verified by neurological reports. Each also exhibited accompanying aphasia, as determined by standardized aphasia tests and the judgment of a certified speech–language pathologist. All subjects were native speakers of American English and were right-handed. Months postonset (MPO) of the CVA ranged from 3 to 11 months, with a mean MPO of 4.4 ($SD = 2.46$). Severity of the accompanying aphasia was measured by the Western Aphasia Battery (Kertesz, 1982). Aphasia quotients (AQ) ranged from 45.0 to 80.4, with a mean AQ of 63.94 ($SD = 11.15$). All subjects exhibited aphasic behaviors typically associated with nonfluent, or Broca's, aphasia. Four subjects exhibited concomitant apraxia of speech, as subjectively determined by an experienced aphasiologist. As neither experimental task required verbal response, the apraxia was not expected to impede task performance. Each aphasic subject passed a hearing screening test at the frequencies of 500, 1000, 2000, and 4000 Hz, presented bilaterally at 30 db. Subjects exhibited no visual, mood, or mental impairments judged to impede task performance.

The control group consisted of six males and four females, ranging in age from 59.0 to 85.5 years with a mean age of 71.9 ($SD = 8.64$). No control subject reported a history of neuropathology or audiological deficits (although they received no formal hearing test). The aphasic and control groups did not reliably differ in age [$t(18) = -1.24$, n.s.]. They did reliably differ in years of education [$t(18) = -4.01$, $p < .001$], but the difference was small and it favored the aphasic group (12.8 years) over the control group (12.0 years). Demographic data for all subjects are provided in Appendix A.

Stimulus materials. Two 10-min audiocassettes, each consisting of a series of 10 nontarget pure tones and one target complex harmonic, were constructed. Nontargets consisted of pure tones at the frequencies 550, 580, 620, 680, 720, 780, 820, 920, and 980 Hz. The target sound was a complex harmonic consisting of the frequencies 500, 1000, 1500, 2000, 2500, and 3000 Hz. The target sound was easily discriminable from the nontarget tones. The tones were 500 msec in duration and were recorded at a rate of one onset every 2500 msec, for a total of 24 events per minute. An event rate of at least 24 events per minute is considered fast in a vigilance task (Lanzetta, Dember, Warm, & Berch, 1987). Each 10-min series contained 240 total events with a ratio of 1 target to 4 events, for a total of 60 targets and 180 nontargets. Targets and nontargets were generated and randomized for each series via computer. The cassette recordings were produced at an input level of 70 dB and included verbal instructions for each task before the stimuli.

Procedure. The subjects' primary task was auditory vigilance, or sustained auditory attention, to nonspeech stimuli across two conditions. Subjects listened to a series of pure tones, randomly intermixed with a target complex harmonic, and they identified the target sound by raising the unaffected hand. The vigilance task was performed across two conditions. Condition A consisted of simply listening to a random series of sounds and identifying targets. The auditory series was presented via a professional-quality JVC stereocassette system, calibrated to generate an output signal of 75–80 dB at a distance of 1 m from the subject in a soundproofed, electrically shielded room. Subjects were seated at a table and performed the task

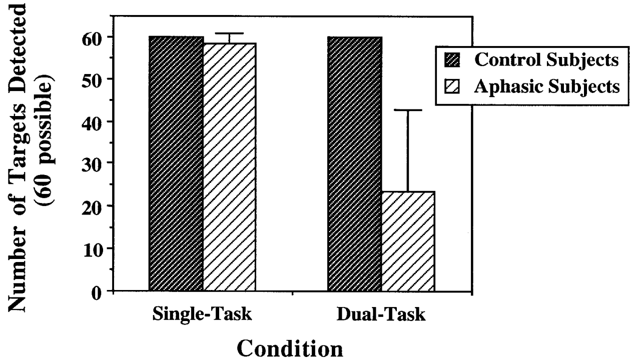

FIG. 1. Auditory target detection rates for both groups across tasks.

individually. The examiner sat behind each subject to avoid distraction while scoring the performance on each task.

Condition B consisted of listening to a random series of sounds and identifying targets while simultaneously sorting cards. The cards, selected from the Wisconsin Card Sorting Test (Grant & Berg, 1981), contained various geometric shapes and differed by number, color, and type of shape per card. Subjects were required to sort the cards into four stacks according to color of the shapes. Subjects picked and sorted cards from a basket, at a comfortable self-determined rate, while simultaneously monitoring for auditory targets.

Each task began with recorded instructions. Instructions for Condition A were as follows: ''You will hear a series of sounds like this (short sample). I want you to raise your hand each time you hear this sound (target). Listen carefully and try not to miss any. Remember, raise your hand each time you hear this sound (target). Are you ready? Let's begin now.'' Instructions for Condition B addressed the dual task: ''You will hear a series of sounds like this (sample). I want you to raise your hand each time you hear this sound (target). Listen carefully and try not to miss any. Raise your hand each time you hear this sound (target). While you are listening to the sounds I want you to sort the cards in front of you by their colors. When we begin, I want you to take a card from the bucket and place it on the one with the same color. You must continue to take cards and sort them the entire time the sounds are playing. Remember also to raise your hand each time you hear this sound (target). Listen carefully and try not to miss any. Are you ready? We will begin now.''

Presentation order of both conditions was counterbalanced to equally distribute fatigue or learning effects. Performance was scored by the examiner, who recorded target detections and false positives on a scoresheet. For Condition B, correctly and incorrectly sorted cards were tallied. A screening task, consisting of two trials of training, was used to teach subjects the task and to ensure that they understood and could complete the vigilance task under both conditions. No subject was excluded for failure to learn the tasks.

RESULTS

Figure 1 displays the results, in terms of the number of targets detected. Aphasic and control subjects performed similarly in Condition A, the single task of auditory vigilance. The mean number of targets identified (out of 60 possible) during the single task was 60.0 ($SD = 0.00$) for the control group and 58.6 ($SD = 2.55$) for the aphasic group. During Condition B, the dual task, the control group performed the auditory vigilance task with the same accuracy as in Condition A, while the aphasic groups' performance declined markedly. The mean number of targets identified during the dual task was 60.0 ($SD = 0.00$) for the control group and 23.5 ($SD = 19.04$) for the aphasic group.

Although this experiment was designed to accommodate analysis by a 2×2 repeated-measures analysis of variance, the lack of variability in the control group precludes such a comparison. Data were instead interpreted via one-sample t tests, evaluating the null hypothesis that aphasic subjects' mean scores did not significantly differ from 60 (the population mean derived from control subjects) in each condition. In the single task, there was no reliable difference between groups [$t(9) = -1.504$, n.s.], but in the dual task, the group difference was reliable [$t(9) = -2.69$, $p < .025$].[1] The mean number of cards sorted in the dual task was 124.0 ($SD = 12.47$) for the control group and 88.3 ($SD = 24.33$) for the aphasic group [$t(18) = -3.01$, $p < .001$]. Only one false-positive was recorded by one aphasic subject across all sessions.

Appendix B presents individual subject performance for both conditions. All subjects performed the single task accurately and with relative ease. In the dual task, subjects A2 and A9 performed in the normal range, although both showed small decrements from their single-task performance. All other aphasic subjects demonstrated considerable inaccuracy in the dual task. The source of such variability among aphasic subjects was not apparent; neither MPO nor aphasia quotients seem to fully predict the results. Informal interviews of the aphasic subjects after participation provided some insight into their difficulty. All aphasic subjects indicated that the dual task was more difficult than the single task, and several pinpointed the increased attentional burden of the dual task. One subject stated, ''Well you have this going here and this going here and you want me to do it . . . I just can't get it.'' Another subject stated, ''There's too much at once.'' Although all aphasic subjects agreed that identifying the targets was easy, 8 of 10 had significant difficulty doing so when required to simultaneously sort cards.

DISCUSSION

The results of this study further suggest that deficient allocation of attention can affect task performance in individuals with neurological injury. The aphasic subjects exhibited a marked decline in auditory vigilance when an-

[1] Nonparametric data analysis is also possible using sign tests, with groups compared several ways: Comparing control and aphasic subjects in the single task, there was no significant difference. But in the dual task, the groups reliably differed ($p < .002$). Alternatively, comparing control subjects' performance in the single task to their performance in the dual task obviously reveals no difference. But, in the aphasic group, single- and dual-task performance reliably differed ($p < .002$).

other task competed for available resources. Card sorting interfered with their ability to monitor a continuous acoustic signal for critical events, even highly salient events devoid of linguistic content. Apparently, the dual task either exhausted the aphasic subjects' attention resources or confused their allocation strategies. The results imply that deficient cognitive processes, presumably involved in normal language processing, contribute to aphasic individuals' inability to follow and comprehend auditory messages (LaPointe & Erickson, 1991).

Theoretical Implications

The results of this study are consistent with a view of aphasia that includes deficient attention and memory processes as basic determinants of auditory comprehension deficits (McNeil et al., 1991). By removing the linguistic content of the target stimuli, we built upon earlier work (LaPointe & Erickson, 1991; Bowles et al., 1992), more clearly identifying an attentional impairment in aphasia. A resource allocation model appears useful for investigating language processing deficits in brain-damaged populations. Aphasic individuals demonstrate an inability to properly allocate attentional resources to auditory signals, even nonspeech signals, in the presence of competing stimuli. This suggests that both deficient cognitive and linguistic processes are required in a comprehensive paradigm of aphasia and perhaps in an account of the variability typically found in aphasic individuals across settings (LaPointe & Erickson, 1991).

Clinical Implications

The ecological validity of aphasia treatment and assessment is a topic of increasing concern (LaPointe, 1989). Whereas typical clinical environments are artificial, even sterile, the everyday environment of the aphasic is not. The natural environment is a cascade of multidimensional stimuli that vie for available resources. Conversations occur in settings with televisions, radios, other people, street noises, children playing, telephones, and countless other distractions. A common complaint among rehabilitation therapists is that patients do well in clinical settings, but are unable to function nearly as well at home. Perhaps a goal of intervention therapy should be to more fully simulate the environment outside the therapy room and to identify environmental influences that degrade attentional performance in aphasics. Such research may help us develop strategies to desensitize aphasic individuals or train them to effectively cope with real-world distractions.

More research is needed to establish reliable assessment and treatment methods for cognitive processing deficits in aphasia. But attentional resource allocation is clearly important in aphasia and should be considered in the development of strategies to help aphasics cope with the deluge of stimuli that compete for their attention, and thereby compromise their efficiency of communication.

APPENDIX A

Demographic Data on Individual Subjects

Subject	Age	Sex	Ethnicity	Education	AQ	MPO
Aphasic 1	74.4	M	Caucasian	16 years	68.5	4.0
Aphasic 2	70.6	M	Caucasian	12 years	80.4	3.0
Aphasic 3	81.3	M	Caucasian	12 years	49.0	11.0
Aphasic 4	76.1	M	Hispanic	12 years	66.0	3.0
Aphasic 5	82.5	F	Caucasian	12 years	45.0	5.0
Aphasic 6	83.5	F	Caucasian	12 years	62.5	3.0
Aphasic 7	72.3	M	Afr-American	12 years	72.5	4.0
Aphasic 8	62.5	M	Caucasian	12 years	57.5	5.0
Aphasic 9	71.8	F	Caucasian	12 years	75.0	3.0
Aphasic 10	71.0	M	Caucasian	12 years	63.0	3.0
Control 1	59.0	M	Caucasian	16 years		
Control 2	63.3	F	Caucasian	12 years		
Control 3	68.5	M	Caucasian	12 years		
Control 4	71.6	M	Caucasian	12 years		
Control 5	85.5	F	Caucasian	8 years		
Control 6	75.3	M	Hispanic	12 years		
Control 7	81.1	F	Caucasian	12 years		
Control 8	75.6	M	Afr-American	12 years		
Control 9	77.1	M	Caucasian	12 years		
Control 10	62.0	F	Afr-American	12 years		

Note. AQ, Aphasia quotient; MPO, months post-onset.

APPENDIX B

Individual Subject Data in Both Conditions

Subject	Single-task	Dual-task	No. of cards	AQ	MPO
Aphasic 1	60	10	110	68.5	4.0
Aphasic 2	60	55	120	80.4	3.0
Aphasic 3	58	5	60	49.0	11.0
Aphasic 4	60	39	99	66.0	3.0
Aphasic 5	52	7	58	45.0	5.0
Aphasic 6	60	27	90	62.5	3.0
Aphasic 7	57	6	89	72.5	4.0
Aphasic 8	59	14	70	57.5	5.0
Aphasic 9	60	52	122	75.0	3.0
Aphasic 10	60	20	65	63.0	3.0

APPENDIX B—*Continued*

Subject	Single-task	Dual-task	No. of cards	AQ	MPO
Control 1	60	60	136		
Control 2	60	60	120		
Control 3	60	60	125		
Control 4	60	60	140		
Control 5	60	60	110		
Control 6	60	60	100		
Control 7	60	60	125		
Control 8	60	60	137		
Control 9	60	60	128		
Control 10	60	60	119		

Note. AQ, Aphasia quotient; MPO, months post-onset.

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