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Attentional Demands of Speech Listening for People with Normal Hearing and with Acquired Sensorineural Hearing Loss: A Dual Task Assessment.

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ATTENTIONAL DEMANDS OF SPEECH LISTENING FOR PEOPLE WITH NORMAL HEARING AND WITH ACQUIRED SENSORINEURAL HEARING LOSS: A DUAL TASK ASSESSMENT

By

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ABSTRACT

ATTENTIONAL DEMANDS OF SPEECH LISTENING FOR PEOPLE WITH NORMAL HEARING ANDWITH ACQUIRED SENSORINEURAL HEARING LOSS: A DUAL TASK ASSESSMENT

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The largest group of hearing aid users are individuals who suffer from acquired sensorineural hearing loss due to aging. Many members of this group report that hearing aids only partially remediate their speech listening difficulties; for them, listening to speech remains effortful, even fatiguing. The hypothesis tested here was that these listeners are compensating for their diminished ability to hear speech cues with an exceptional cognitive effort, or commitment of attention.

The study compared eight mild-to-moderate sensorineural hearing impaired subjects and eight normal hearing subjects. Their primary task was to memorize and correctly report back digit strings in competition with two separate listening conditions: meaningless noise, or a spoken passage. Fourteen of the sixteen subjects forgot more digits with speech interference. The more notable finding was that the amount of added forgetting due to speech interference was significantly greater for members of the hearing impaired group than for their normal hearing counterparts.

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INTRODUCTION

For individuals with normal hearing, listening to and understanding speech is a pleasant activity that requires little conscious effort or attention. The task only becomes cognitively effortful when the speech is degraded as, for example, when it is transmitted over a poor telephone line, or when it is masked by other co-occurring sounds. However, even under ideal conditions some cognitive resources must be devoted to speech listening and understanding. Factors that affect the amount of attention that will be required include the quality of the speech signal itself and the nature of the environment in which the speech signal is being transmitted. Thus, varying amounts of attentional resources are needed to fully process speech signals.

Particularly relevant to the present investigation are studies assessing the cognitive commitment that normally hearing listeners must make in order to understand synthetic speech. In one such study, Pisoni, Manous & Dedina (1987; see Pisoni & Greene, 1990), asked listeners to report whether the propositions conveyed by sentences were true or false. Reaction times to reach a decision proved to be significantly longer when the sentences were produced by a high quality speech synthesizer (Dectalk) than when they were spoken naturally. The authors attributed this increased response time to the added cognitive effort required to fully process the synthetic speech signal.

Luce, Feustel & Pisoni (1983) showed that encoding and maintaining synthetic speech in one's short term memory requires more capacity than does the memorization of comparable natural speech. They asked subjects to memorize visually presented digit strings and thereafter to memorize words presented auditorily where the latter were either synthetic or natural. Subjects recalled fewer of the digits in the synthetic speech condition.

The implication of these studies is that, even under ideal listening conditions, high quality synthetic speech must be processed differently than natural speech by normal hearing listeners. In effect, synthetic speech must be cognitively processed more fully which requires more time and more cognitive resources. Pisoni and his colleagues have argued that this added processing is needed to compensate for the impoverished nature of the synthetic speech signal. Synthetic speech lacks many of the phonetic cue redundancies which are present in natural speech and the listener must work to overcome this limitation.

Individuals with sensorineural hearing impairments are at risk for their ability to detect all of the naturally occurring speech cues even under conditions of optimal hearing aid fitting (Studebaker & Bess, 1982; Boothroyd, 1984; Summers and Leek, 1992). They are in effect, receiving a cue impoverished version of the natural speech signal. The purpose of the present study was to test the hypothesis that they cope in the same way that normally hearing listeners do with synthetic speech, that is, they cope by making an exceptional commitment of cognitive resources to compensate.

This possibility was tested with particular focus on the largest group of sensorineural hearing impaired listeners - those who suffer from hearing loss due to presbycusis, or aging.

PROCESSES OF ATTENTION

This study focused on an individual's allocation of attention. Attention is a central process that co-ordinates and controls performance in some task environment (Logan, 1979) and it is generally accepted that human attentional capacity is limited (Shiffrin & Schneider, 1977). Basic to the consideration of attentional demands in regards to speech understanding is the distinction between cognitive processing that is automatic and processing that is controlled.

Automatic Processing: Automatic processing is considered to be self managed or effortless, requiring little active attention in order to be carried out. For example, on hearing your own name, you cannot help but become aware of it. The perception is so ingrained as to have become virtually automatic. According to Schneider and Shiffrin (1977), these effortless cognitive processes are activated by a learned sequence of elements in long term memory, that are initiated by appropriate inputs.

Another example of an automated process is skilled reading. A good reader, once presented with a letter string, cannot help but decode its content. This may best be illustrated by the Stroop Effect. With the Stroop Effect, subjects are asked to state the physical color of words presented to them and to ignore the word meanings. However, when the words happen to be actual names of colors, for example the word yellow presented in purple ink, meaning interferes with the ability to simply state the color of the word being presented (Stroop, 1935; Logan, 1985). Upon viewing a familiar word, a reader cannot help but read it for meaning.

Controlled Processes: Controlled processes contrast with automatic processes in that the former demand more attentional resources in order to be accomplished. These processes are considered to be "temporary activations" of sequential elements that, while able to be set up quickly and easily, require additional conscious effort or attention to execute (Schneider & Shiffrin, 1977). Examples of situations in which controlled processing is necessary are search, detection, and memory rehearsal.

Important to keep in mind is that automatic and controlled processes need not be viewed strictly as opposites or dichotomies. Rather, as Logan (1985) has pointed out, they are different points along a continuum. This contention receives support from studies using synthetic speech whereby listeners' performance on speech understanding and comprehension tasks improve with practice and subsequent familiarity with the speech signal (Humes et al., 1991; Pisoni & Greene, 1991).

THE DUAL TASK PARADIGM

The particular method used to measure allocation of attention is the dual task paradigm (Anderson & Craik, 1974; Logan, 1979). Early models of attention as a single channel or single capacity (Broadbent, 1958) have been replaced by models involving multiple resources (Baddeley, 1992). However, the concept of a resource limit has remained. The fundamental premise to any dual task design is that there will be interactions among task performances if those tasks are drawing from the same limited resources. In this study, the dual tasks of interest were listening to a spoken passage or to meaningless noise and memorizing a string of digits. Storing digit strings in working memory for recall is an attention demanding, cognitively effortful task (Shiffrin & Schneider, 1977; Baddeley, 1992). And if listening to and understanding a spoken passage is, likewise, attention demanding, then it can be expected to create attentional competition, thereby degrading digit memory performance. The magnitude of the degradation becomes an index of the cognitive effort, or attention, required to process the speech passages for content. Moreover, it can be expected that if hearing impaired listeners must devote greater attention to speech processing than do normally hearing listeners, as hypothesized earlier, then hearing impaired listeners should experience proportionally greater degradation under the dual task load.

THE CENTRAL HYPOTHESIS

The central hypothesis of the present study can be restated as follows: Sensory-perceptual processing of speech is largely automatic for normally-hearing listeners and more controlled for individuals with an acquired sensorineural hearing loss, even under 'ideal' amplification and listening conditions. In other words, speech understanding requires substantially more cognitive effort, or increased attention, for listeners with sensorineural hearing impairments due to reasons such as reduced frequency selectivity and poor temporal processing, which limit their access to speech cues (Hannely and Dormann, 1983; Gagne, 1988; CHABA, 1988; CHABA, 1991).

The specific prediction to be tested here is that, relative to normally-hearing listeners, hearing-impaired listeners should suffer a greater loss in the performance of a memory task when they must concurrently focus their attention on speech understanding. If this hypothesis proves correct, then it would lend support to the contention that hearing impaired listener's speech processing requires a higher degree of controlled cognitive processes and that different processing strategies for effective listening may need to be employed by members of this group.

COGNITION, AGING, & HEARING LOSS

The focal group of this study were individuals with acquired mild-to-moderate sensorineural hearing losses who clinically demonstrated good speech discrimination abilities. When addressed casually, all of the hearing impaired individuals tested in this study appeared to follow and understand the majority of conversational content with little to no difficulty. This study sought to find out whether they were nevertheless bearing an especially high cognitive burden when speech listening, and hence were more cognitively disadvantaged than one might have realized on casual or even clinical inspection.

Since the vast majority of hearing aid users are individuals who suffer from presbycusis, the subjects in this study were drawn from the presbycusic population in order to address circumstances specific to them. The specific interest in the presbycusic population was on cognitive deficits that result from hearing loss, per se. However, aging adults often experience cognitive deficits for reasons unrelated to their hearing status (Otto & McCandless, 1987). Therefore, in an attempt to 'separate out' declining cognitive skills and cognitive effects of hearing disorders, the hearing impaired subjects in this study were selected so as to include two subgroups: "younger" presbycusics and "older" presbycusics. The control group for this study were normal hearing young adults - a group comparable to the one used to set the audiometric standards for normal hearing (ANSI, 1969). It was anticipated that the "younger" presbycusics would, overall, behave cognitively much like the control group and that the "older" group would behave less like the control group. This separation of age groups would allow for the appropriate comparisons of cognitive changes due to aging and for cognitive changes perhaps enhanced by presbycusis.

RELATED STUDIES

A hearing loss present with the elderly person does not necessitate a cognitive decline. Likewise, it also true that a cognitive decline need not be accompanied by a hearing impairment. As it so happens the group of people at highest risk for hearing losses are the same group of people who are at greatest risk for cognitive deficits (CHABA, 1988). In fact, the sort of generalized cognitive decline that accompanies aging seems to have relatively little to do with speech perception by the elderly, at least in other contexts. From their research, van Rooij and

Plomp (1991), developed the "Auditive Hypothesis" which states that speech perception is a skill that is relatively impervious to the effects of aging.

In another study, Humes et al. (1991) came to similar conclusions regarding results from speech listening tasks performed by elderly people with sensorineural hearing losses and younger individuals with either real or masked hearing losses. Hearing loss determined performance on tasks, not age differences. This design allowed for a comparison of performance based on hearing loss and not cognitive concerns per se.

To reiterate, the focus of the present study was like that of Humes et al (1991) on cognitive effects that accompany hearing loss, not on more general cognitive changes of other origin.

METHODS

Subjects: Eight normal hearing adults and eight adults with acquired sensorineural hearing loss participated in this study. These subjects were paid for their participation. The subjects with hearing loss were identified from clinical files from the Oyer Speech-Language-Hearing Clinic and invited to participate based on their audiological profiles.

Audiological Selection Criteria - Normal Hearing: The selection criterion for normal hearing participants was audiometric pure tone thresholds at or below 20 dB HL bilaterally from 250 Hz to 8,000 Hz. In addition, subjects had to perform satisfactorily on the individual tasks that, combined, comprised the dual task paradigm (see below). The eight subjects in this group ranged in age from 20 - 29 years with a mean age of 23.6 years.

Audiological Selection Criteria - Acquired Sensorineural Loss: All hearing impaired subjects had full audiological evaluations within the previous two years. The audiological criterion for participants with acquired sensorineural hearing loss was pure tone speech frequency (0.5, 1 and 2 KHz) averages (PTA) indicating bilateral mild-to-moderate hearing loss; that is, mean PTA's between 30 and 50 dBHL. Another criterion to be met by these individuals were word recognition scores of 80% or better bilaterally.

In addition, hearing losses for this group had to be bilaterally symmetrical, with ear differences at each speech frequency not to exceed 15 dB HL. Also, a listener's thresholds at each of the speech frequencies had to be similar; specifically differences among the thresholds at 0.5KHz, 1KHz, and 2KHz could not exceed 20 dB HL. Figure 1 presents a group audiogram for the acquired loss subjects. Within the speech range, these subjects had essentially flat losses. With this pattern of loss, the amplification provided by an audiometer (see apparatus section) can be considered a reasonable approximation of the target gain needed for individuals within the speech frequency range.

The eight subjects of the hearing impaired group were counterbalanced, as closely as possible, with respect to age, sex, years of hearing aid use, and use of binaural or monaural amplification devices. The subjects had varying degrees of higher frequency sensorineural loss. Hearing aid experience among the subjects ranged from hearing aid candidacy to 10 years of use. Subjects with acquired losses ranged in age from 42 - 68 years with a mean age of 57.0 years. Details regarding the individual subjects are presented in Table 1.

As previously mentioned, general cognitive deficits are known to accompany aging (CHABA, 1988). To permit a statistical dissociation of these effects for hearing impaired subjects, subject groups were chosen to represent two age groups: a 'younger' group aged 42 to 52 and an 'older' group aged 60 to 68 years. There were four members in each group.

COGNITIVE & LANGUAGE SCREENING

On the initial visit, hearing impaired subjects were administered a subset of the Peabody Picture Receptive Vocabulary test (PPVT) as a screening measure to ensure that their receptive vocabulary skills exceeded the grade level of the story passages presented to them. Specifically, all stories were intended for students at the Junior High School level and below. All subjects passed this screening. To test the level of their receptive vocabulary, they were presented 25 items from the PPVT. Those items began at the median basal item for 15 year olds

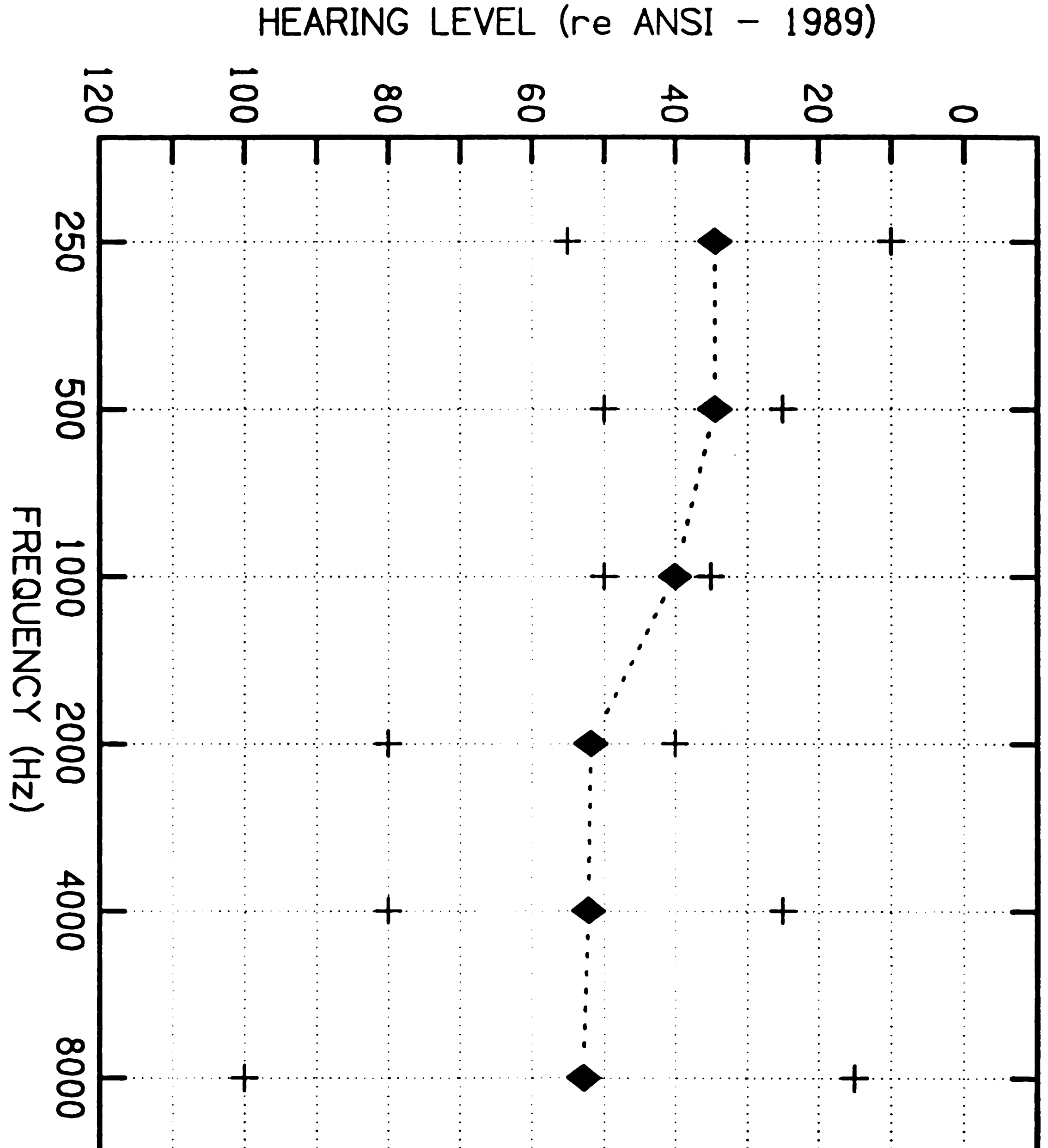


Figure 1: Combined Audiogram (test ear only) for the Acquired Loss Subjects (n=8).

TABLE 1: Personal History Details for Acquired Hearing Loss Subjects.

Subject	Age	Sex	Speech Frequency Loss	Word Recognition Scores Bilaterally	Hearing Aid Use	Monaural vs. Binaural Amplification	Years of Use
DS	42	F	Moderate	Excellent	Consistent	Binaural	< 1 year
CB	51	F	Moderate	Excellent	Candidate		
TG	52	M	Mild	Excelllent	Consistent	Binaural	< 1 year
YA	52	F	Moderate	Good	Consistent	Monaural	10 years
GS	60	M	Moderate	Good	Consistent	Binaural	8 years
DD	65	M	Moderate	Good	Occasional	Binaural	< 2 year
EE	66	F	Mild	Excellent	Occasional	Monaural	3 year
SA	68	F	Moderate	Good	Consistent	Monaural	10 years

(Item # 105, Form M). In order to be retained in the study a subject was obliged to: (1.) Correctly identify a string of eight consecutive items within the set of 25, i.e., to establish a personal basal that was greater than that for an average 18 year old and, (2.) To miss no more than five consecutive items within the list of 25 i.e., not to have reached a ceiling by the end of the list.

The First Visit - Task Familiarization and Performance: On their first visit, all subjects were administered exercises designed to familiarize them with the test procedures. At this time, subjects also chose their preferred ear for monaural listening and indicated a most comfortable listening level (MCL) for each stimulus. These levels were maintained constant thereafter. Finally, a subject's ability and willingness to participate were evaluated. Individuals who performed the individual tasks in an unacceptable manner were to be eliminated; however, no one was, in fact, eliminated from participation.

Task Familiarization - Digit Memorization: A practice block of five trials was administered to familiarize subjects with the task of memorizing digit strings. On each trial a unique seven digit string was presented visually (on a computer screen) for memorization for a period of 15 seconds. Digits were then blanked from the screen and replaced by underlines at each digit position. The underlines remained on the screen for 60 seconds. During this interval the subjects were instructed to maintain the memory of the digit string presented in any manner they chose. By report, preferred manners included repeating the digits aloud or subvocally. At the end of the interval the subjects were required to report, on paper, the content of the digit strings, with each digit presented in its correct serial position.

Task Familiarization - Speech Listening: A practice block of five trials was run to familiarize subjects with the task of speech listening. A subject listened to one minute speech passages (presented at MCL) and immediately thereafter answered, in writing, five questions pertaining to the story content. These questions were taken directly from the passage and in most instances required one word or short phrase answers. There was no time constraint imposed on the answering of these questions.

EXPERIMENTAL PROCEDURE

The actual experimental procedure was a more difficult combination of the two previously described familiarization tasks. It required, first, that a subject perform the digit memorization task according to the following protocol: A randomized digit string was presented visually for memorization for a period of 15 seconds. For most subjects the digit string length was fixed at 11 digits. This length was established as a result of a pilot study at Gallaudet University that revealed a ceiling effect for college aged subjects with the use of 9 digit strings (Rakerd, Personal Communication). For a few subjects (n=3) the digit string length departed from 11 digits in later runs to adjust task difficulty to match a subject's skill level. In these instances, the fewest digits presented was 9 and the most was 13. For two subjects the runs began at 7 digits, a modest number, and the number was gradually increased as dictated by performance. One of these subjects was incremented to 11 digits by the end of the fourth run and kept at that level thereafter. The other subject did most runs at 11 digits but, in the final two, was incremented to 13.

Digit memorization was followed by a one minute retention interval during which the subject performed one of the two listening tasks. Task NI involved listening to a one minute segment of speech noise, presented at an individually selected comfortable listening level. This condition will be referred to as the No Interference condition. Task SI required listening to a one minute spoken passage about which the listener was required to answer questions immediately after reporting the digits.

This condition will be referred to as the Speech Interference condition. A complete test consisted of 10 blocks of 5 trials in each listening condition.

Test sessions were arranged at subject convenience. Sessions involved four separate meeting times of approximately one and a half hours each. The first session dealt primarily with familiarization tasks (see above) and the completion of one block pair, where a pair comprised a five trial block with no interference and a five trial block with speech interference. The completion of the remaining nine block pairs was evenly distributed over the rest of the sessions. Breaks were given halfway through a session, and as needed. There was no time constraint for reporting either the digits or for answering content questions. Typically three experimental block pairs were completed per visit. Listening conditions were alternated throughout, with half the subjects starting in the No Interference condition and half beginning with the Speech Interference condition.

APPARATUS

During testing a subject was seated in one of two adjacent sound booths that were connected by a facing patch panel and a double-plated glass window. All equipment, including the computer screen which displayed the digit strings, was housed in the experimenters booth. The computer screen was viewed through the window from a comfortable viewing distance.

High fidelity recordings of the spoken passages and speech noise were played from a cassette tape deck (Kenwood KX46C), amplified by an audiometer (Grassen Stadler 1710) and presented monaurally via headphones (TDH-49 Telephonic). Presentation levels ranged from 60 - 80 dB SPL for hearing impaired subjects and 45 - 65 dB SPL for subjects with normal hearing.

The digit strings were produced by a random number generator, and displayed, in large font, on the screen of a personal computer (AT&T 6300). The computer also served as a timer. After the fifteen second study interval the digit string was replaced by individual place holders (underline characters). Sixty seconds after that, the screen displayed REPORT DIGITS and simultaneously a tone was presented to alert both the subject and experimenter to the end of a trial; the subject would then report digits and the experimenter would prepare for the presentation of the next trial.

THE PASSAGES

The speech passages were tape recorded in a sound treated room. They were read comfortably by a speaker who had previously rehearsed the specific text. A passage was re-recorded if either the reader or the recording 'engineer' detected a speaking error. Speech passages were taken from the 1959 edition of the Junior Britannica Encyclopedia which is intended for an audience of Junior High School students and below. Over the last three seconds of recording a speech passage, the intensity level was 'faded out' to zero. This served the dual purpose of cuing both the subject and the experimenter to the end of a trial. A single sample passage and its content questions are presented below. Additional samples appear in Appendix A.

Passage: The Opossum

Opossums belong to a group of animals called Marsupial. The females of this group have pouches on the underside of the body in which the young develop. The Kangaroos of Australia and the opossums of the United States are best known of this group. Opossums are from 9 to 20 inches long. Their fur is grayish white in color. Their round ears, long narrow tails, and the palms of their feet are hairless. The inside toe of the hind foot can be bent like a thumb to meet any of the other toes. The opossum uses his hind feet as hands. They help him climb trees. His long flexible tail is also used in tree climbing. Opossums spend alot of time in trees, hunting and eating. They like to eat upside down. To do this, they wrap their tails around a branch, hang down, and grasp their food by all four feet.

Content Questions and Representative Accepted Answers:

1. Which group of animals do opossums belong to?

   Marsupials

2. Name another member of the Marsupial family.

   Kangaroo

3. What are the colors of the opossum? Grayish White

4. What does the opossum use his hind feet as? Hands

5. How does the opossum like to eat? Upside Down

SCORING OF THE DATA

<u>The Memory Task:</u> The dependent variable in this experiment was the accuracy of recall for the digit string presented at the beginning of each trial. Digit strings were scored on a position by position basis, i.e., to be correct a digit had to appear in its specific location within the string. Subjects indicated digit position by reporting on an appropriately marked answer sheet (See Appendix B).

<u>The Listening Task:</u> In a listening task pilot study at Michigan State University, each recorded passage was played to at least three subjects under casual listening conditions. Listeners were required to answer questions, developed by the experimenter, regarding the passages. No time limit was imposed on the completion of this task. Answers were scored against an original answer list prepared by the experimenter. Questions that were responded to correctly by most listeners were kept as acceptable questions. Questions that were not answered correctly were either dropped or modified. Participants were encouraged to add questions

they felt might be appropriate. A final list, used in the study, was thus derived.

Dual Task Reporting: Subjects were instructed to immediately report digits at the completion of listening to a story passage and then to respond to the content questions. The questions were provided for subjects typed out in a separate notebook they could read from. They were instructed to record their answers to these questions in the spaces provided on the back of the digit string answer sheet (See Appendix B). They were informed also that for responding to most questions, one or two word and short phrase answers would be appropriate. Data collected on speech passages in the study were scored by the experimenter and by a second judge. Conflicts in scorer judgment were resolved by conference.

RESULTS AND DISCUSSION

Individual Subjects - Performance Block by Block: Figures 2 and 3 represent the complete data records of two subjects: Subject BD, who is a representative member of the Normally Hearing group (NH); and subject SA, a representative member of the Acquired Sensorineural Hearing Loss group (AL). Comparable figures presenting data for the remaining subjects are included in Appendix C. Symbols in these two figures indicate the number of digits that a subject correctly recalled in a block of 5 test trials, where the maximum possible number was 55 (11 digits per trial x 5 trials per block). Open squares represent performance in the No Interference condition, filled squares performance in the Speech Interference condition. Data are shown for each of the 10 blocks of trials that together comprised a full test.

Some personal history details such as age and hearing status are found at the top of the figures. Both subjects generally recalled more digits in the No Interference condition - open symbols generally lie above the filled symbols in the figures. This pattern of recall is consistent with the resource theory of attention, which holds that multiple demands on attention will cause a decline in collective performance provided that the tasks are actually tapping into the same resource. In this case, the task of speech listening combines with the task of digit memorization to create a larger demand on working memory resources, which in turn leads to poorer performance on digit recall than occurs with digit memorization alone.

Individual Subjects - Overall Performance: The difference between

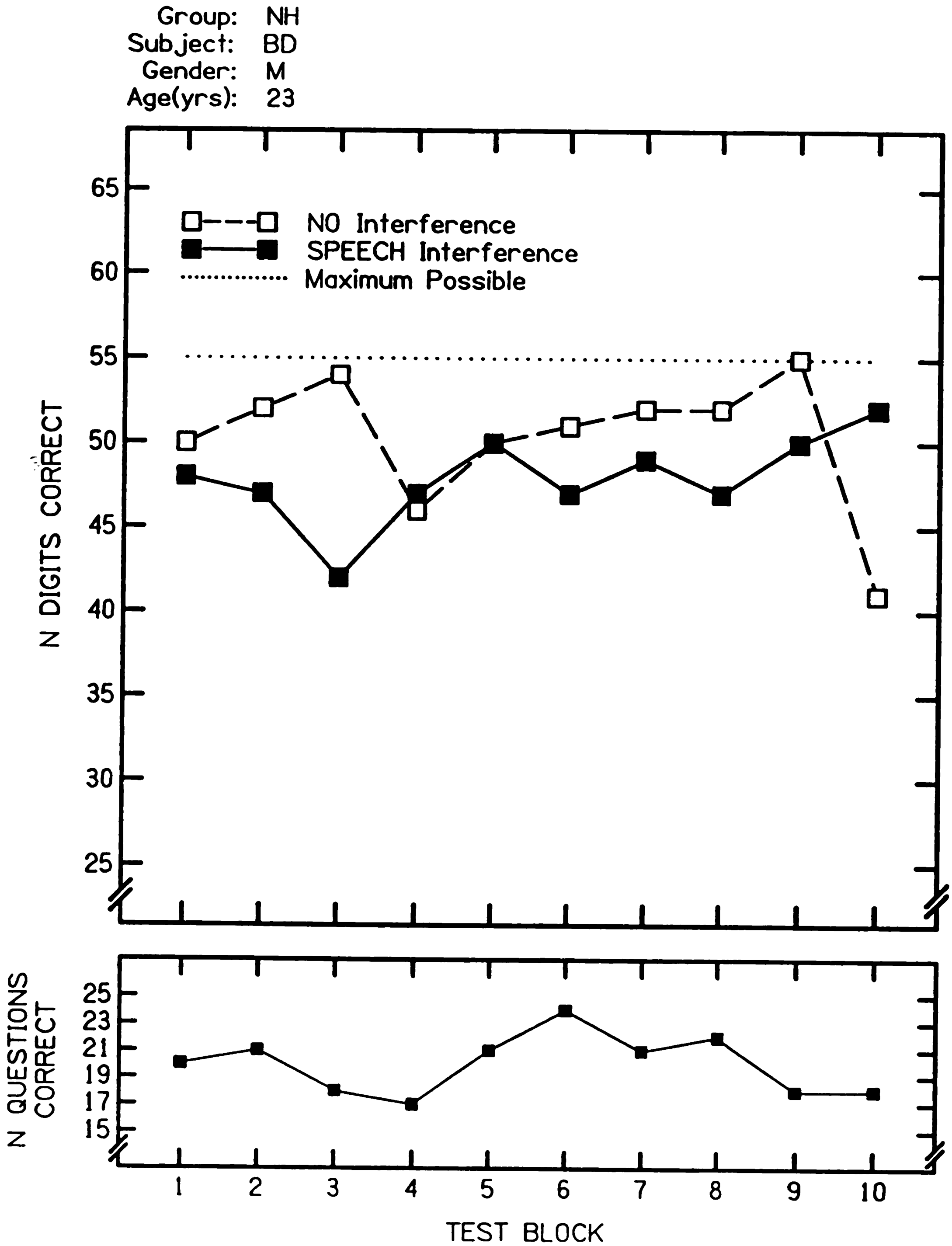


Figure 2: Block by Block Performance of Normal hearing Subject BD. The top panel shows the number of digits correctly recalled from memory in each block (maximum possible = 55). The bottom panel shows the number of content questions about spoken passages correctly answered per block (maximum possible = 25).

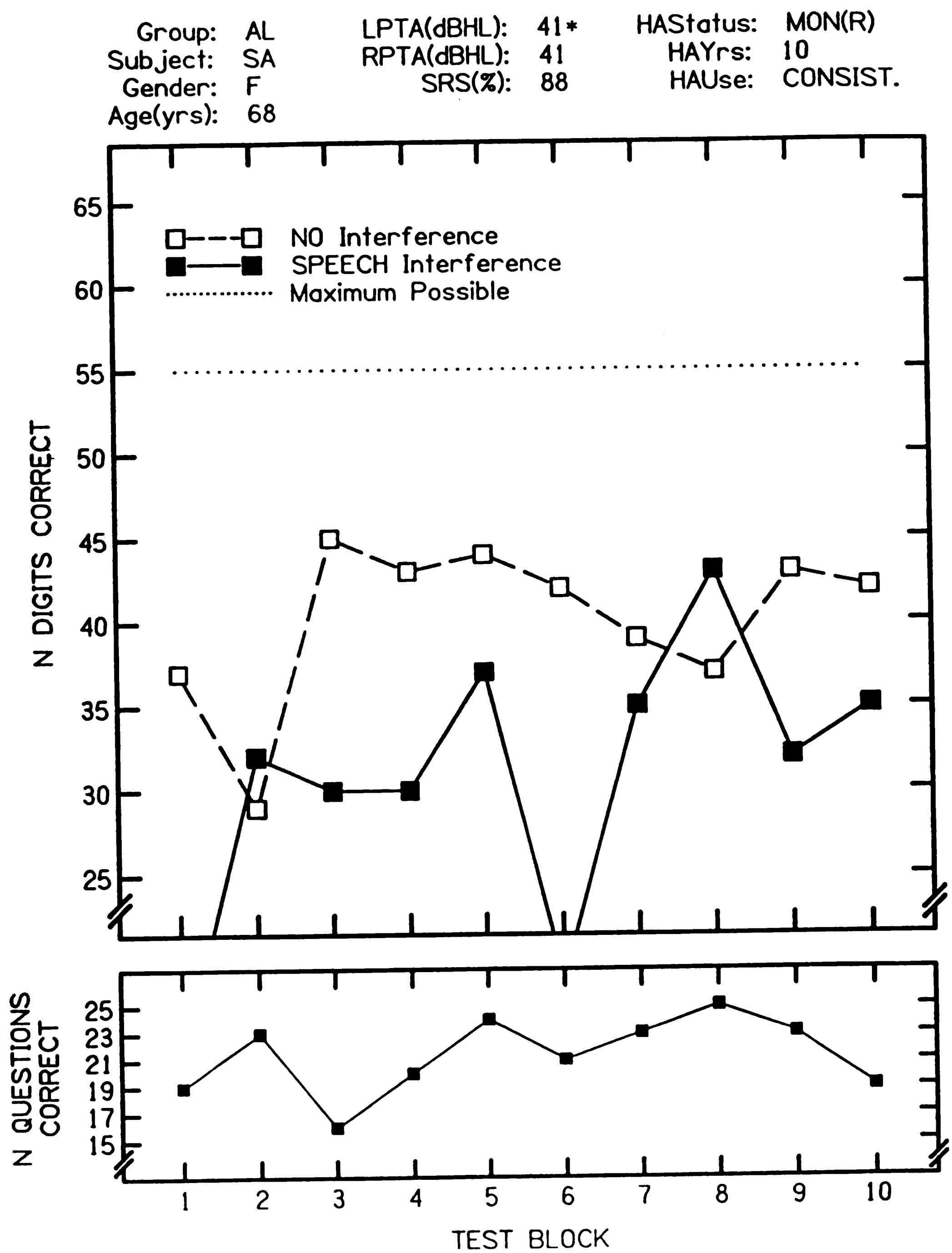


Figure 3: Block by Block Performance of Acquired Loss Subject SA. The top panel shows the number of digits correctly recalled from memory in each block (maximum possible = 55). The bottom panel shows the number of content questions about spoken passages correctly answered per block (maximum possible = 25).

mean recall in the No Interference condition (NI) and the Speech Interference condition (SI) represents an estimate of the amount of forgetting a subject experienced overall due to the attentional demands of speech listening. Normal hearing subject BD forgot an average of 2.4 digits per block due to speech listening (50.3 NI - 47.9 SI). Acquired loss subject SA forgot an average of 9.4 digits per block (40.1 NI - 30.7 SI), three and a half times as many her normal hearing counterpart.

A second point to note in Figures 2 and 3 is the overall higher baseline performance of subject BD relative to subject SA. The former recalled an average of 50.3 digits in the baseline NI condition, the latter just 40.1 digits. This difference of 10.2 digits in the No Interference condition for these two subjects is likely due to the cognitive changes that accompany aging - subject BD was 23 years old, subject SA was 68 years old. Older adults tend to perform more poorly than younger adults on a variety of cognitive tasks, including memory tasks (Moore, 1982).

The entire pattern of results exhibited by subjects BD and SA is consistent with the hypothesis that motivated this study, namely, that individuals with an acquired sensorineural hearing loss are disadvantaged for speech listening, even when listening with amplification. Specifically, they are disadvantaged in that listening is more cognitively effortful with a hearing loss, and hence draws more attention away from other concurrent cognitive activities which, in the present case, leads to added forgetting.

"Younger" vs. "Older" Presbycusics - A Comparison: As previously mentioned, the presbycusic subjects were divided into 'younger' and 'older' subgroups. When these two subgroups baseline performance on digit recall without the competition of speech listening was compared, the data did not support the anticipated result of 'younger' subjects having digit recall performance that was better and hence more like that of normally hearing young adults. In fact, there was no difference between baseline performance for the two subgroups of presbycusic subjects. ("Younger" presbycusic mean baseline performance NI condition = 39.9 out of 55; "older" presbycusics baseline performance NI condition = 39.7 out of 55). Given the near identical performance of the two subgroups, their data were pooled in all analyses.

Whole Subject Groups - Performance Block by Block: Figure 4 shows the average performance of the eight subjects in each experimental group. Specifically, the figure shows means for the eight subjects in a group on a block by block basis. As in Figures 2 and 3, open symbols represent performance under the No Interference condition and filled symbols performance under the Speech Interference condition. Squares in Figure 4 (both open and filled) show results for the normally hearing subjects, circles show results of the acquired loss subjects.

STATISTICAL ANALYSIS

Statistical differences among the means shown in Figure 4 were assessed with a three factor (1 between, 2 within) mixed model analysis of variance (Meyers, 1972), as detailed in Table 2.

Cognition and Aging: GROUP, a two-level (NH=normal hearing, AL=acquired loss) between-subjects factor indexed the cognitive effect of aging remarked earlier. On average, the younger, normally hearing subjects were able to remember 9 more digits than their elderly hearing impaired counterparts (mean NH=47.4, mean AL=38.4); this difference was significant [$F(1,14)=7.71$; $p=0.014$].

Attention and Speech Listening: INTERFERENCE was a within-subjects factor with two levels (NI=No Interference, SI=Speech Interference). On average, the sixteen subjects recalled 44.6 digits per block with no interference and 41.2 digits with speech interference. The difference of

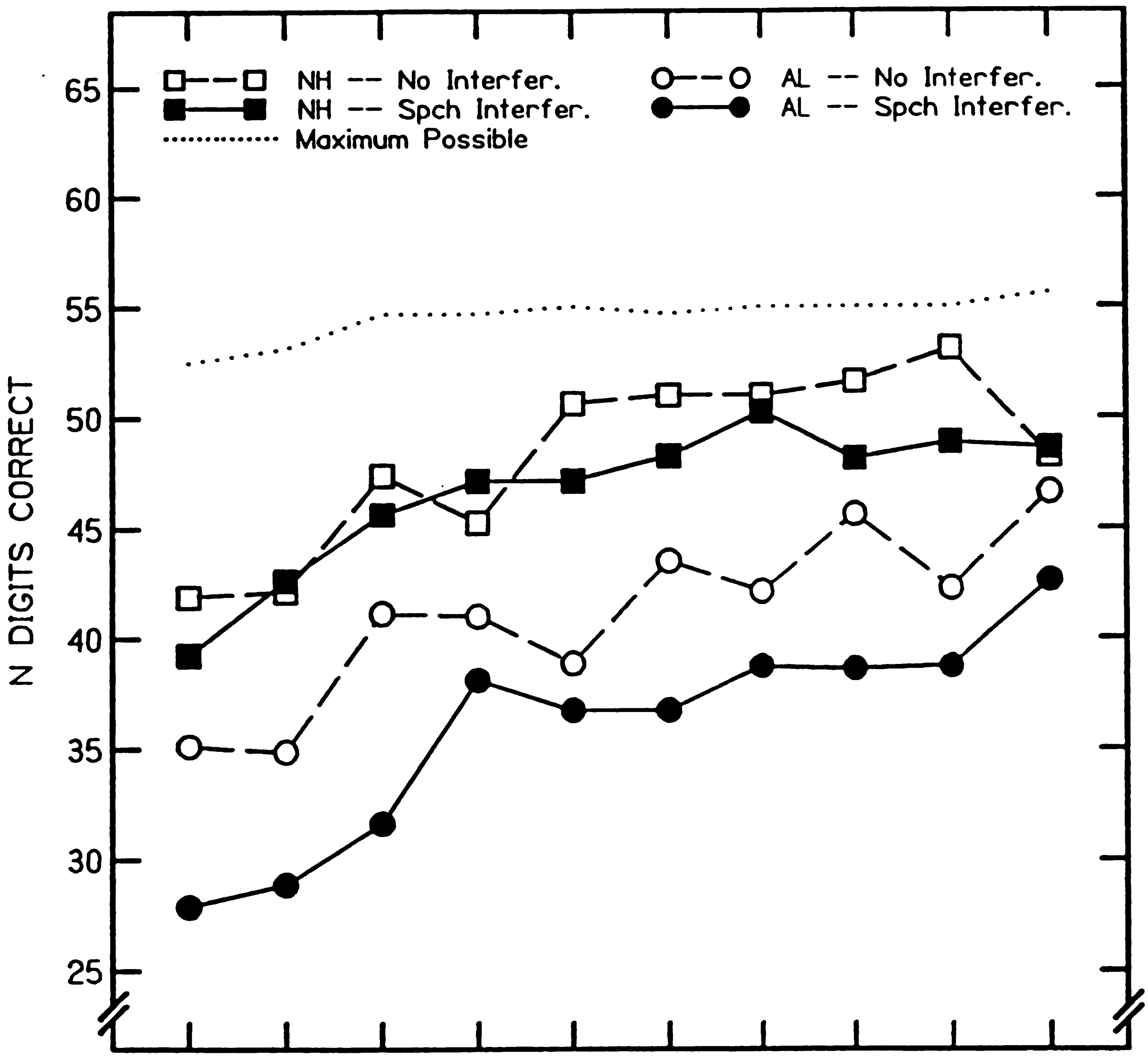


Figure 4: Average Performance of the Eight Subjects in Each Experimental Group Presented on a Block by block Basis. Open and filled squares represent results from the normal hearing group; open and filled circles represent results from the acquired loss group.

3.4 digits, which was significant [$F(1,14)=16.8$; $p=.001$], represents the forgetting from memory that can be attributed to the attentional requirements of speech listening in the experiment overall.

Of particular relevance to the present study is whether the magnitude of this forgetting was different for the two subject groups. The relevant means are shown in Figure 5. Normally hearing subjects forgot an average of just 1.6 digits due to speech interference, whereas acquired loss subjects forgot 5.1 digits, more than three times as many.

This interaction between GROUP and INTERFERENCE was significant [$F(1,14) = 4.6$; $p< 0.05$]. This finding supports the hypothesis under test. The acquired loss group was influenced by the added cognitive demand of speech listening to a greater extent than the normally hearing group. However, the normally hearing listeners were not completely immune to the cognitive demands of speech listening and, although to a much lesser extent, were consistently influenced by the presence of story passages.

Practice: BLOCKS was a second within subjects factor included to test the possibility that there were practice effects across the 10 block pairs of trials comprising an experiment. The generally upward slope of the functions shown in Figure 4 suggests that there was a practice effect and, indeed, the main effect of Blocks was significant [$F(9,126)=14.84$; $p=0.000$].

Importantly, however, neither of the other two factors significantly interacted with BLOCKS; nor was there a three way interaction ($p > 0.05$). Hence the practice effects were roughly equal for the two subject groups, both when they were listening with and without speech interference.

Note that the performance of the acquired loss group never approached that of the normally hearing group at any point. Also note that neither group had reached "ceiling" by the end of the study.

TABLE 2: Results of Analysis of Variance Performed on the Data Presented in Figure 4.

Variable	Source	DF	SS	MS	F-Ratio	Probability
	Between Subjects					
Group	A	1	6354.6	6354.6	7.71	0.015
	S/A	14	11545.6	824.6		
	Within Subjects					
Interference	B	1	945.3	945.3	16.8	0.001
	A/B	1	259.2	259.2	4.6	0.050
	SB/A	14	788.1	56.3		
Block	C	9	3986.7	442.9	14.84	0.000
	AC	9	365.8	40.6	1.36	0.212
	SC/A	126	3761.5	29.9		
	BC	9	210.1	23.3	0.97	0.465
	ABC	9	146.8	16.3	0.68	0.725
	SBC/A	126	3021.5	24.0		

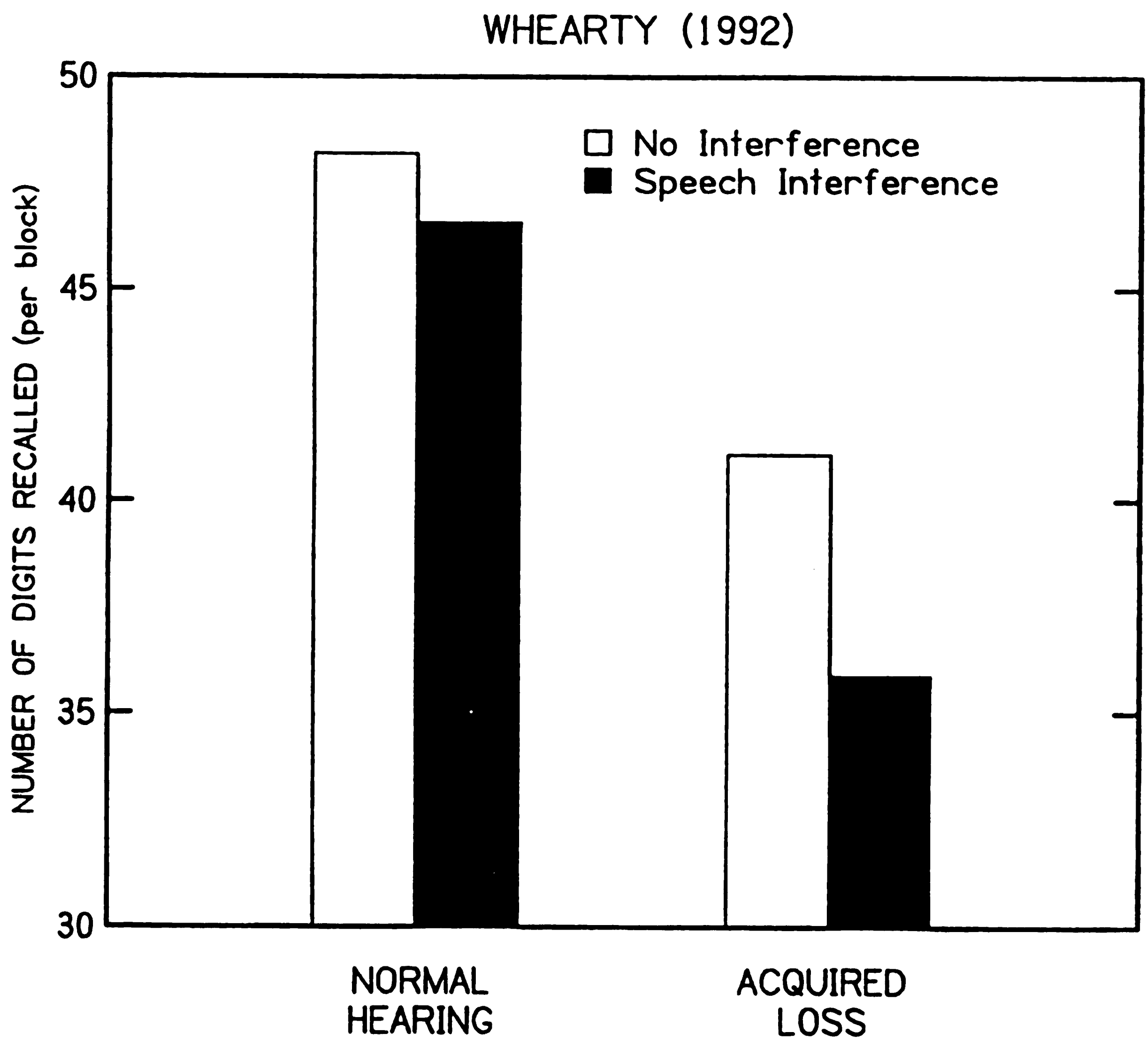


Figure 5: Average Performance of the Eight Subjects in Each Group for the Study Overall.

INDIVIDUAL DIFFERENCES

Figures 6 and 7 show the amount of forgetting due to speech interference that was measured for each individual subject. Figure 6 presents the "raw" scores, i.e., the mean difference between the number of digits remembered under no interference and speech interference conditions. In Figure 7, the data have been scored relative to a subjects' baseline performance level in the NI condition to adjust for the cognitive differences between subject groups. Specifically, the number of digits a subject forgot due to speech interference has been expressed as a percentage of the No Interference mean, as follows:

$$\% \text{ Forgotten} = \frac{(\text{Mean NI} - \text{Mean SI}) \times 100}{\text{Mean NI}}$$

The "raw" and percentage analyses (Figures 6 and 7) tell a similar story about the performance of individuals in the two subject groups, although the between group differences are more apparent in percentage terms.

Normally Hearing Subjects: Under both forms of analysis, six of the eight normally hearing subjects performed in a comparable fashion, with forgetting of about 1 to 5 digits or 2 to 10%. The two remaining NH subjects had negligible amounts of forgetting (JS), or measurable "negative" forgetting (AR). Possible reasons for these results are discussed later in this paper.

Acquired Loss Subjects: Regarding the percentage digits forgotten (Figure 7), six of the eight acquired loss subjects performed more poorly than even the worst normally hearing subject. The data reported in Tables 1 and 3 regarding personal and audiological information were analyzed to determine whether any of that information suggested a basis for distinguishing between these six acquired loss subjects who had notable

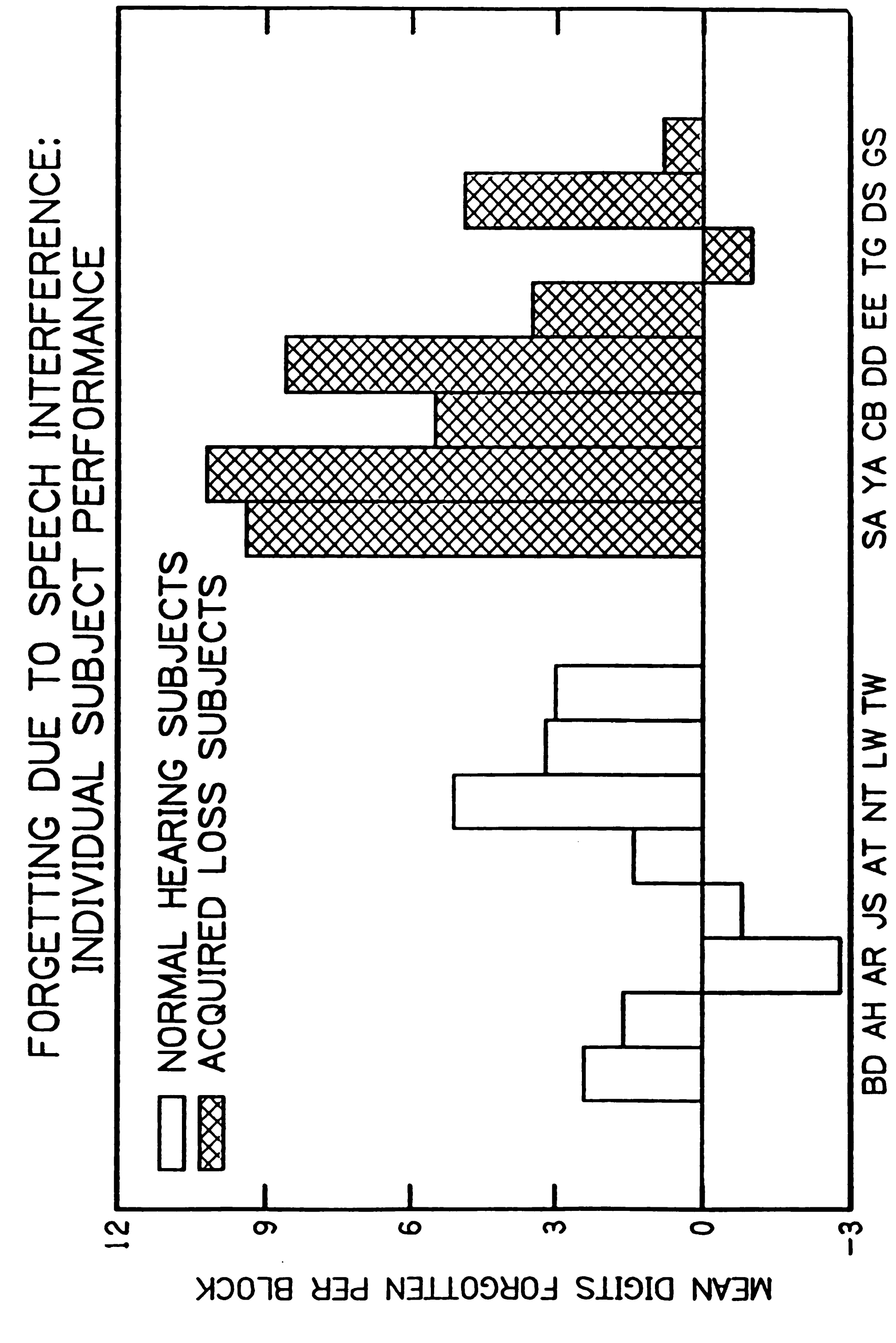


Figure 6: Overall Performance of Individual Subjects. Reported are the number of digits forgotten due to speech interference. This value is the difference between the number of digits recalled with no interference and the number of digits recalled with speech interference.

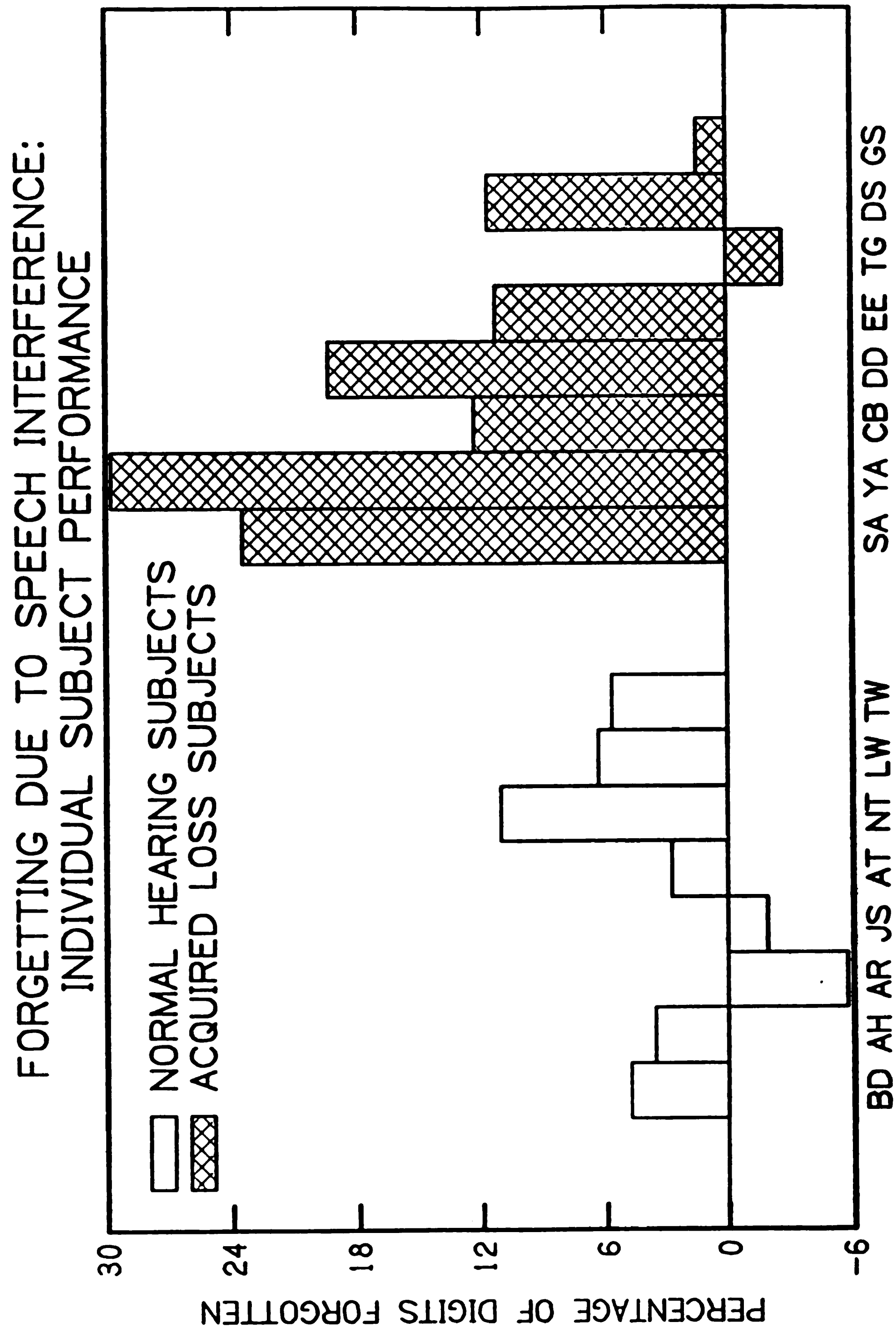


Figure 7: Overall Performance of Individual Subjects. Reported are the number of digits forgotten due to speech interference (see Figure 6) expressed as a percentage of the number of digits recalled in the no interference condition.

difficulty and the two who did not. No basis could be found. Factors that were considered included: age, sex, PTA for the test ear, higher frequency loss (i.e. > 2KHz), hearing loss configuration, word recognition score for the test ear, selected comfortable listening levels for both conditions, frequency of hearing aid use, hearing aid configuration (i.e. monaural vs. binaural amplification), years of hearing aid use, type of hearing loss (i.e. purely sensorineural or mixed); average number of questions answered correctly over all test blocks of speech listening and, case histories. This lack of correlation suggests that the underlying pathology of a mild-to-moderate sensorineural hearing impairment, common in all subjects, played the key role in determining task performance.

Two subjects of interest are members from the smaller acquired loss subgroup having overlapping performance with certain individuals from the normally hearing group. Subject TG shared similarities in task performance with normally hearing group member JS to some extent, but more so with subject AR, in that the speech interference task did not influence digit recall performance as would be expected; the presence of story passages did not adversely influence digit recall ability under that condition. To the contrary, it led to a slightly "negative" effect. The only detectable similarities between these two subjects comes by way of anecdotal remarks. Both said it was easier to remember digits when a story passage was presented because it allowed them to focus their attention on the task at hand, digit memorization, and both felt the presentation of speech noise alone to be distracting.

Subject GS can be compared to another member of the normally hearing group, TW. Both GS and TW were presented with longer digit strings of 13 on later trials due to ceiling effects with 11 digits. These two subjects share a common background regarding work with numbers. GS was an accountant who reported that he encoded the 11 digit string as an 1 - 800

TABLE 3: Subject Information: Experimental Performance; Experimental Parameters; Personal History Data.

%Digits Forgot	#Digits Forgot	Subject (Age)	Overall Frequency Loss	Story Passage MCL SPL	Speech Noise MCL SPL	Mean # Questions Correct	Case History
29.7%	10.2	YA (52)	Moderate Severe	85	70	18	Vision/ Tinnitus
19.4%	8.6	DD (65)	Moderate Severe	75	70	17.3	Noise Exposure
23.4%	9.4	SA (68)	Moderate	85	70	21.3	Vision
18.0%	3.5	EE (66)	Mild Moderate	75	60	17.9	Vision
12.3%	5.5	CB (51)	Moderate Mild	75	65	14.9	Vision/ Ear Infections
11.6%	4.9	DS (42)	Moderate	70	60	13.9	Vision/ Ear Infections
******							
1.4%	2.0	GS (60)	Moderate Severe	90	80	20.7	Vision/ Tinnitus/ Noise Exposure
-2.7%	-1.0	TG (52)	Mild Moderate	75	70	18.4	Vision/

number and subject TW was a student studying mathematics. While GS may not have been as cognitively taxed as those who did not devise such effective memorization strategies, the presence of speech passages nevertheless impaired his ability to correctly report digits under that condition.

The two members of the acquired loss group, TG and GS, have already been discussed in relation to members of the normally hearing group but have not been compared to one another. No compelling similar characteristics between the two subjects could be found. The only characteristic that could be considered a similarity between subjects TG and GS was use of binaural amplification, however, this use is not exclusive to these two subjects and the years of use discredits that similarity due to the fact that TG is a new user of binaural hearing aids and GS has been using binaural amplification consistently for eight years.

Subjects SA, YA, CB, DD, EE, and DS comprise the larger portion of the acquired loss group - those who were cognitively burdened by speech listening. Their heterogeneity is apparent in the following summary of personal variables. The ages of these subjects range from 42 (DS) to 68 (SA) years, one member of this group was male (DD). All hearing losses for speech frequencies except one, which was mild (EE), are characterized as moderate with higher frequency losses ranging from mild to severe including one subject (DD) with a conductive component at that level. Word recognition scores ranged from 80% to 100%. Dissimilar patterns, years and type (monaural vs. binaural) of hearing aid use ranging from hearing aid candidacy (no use at present time CB) to 10 years of use (SA) are also characteristic of this group.

Considering performance on story passage questions does not reveal anything either. While TG and GS performed comparably with each other on story content, their scores fall in the midrange of the other members of the acquired loss group who performed more poorly on digit recall measures.

In a review of case histories, all subjects except DD reported a visual impairment. At least one member of each subgroup had a history of noise exposure, ear infections and tinnitus. Two subjects (SA and EE) had no related audiological complaints in their case histories other than hearing loss. Both of these individuals did report visual impairments and were part of the cognitively affected subgroup.

From these findings, there is no strong evidence that any one of these, or any combination of these factors are in and of themselves critical in the determination of attentional requirements for speech listening. Rather the attention demand appears to be a quite general phenomena that is likely to affect most individuals who have at least a moderate acquired sensorineural hearing loss.

SUMMARY

This study was designed so that conditions would at least approximate those of hearing aid listening for the ear under test: A relatively flat loss over the speech frequency range was corrected by amplification to MCL with an audiometer. It is apparent that amplification of this type was insufficient to overcome the speech processing difficulties by elderly hearing impaired individuals who were obliged to listen to a lengthy and unfamiliar sample of speech.

The findings reported here are supportive of the hypothesis that individuals with acquired sensorineural hearing loss, are placed at a cognitive disadvantage when speech listening, particularly when listening in conjunction with another attention demanding task. Consistent with this hypothesis, subject SA made verbal reports throughout the experimental procedure that either the digit string, after the presentation of a story passage, was "completely gone" or "it was as if it never happened". Due to an increased effort, or greater attentional demand on the part of the listener, or due to the presence of speech that is not easily decoded by the individual with a compromised auditory system, this is the dilemma in which these individuals are placed. SA also commented that "it was one or the other"; that is, she found it difficult to divide her attention between digit recall and attending to a speech passage. Again, this may be related to speech signals requiring a greater amount of processing time due to a lack of accessible phonetic cues and a lack of natural language redundancy provided by those cues to facilitate the decoding of the message.

That subjects with normal hearing generally forgot more digits under the Speech Interference condition than No Interference condition, supports the premise that some cognitive resources must be devoted to speech listening and understanding even under the most ideal circumstances. As suggested by Logan (1979), this indicates that speech understanding is in fact only automatized by degree, along a continuum.

THE SPEECH PASSAGES

Speech Understanding Under A Dual Task Load: As noted above, some care was taken in the selection of passages for the speech listening condition of the study and in the development of content questions assessing listeners' understanding of those passages. This section reports the details of subject performance regarding these materials.

Table 4 shows the number of questions answered correctly out of 25 by each subject in each test block. It shows that members of the acquired hearing loss group perform more poorly on answering content questions than do normally hearing listeners under the dual task of digit memorization. The combined mean number of questions answered correctly for the normally hearing group was 19.5, compared to 17.6 for the acquired loss group. Also, the overall pattern of normally hearing individuals having a higher level of performance or being influenced to a lesser extent on digit recall by additional cognitive demands is clear. On average, per block, the acquired loss group never out-performed the normally hearing individuals on this task.

Interestingly, a similar pattern of content question errors is followed by both subject groups. Story blocks that proved difficult for the normally hearing individuals, also proved difficult for the individuals with acquired hearing losses.

The Practice Block: All subjects answered at least 19 of the 25 practice block questions correctly. This indicates that the content of the passages was accessible to all subjects when listening without dual task pressures.

TABLE 4: Number of Questions That a Subject Answered Correctly Presented with Respect to the Test Materials. There Were Five Passages in Each Block and Five Question's Per Passage; Hence, the Maximum Possible Score in Each Block Was 25.

	Block of Passages										
Subject (NH)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**
BD	21	22	18	18	20	21	21	24	18	17	20.0
AH	22	19	17	12	20	22	19	19	21	18	18.9
AR	19	25	17	19	20	21	22	14	21	22	20.0
JS	15	19	21	11	18	18	16	19	17	14	16.8
AT	19	21	15	17	20	21	19	20	21	21	19.4
NT	19	16	16	16	21	22	21	19	18	22	19.0
LW	20	20	21	17	25	19	21	24	18	19	20.4
TW	19	23	18	21	23	21	20	22	22	21	21.0
Mean	19.3	20.6	17.8	16.4	20.9	20.6	19.9	20.1	19.5	19.3	19.5
Subject (AL)											
SA	19	23	16	20	24	21	23	25	23	19	21.3
YA	22	18	15	14	19	16	18	18	15	14	18.0
CB	13	18	12	13	15	17	19	18	10	14	14.9
DD	19	16	18	15	18	19	20	14	16	18	17.3
EE	18	20	15	17	21	17	19	17	16	19	17.9
TG	20	17	14	12	21	20	23	20	20	17	18.4
DS	12	15	15	9	17	17	14	13	13	14	13.9
GS	19	24	19	21	22	20	23	21	18	19	20.7
Mean	17.8	18.9	15.5	15.2	19.6	18.4	19.9	18.3	16.4	16.8	17.7

Response Styles: Normally hearing subjects, who were students,tended to respond to all of the questions presented to them. The lack of response to all questions for a given passage on the part of the acquired hearing loss group may possibly be attributed to their reduced exposure to 'test taking' situations or perhaps an uneasiness about writing a potentially incorrect answer.

Individual Content Questions: Content questions were intended to pose a roughly equal amount of difficulty per block of stories. Table 5 reports question difficulty as a tally of the number of times each question was missed. It also shows that the distribution of difficult and easier questions was fairly even across the passage blocks, with the exception of blocks 3 and 4 which were somewhat more difficult than the others. However, it is not apparent that particular story passages influenced digit recall ability for subjects on particular blocks. It appears to be the case that the added task of attending to a speech passage was in itself sufficient in almost all cases to distract the listener from the digit recall task regardless of the story content.

TABLE 5: Tally of the Number of Subjects Who Missed Each Question About Passage Content. Maximum Possible Tally Was 16 (8 NH subjects + 8 AL subjects).

		Block of Passages									
		1	2	3	4	5	6	7	8	9	10
Passage#	Question#										
1											
	1	0	0	0	7	0	2	0	1	4	0
	2	1	7	3	8	2	0	2	13	8	7
	3	11	11	3	10	2	1	2	8	1	3
	4	14	7	5	7	8	2	0	0	2	0
	5	8	6	13	6	3	4	1	5	0	6
2											
	1	0	0	2	1	0	0	0	1	0	0
	2	1	6	5	3	2	5	1	8	2	6
	3	6	4	10	9	3	1	0	3	9	1
	4	9	3	10	1	1	3	12	6	6	6
	5	5	6	5	8	2	11	2	5	1	1
3											
	1	0	0	0	0	2	2	0	4	0	0
	2	1	5	4	7	9	1	1	10	11	3
	3	4	1	7	15	2	7	4	2	7	11
	4	5	6	11	8	4	2	3	0	0	10
	5	3	1	6	15	7	6	1	4	3	15
4											
	1	1	0	0	0	2	9	0	0	11	0
	2	4	1	16	9	3	10	9	0	9	9
	3	4	3	5	9	9	2	8	0	4	14
	4	14	1	3	0	3	4	3	0	0	3
	5	5	1	3	7	4	2	0	1	1	1
5											
	1	0	1	1	1	0	5	5	0	0	2
	2	1	6	5	3	2	11	8	11	6	2
	3	1	5	12	2	8	0	9	9	0	0
	4	6	3	1	8	0	2	5	2	5	6
	5	1	1	4	4	0	0	8	2	3	2

==

CONCLUDING REMARKS

Aging, Cognition and Speech Perception: Individuals with acquired sensorineural hearing loss due to aging - by far the largest hearing impaired group and the largest group of hearing aid users - were the focal group of this study. Members of this group, particularly those of advanced age, may be expected to have some cognitive deficits, as well as hearing deficits (CHABA, 1988). Both of these deficits, general cognitive decline and hearing loss, have the potential to influence the perception of speech. Cognitive factors influence "top down" processing and peripheral sensory factors influence "bottom up" processing. An original intent of this paper was to compare the performance on digit recall among the 'younger' and 'older' members of the acquired hearing loss group to index cognitive effects. This failed, in the end, because the digit recall performance between these two subgroups did not differ. Therefore, we were unable to 'factor out' cognitive influences due to aging. This is particularly true since control subjects with normal hearing actually learned to some extent over the course of this experiment, as evidenced by their overall improved performance on digit recall in conjunction with a speech listening task. This means that normally hearing subjects were not operating exclusively under 'automatic' processes but also were influenced by controlled processes. Speech processing in and of itself is an attention demanding endeavor for all individuals, and just how this interacts with cognitive deficits due to aging remains a matter of question.

One thing that can be said, unequivocally, is that the present findings show elderly individuals with at least mild-to-moderate sensorineural hearing losses to be "at risk" when they must listen to speech in complicated circumstances, or when involved with competing tasks. Whether the explanation for that finding will ultimately turn on their hearing loss or on aging factors cannot be so confidently stated. There are, though, several reasons to think that hearing loss will play the greater role.

AGING AND MEMORY CAPACITY

Smith and Fullerton (1981), have reported that working memory capacity changes little with aging. Therefore the results obtained here cannot be explained through an overall deficit in cognition due to aging, leaving the presence of hearing loss a factor.

Experimentally Matched Hearing Loss Among Younger and Older Listeners: In a study by Humes et al. (1991), performance on speech perception tasks by elderly hearing impaired subjects was compared to performance by normally hearing college age subjects, where the latter listened under normal conditions and under conditions of a simulated presbycusic hearing loss. The experimental design of this study is important because it allows for two separate comparisons; the first being the natural comparison of performance among the elderly and young subjects which indexes the general effects of aging, and the second, due to the intact cognitive differences in the face of matched peripheral losses, allows a comparison of performance based on hearing loss and not cognitive concerns per se.

Similar performance was observed between the two groups with hearing loss, real and masked, despite age differences. In fact, the older subjects with the actual sensorineural loss performed slightly better than the younger 'hearing impaired' group. This could be attributed to the lack of familiarity this group had with attending to speech signals in lieu of a hearing loss or conversely the ability of the elderly group with the actual hearing loss to utilize their top down processes compensating for their less accessible bottom up strategies. These results suggest that the peripheral hearing loss and not effects of cognition per se were responsible for the increased difficulty.

The Auditive Hypothesis: Further support for this line of thinking comes from research by van Rooij and Plomp (1991) who worked with speech reception thresholds (SRT's) as a measure of speech perception performance. They found that SRT's of the elderly can be predicted for better by the audiogram than by measures of cognitive skill. They are proponents of the "Auditive" hypothesis, which states that speech perception is a skill that is relatively impervious to the effects of aging.

Age Matched Comparisons for Young Normal Hearing and Congenitally Hearing Impaired Individuals: Finally, in a study at Gallaudet University, utilizing the same experimental procedures as this study, college age individuals with moderate-to-severe congenital losses were tested. When those results are compared to the data obtained from normally hearing college age subjects in the present study, there is a significant difference in ability to recall digits under the speech listening condition with the hearing impaired subjects performing much more poorly. Considering the age match, peripheral hearing loss and not cognitive factors would seem to account for this discrepancy in performance.

Hannely and Dormann (1983) caution, however, that not all sensorineural hearing losses based on audiological configuration alone can be considered homogeneous. There most likely exist great amounts of intersubject variability with varying degrees of cochlear pathology and unspecified cochlear distortions. This may account for subject variability on performance for the acquired loss group while not negating the general finding that it is predominantly hearing loss and not cognitive factors that reduce speech intelligibility.

FUTURE STUDIES

Recent studies have looked specifically at the effects of cognition due to aging and influence of peripheral hearing loss on the ability to perceive and understand speech as separate factors (CHABA, 1988). More studies are needed in this area. Regarding the present study, an additional experimental group of age matched individuals for the acquired loss group with normal or near normal hearing abilities would have allowed us to address the issue of cognitive factors more explicitly. Another approach would have been to mimic a specific hearing loss in a large group of subjects with normal hearing and compare performance on digit recall ability under some speech listening or speech monitoring condition. If performance proved to be similar among a large population of different age groups, hearing loss would be shown to be the main contributing factor to performance. However, if poorer performance tended to be among older individuals of this group, cognitive decline may be the crucial factor.

METHODOLOGICAL CONSIDERATIONS

If this study was to be extended using larger populations it would be necessary to streamline the procedure to make data collection more feasible. Ways in which it would be appropriate to modify present procedures are to reduce the total number of block pairs, perhaps from ten down to five. Subject performance after five blocks begins to plateau (see Figure 4). Perhaps analysis of the data from the last three block pairs of 5 would be sufficient, the initial two block pairs being considered practice blocks. The actual time required for an individual trial could also be reduced by presenting a 30 second story passage as opposed to a full minute segment. Finally, digits could be presented serially for a brief period each. Informal comments by subjects, and personal experiences of the experimenter suggest that this duration would be adequate. Also, serial presentation of single digits would not only tax the working memory in a different way - precluding coding of digit information - but also for practical concerns require less time.

In regards to addressing the question of cognition more directly, a simple alteration to the present method would be to employ the use of computer operated response systems that recorded response time for both digit recall and answers to content questions. Questions to story passages would be presented in a multiple choice form.

Finally, the present study required subjects to engage in a listening task that was familiar and replete with linguistic, syntactic and semantic cues. Its virtue was that the task tapped the language processing system as a whole. But perhaps the next study could begin to tap different language sub-processes. For example, a largely phonetic listening task would involve detecting the presence of a single phoneme or making the distinction between two separate phonemes. Lexical decision tasks involving the use of related and unrelated primes with their reaction times or a task involving word identification from definitions would probe higher levels of processing than phoneme detection alone. In determining the amount of attention required to more fully process a speech signal, tasks requiring syntactic and semantic decisions would be useful. This type of decision would not only entail the correct encoding of the acoustic phonetic information (bottom up processes), but would also rely on the intervention of knowledge of the linguistic rules and familiarity with the language (top down processing) by the subject. Being able to decipher which levels of processing prove to be most difficult is not only important for hearing impaired listeners but could also provide more specific insights into the cognitive demands of processing speech information.

CLINICAL NOTE

An important clinical finding from this study is the necessity of those with acquired sensorineural hearing losses to focus their attention during speech listening to the speech signal itself and avoid additional or simultaneous inputs of information. This does not necessarily imply a cognitive deficit but more specifically a hearing loss that is unforgiving of multiple channels of input in regards to speech listening.

APPENDICES

APPENDIX A

APPENDIX A

NAPOLEAN

Napolean Bonaparte was born at Ajaccio in Corsica. His father was poor but of noble blood. His mother was an energetic and determined woman. When he was a child his favorite toys were a drum and a sword. In 1779 he went to school at Brienne in France where he took great interest in history. He was especially interested in the lives of the great generals of antiquity as told by Plutarch. He entered the military school at Paris in 1784. A year later he was appointed to the artillery regiment stationed at Valence. Although his notes and essays show that he was rapidly mastering his profession Napolean spent little time with his regiment. He was determined to free Corsica which was forcibly annexed by France.

1. Who was this story about? Napolean
2. What were Napoleans favorite toys? Drum and Sword
3. Where did he go to military school? France
4. Did his notes and essays show he was rapidly mastering his profession? Yes
5. What was Napolean determined to free? Corsica

APPENDIX A

OSCEOLA

One of the most famous chiefs of the Seminoles was Osceola. He was their leader during their second war against the United States government. Osceola was the son of an Englishman named William Powell, and a Creek woman, the daughter of a chief. He was born in Georgia, near the Chattahoochee River. When he was four, his mother took him to Florida to live among the Seminoles and he became their chief. In 1832 the Seminoles signed a treaty with the United States by which they agreed to move west of the Mississippi. Osceola was angry with the white man because of unfair treatment he had received at the hands of the Indian agent, General Wiley Thompson. He urged the Seminoles not to carry out the treaty. The war began in 1835 when Osceola killed the Indian agent and his men killed 100 United States soldiers.

1. Who is the story about? Osceola
2. Who did he live among? Seminoles
3. Was Osceola the son of an Englishman? Yes
4. Where did his people agree to move? West of the Mississippi
5. Why did war begin? Osceola killed the Indian agent and his men killed 100 United States soldiers.

APPENDIX A

NATIONAL ANTHEM

During the war of 1812, British ships under Sir Alexander Cockburn shelled Fort McHenry near Baltimore. A young United States lawyer, Francis Scott Key, who had gone to make arrangements with the British for the release of a friend, was detained on board his ship during the battle. Key spent the night watching the bombardment. When morning came, and through the mist he saw the United States flag still flying over Fort McHenry, his relief and joy were so great that he was inspired to write the words of "The Star Spangled Banner." Key's lines were almost immediately set to the music of an old English song, "Anacreon in Heaven", by John Stafford Smith. The song with its new words became very popular and was officially declared the National Anthem of the United States in March, 1931. "My Country Tis of Thee", is not a national anthem.

1. Who is the story about? Francis Scott Key
2. What did Key spend the night doing? Watch Bombardment
3. What did key write? Star Spangled Banner
4. What song were the lyrics of the National Anthem put to? Old English Song "Anacreon in Heaven".
5. Is "My Country Tis of Thee" a national anthem? No

APPENDIX A

NAVIGATION

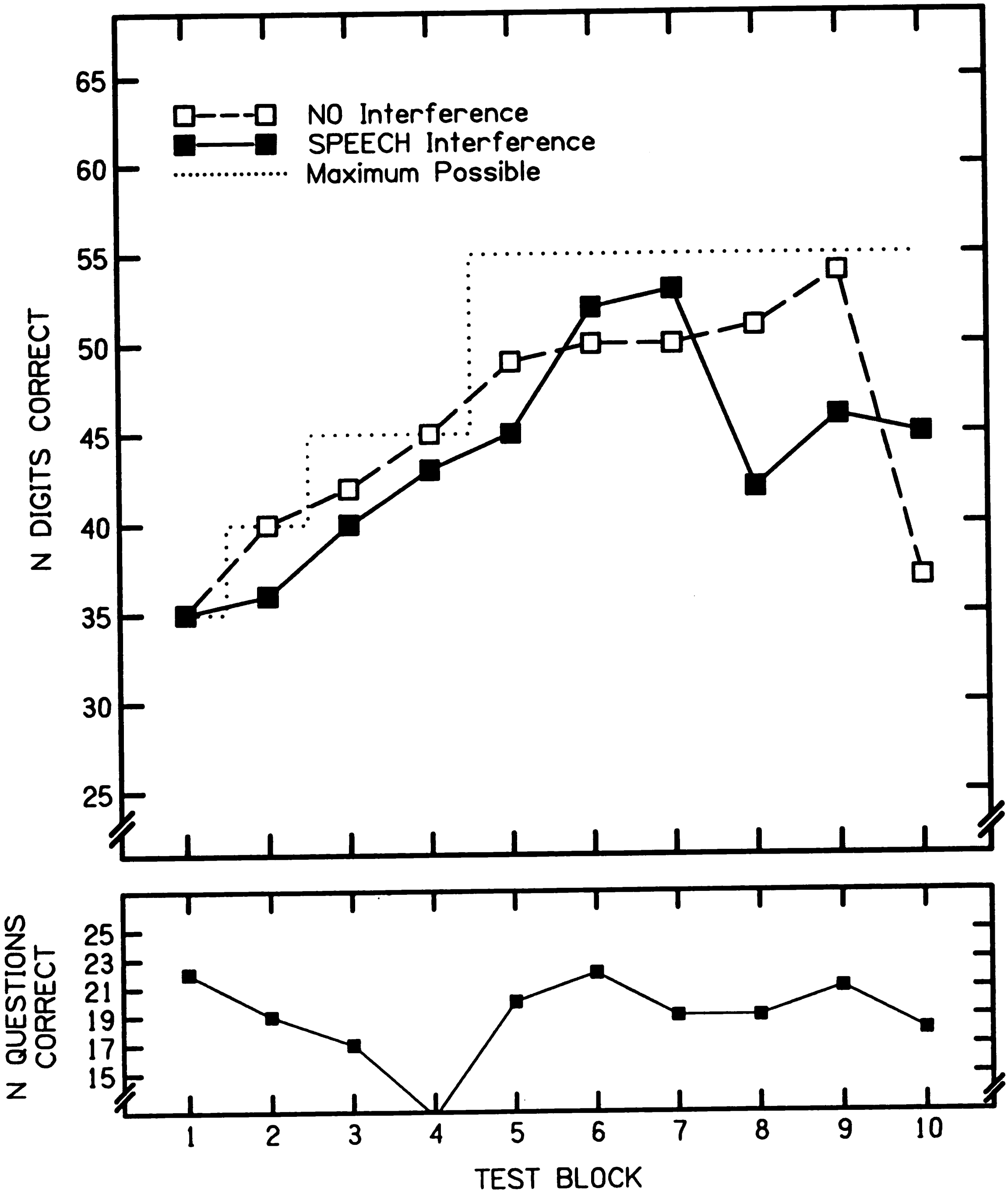
Navigation is the science of finding the position and directing the course of vessels at sea. When speaking of airplanes, the term, "air navigation" is used. Piloting is the part of this science in which a vessel's position is obtained and its course directed by landmarks, such as headlands, mountains, church steeples, lighthouses and buoys. Navigation in foggy weather by short range aids such as the radio detection finder and radar, and by measuring the depth of the water, is also called piloting. There are several very important instruments used in piloting. The compass is used for steering and for taking bearings. The radio detection finder is used to take bearings of radio beacons in foggy weather. The fathometer measures the depth of the water. The patent log is a device for measuring the speed of a ship through the water. Radar with the P.P.I. gives a continuous position of the ship.

1. Which science is this story about? Navigation
2. When speaking of airplanes what navigation term is used? Air navigation
3. What are used as landmarks for navigation? Headlands, mountains, church steeples, and buoys.
4. Name one instrument used for navigation. Compass, radio detection finder, fathometer, patten log, radar.
5. Is measuring the depth of the water also a form of piloting? Yes

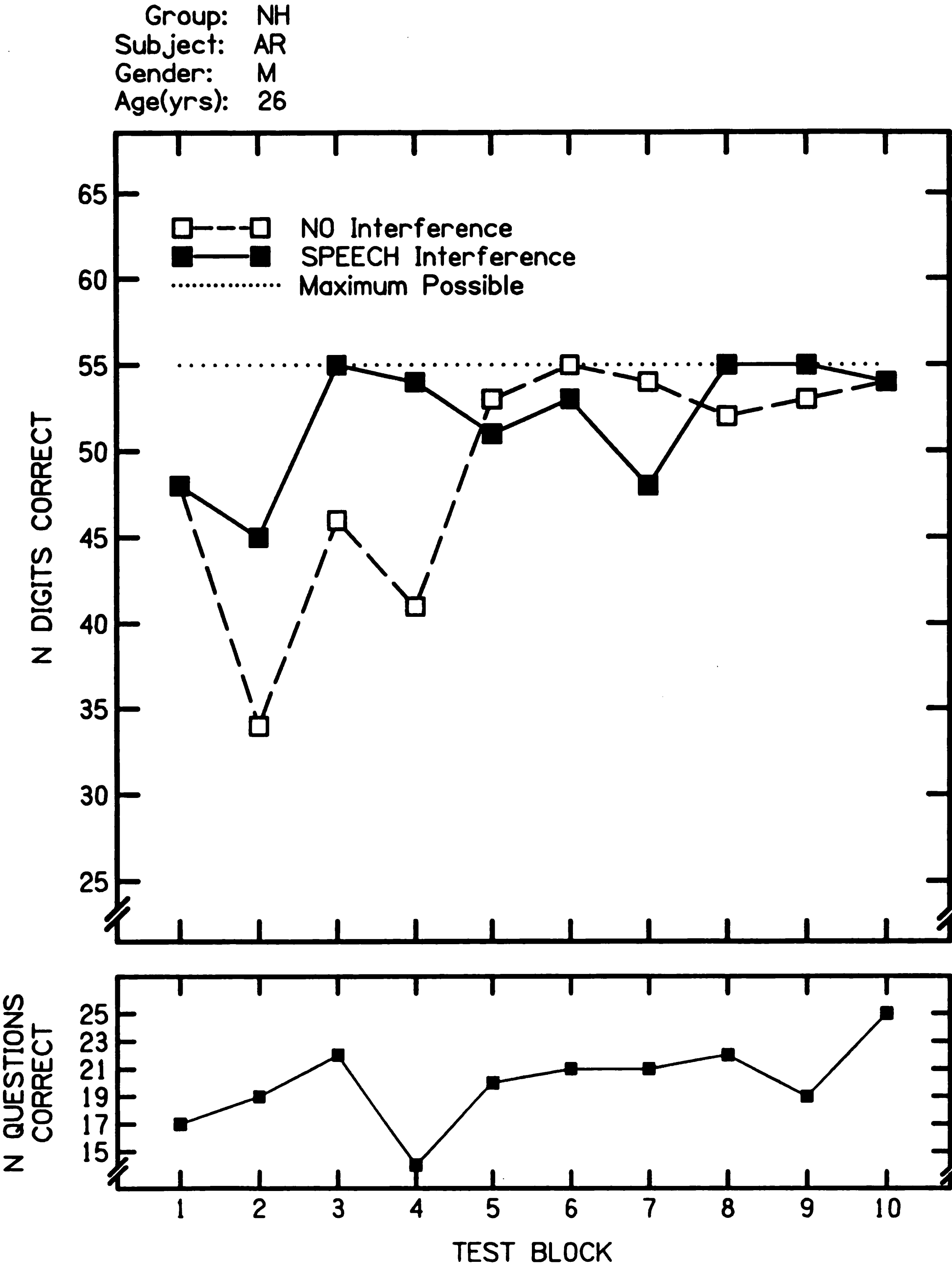
APPENDIX B

APPENDIX B

Group: NH
Subject: AH
Gender: F
Age(yrs): 21

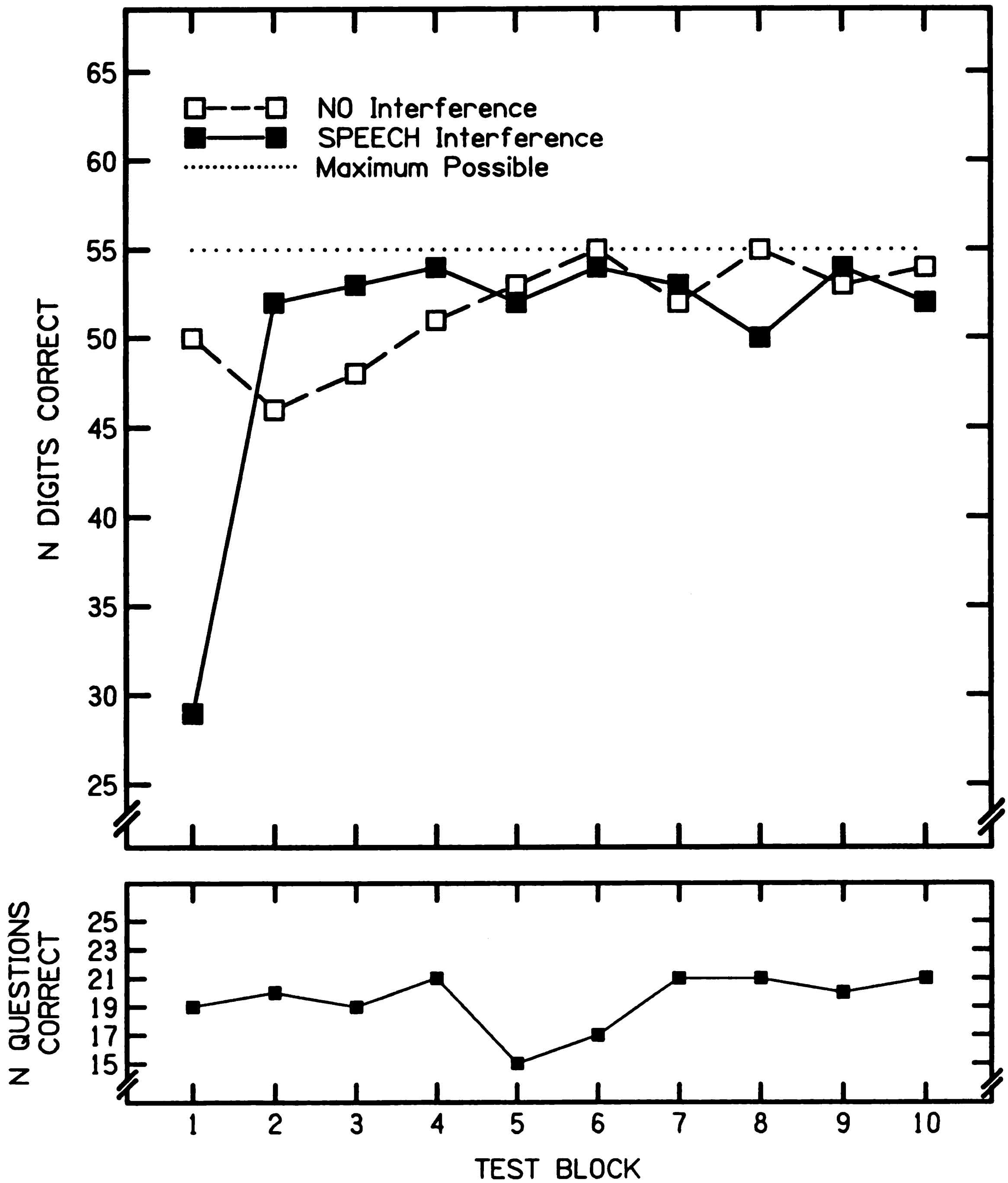


APPENDIX B

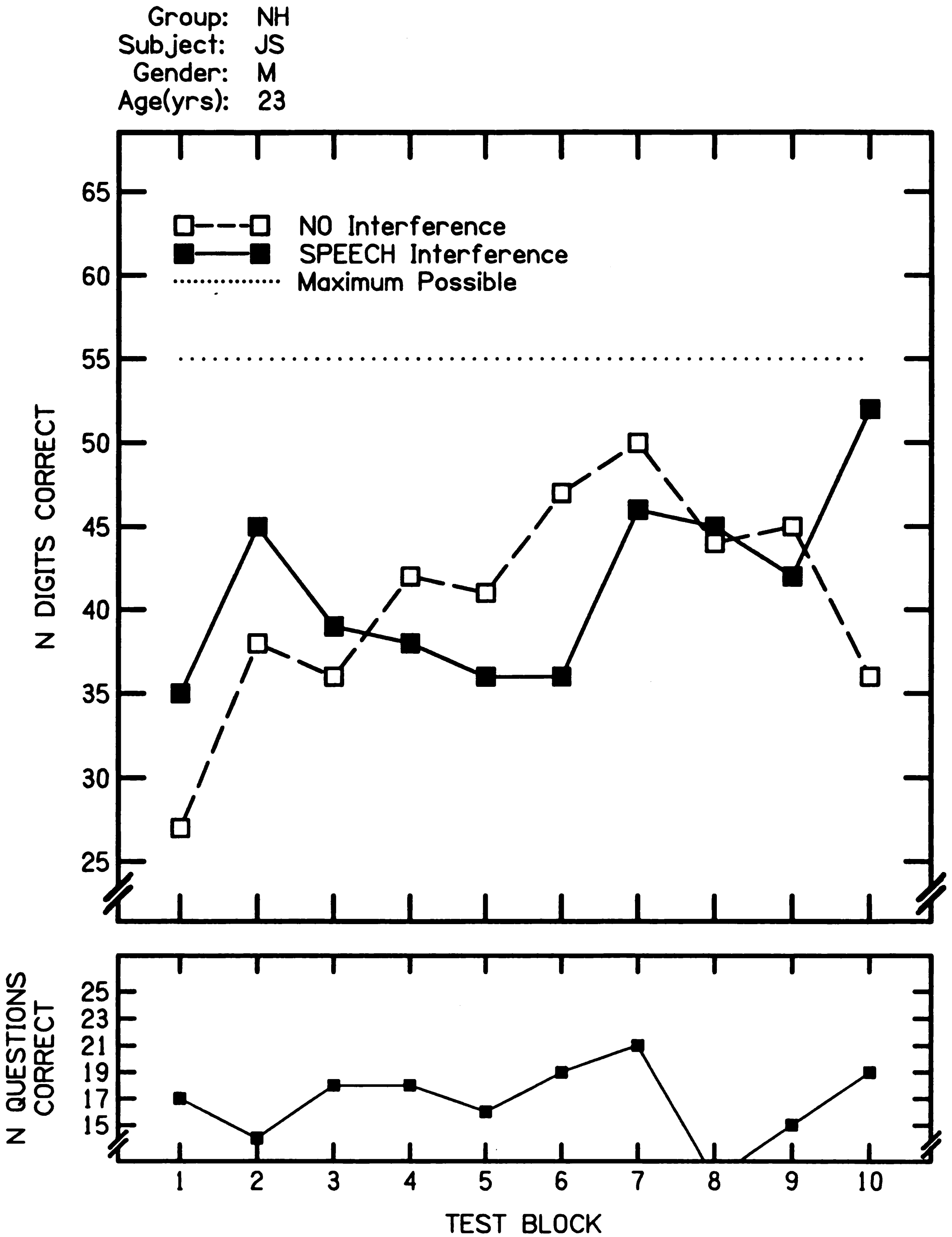

Group: NH
Subject: AR
Gender: M
Age(yrs): 26
NO Interference
SPEECH Interference
Maximum Possible
N DIGITS CORRECT
65
60
55
50
45
40
35
30
25
N QUESTIONS CORRECT
25
23
21
19
17
15
1
2
3
4
5
6
7
8
9
10
TEST BLOCK

APPENDIX B

Group: NH
Subject: AT
Gender: F
Age(yrs): 20



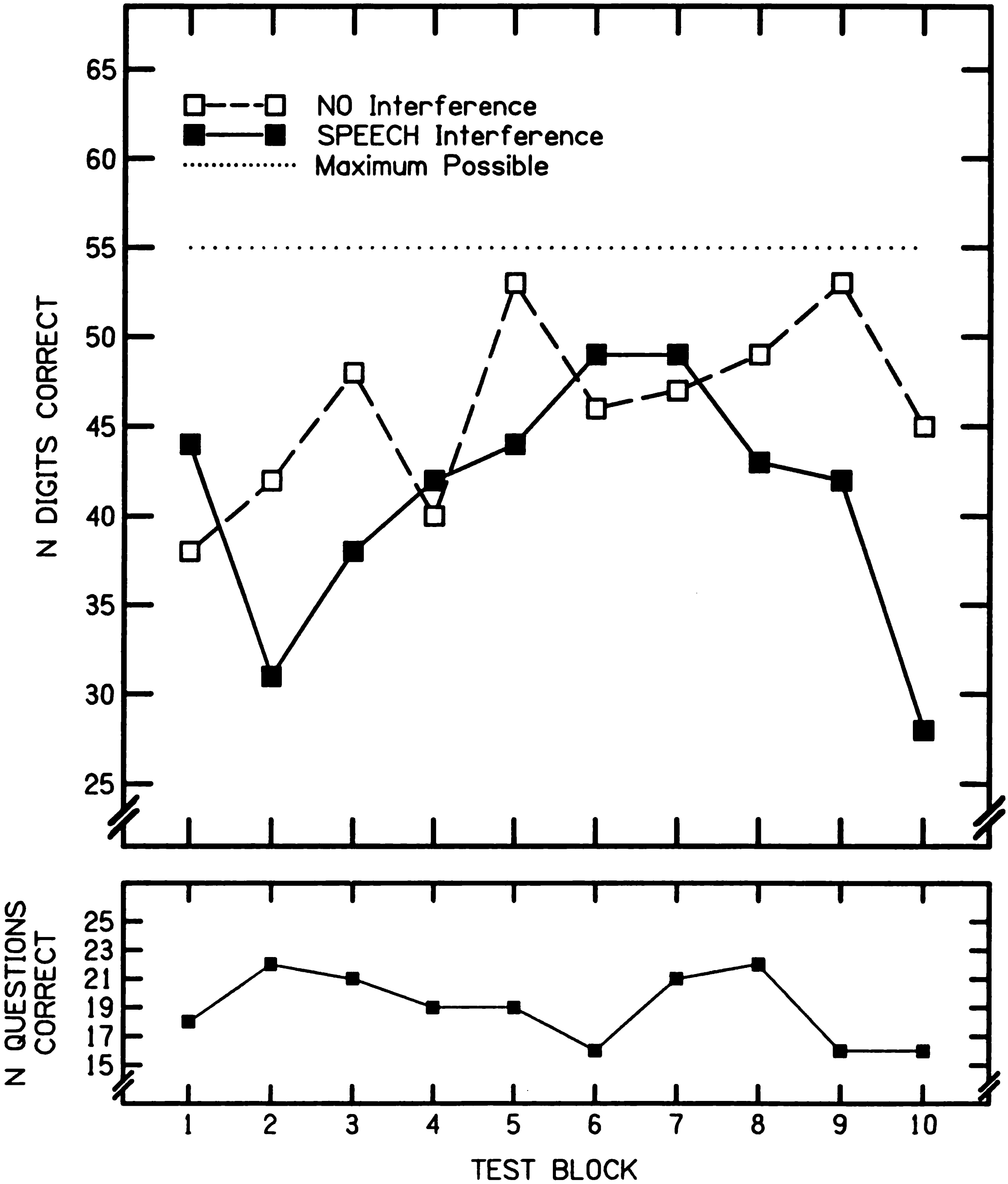
APPENDIX B



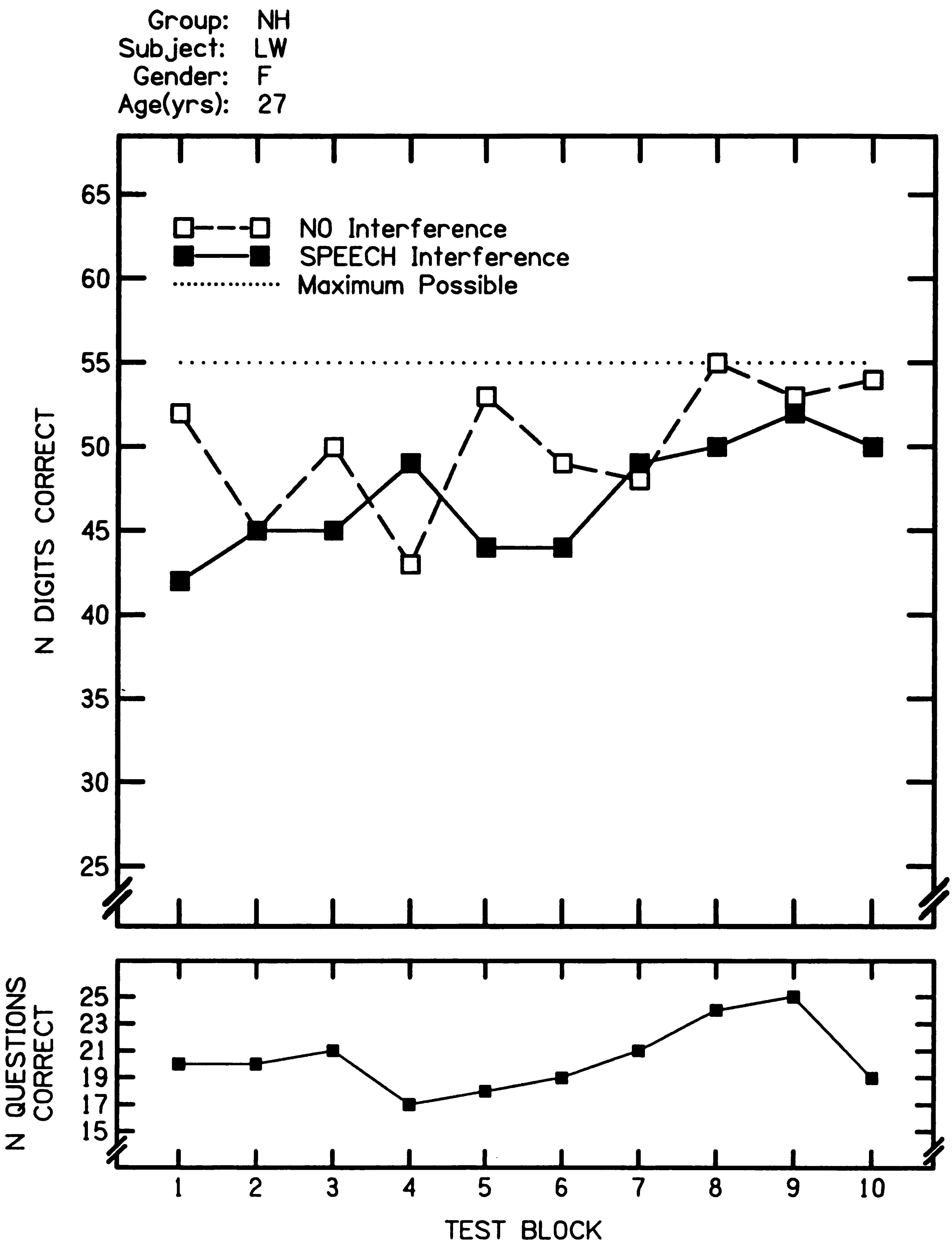
Group: NH
Subject: JS
Gender: M
Age(yrs): 23
NO Interference
SPEECH Interference
Maximum Possible
N DIGITS CORRECT
65
60
55
50
45
40
35
30
25
N QUESTIONS CORRECT
25
23
21
19
17
15
1
2
3
4
5
6
7
8
9
10
TEST BLOCK

APPENDIX B

Group: NH
Subject: NT
Gender: M
Age(yrs): 20



APPENDIX B


Group: NH
Subject: LW
Gender: F
Age(yrs): 27
NO Interference
SPEECH Interference
Maximum Possible
N DIGITS CORRECT
65
60
55
50
45
40
35
30
25
N QUESTIONS CORRECT
25
23
21
19
17
15
1
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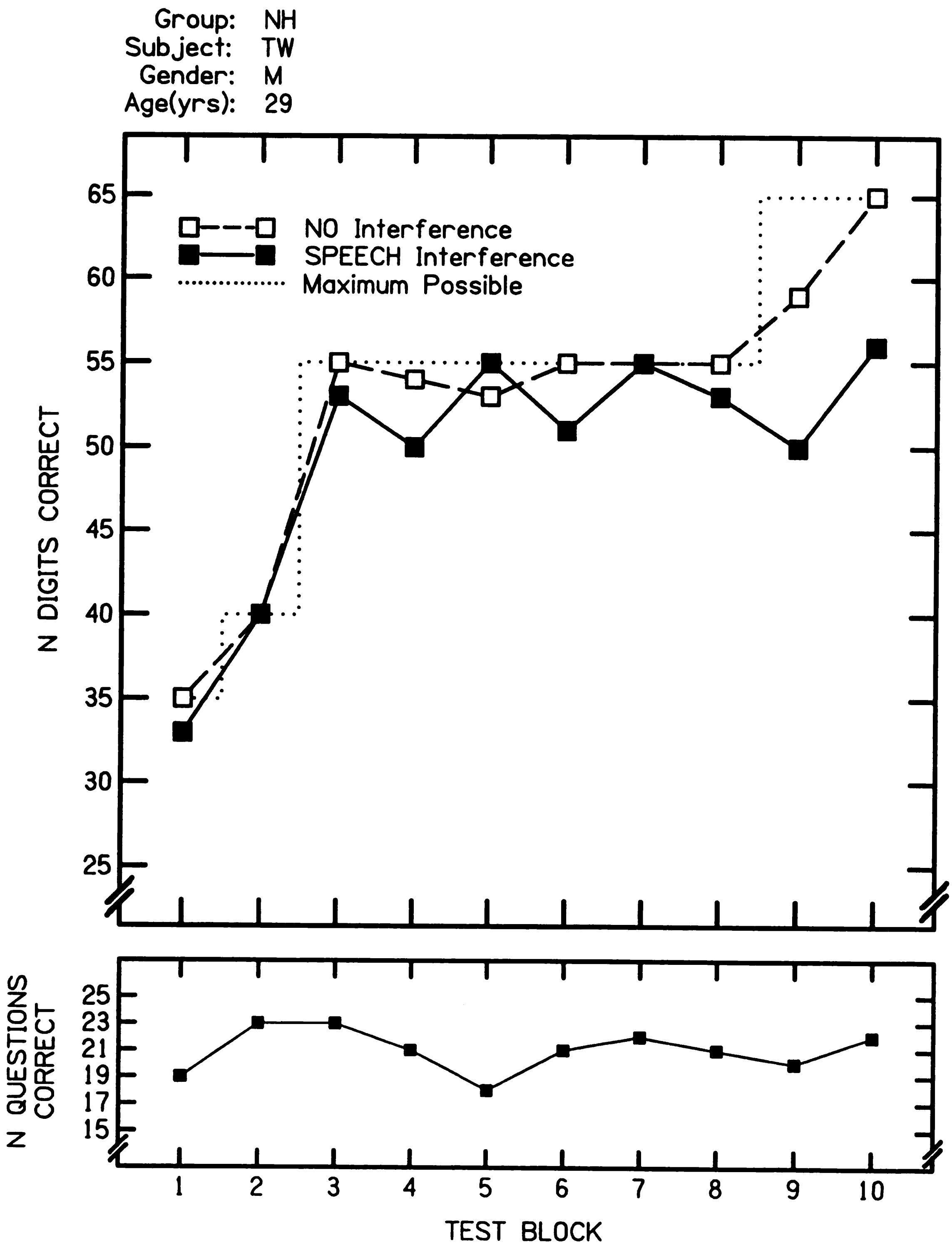
9
10
TEST BLOCK

APPENDIX B


Group: NH
Subject: TW
Gender: M
Age(yrs): 29
NO Interference
SPEECH Interference
Maximum Possible
N DIGITS CORRECT
65
60
55
50
45
40
35
30
25
N QUESTIONS CORRECT
25
23
21
19
17
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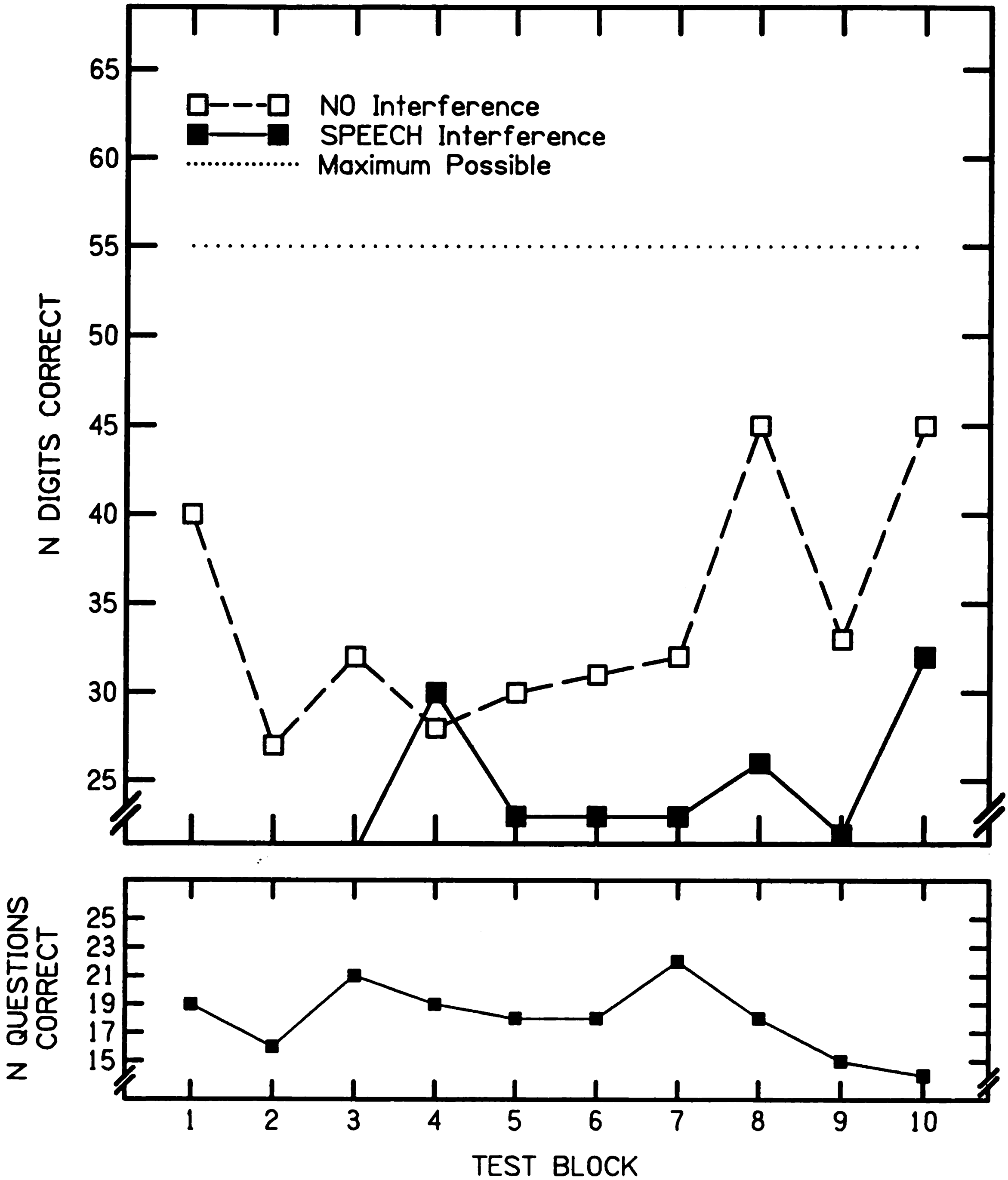
TEST BLOCK

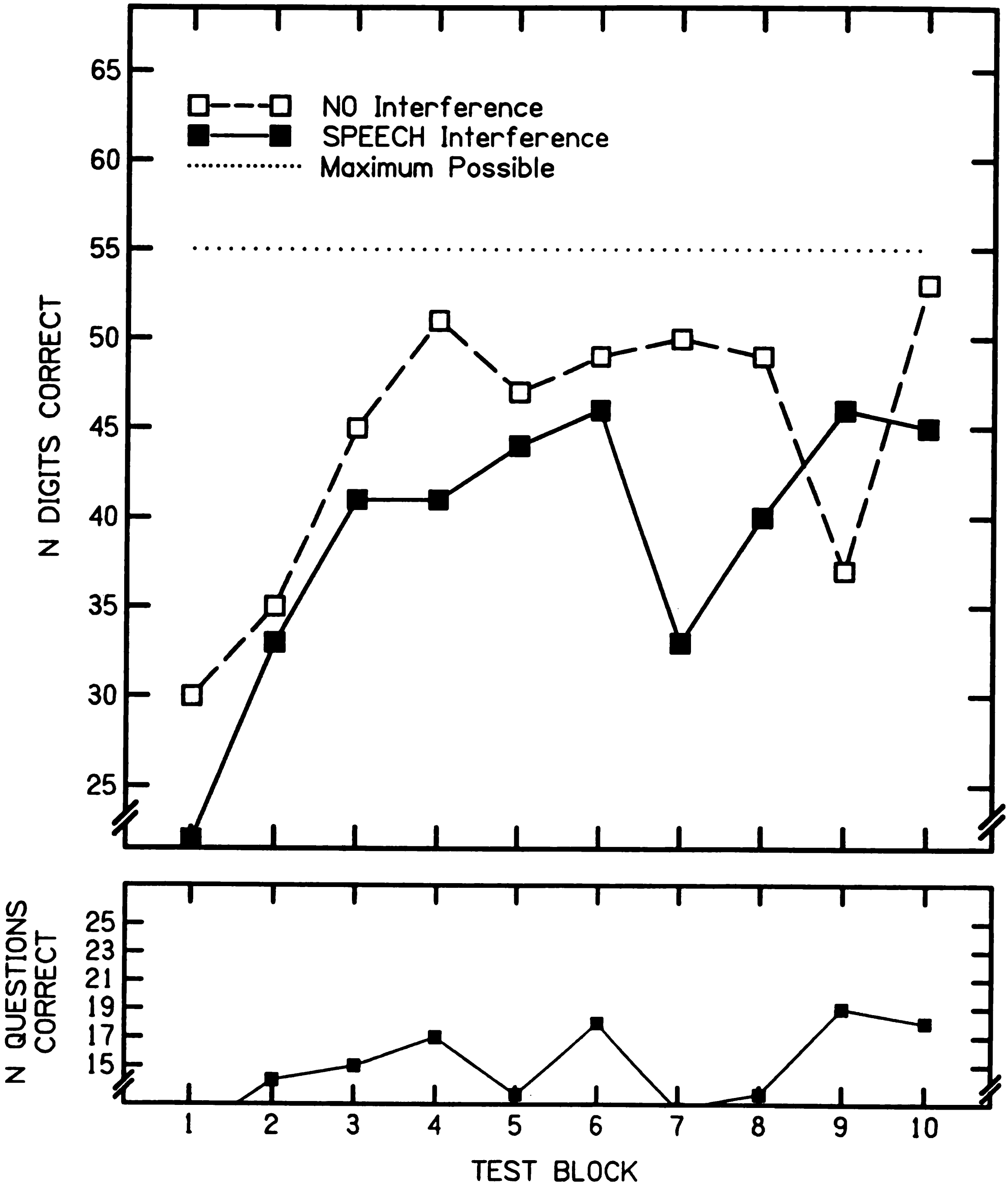
APPENDIX B

Group:	AL	LPTA(dBHL):	50*	HAStatus:	MON(R)
Subject:	YA	RPTA(dBHL):	45	HAYrs:	10
Gender:	F	SRS(%):	80	HAUse:	CONSIST.
Age(yrs):	52				



APPENDIX B

Group:	AL	LPTA(dBHL):	30	HAStatus:	N/A
Subject:	CB	RPTA(dBHL):	40*	HAYrs:	0
Gender:	F	SRS(%):	100	HAUse:	NONE
Age(yrs):	51				

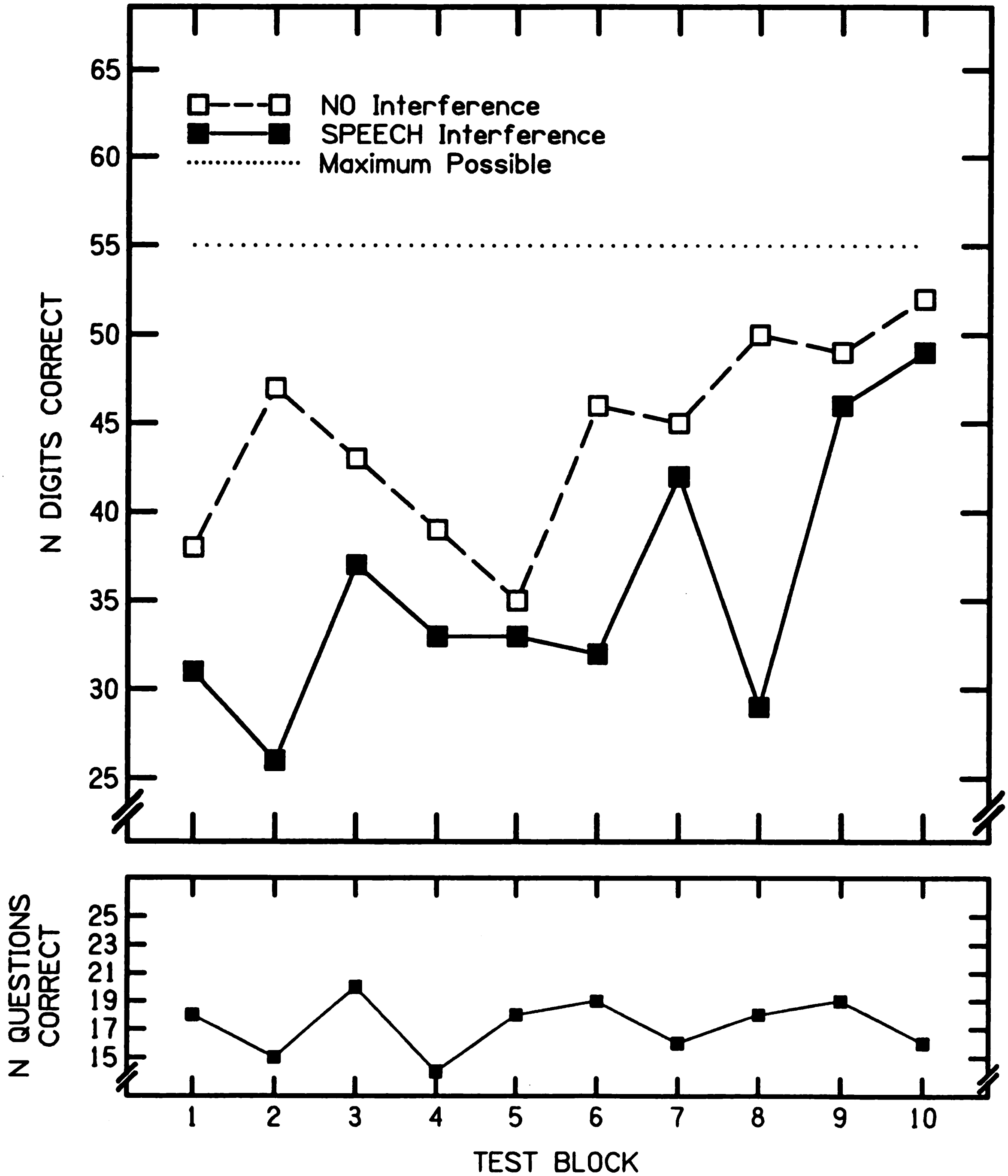


APPENDIX B

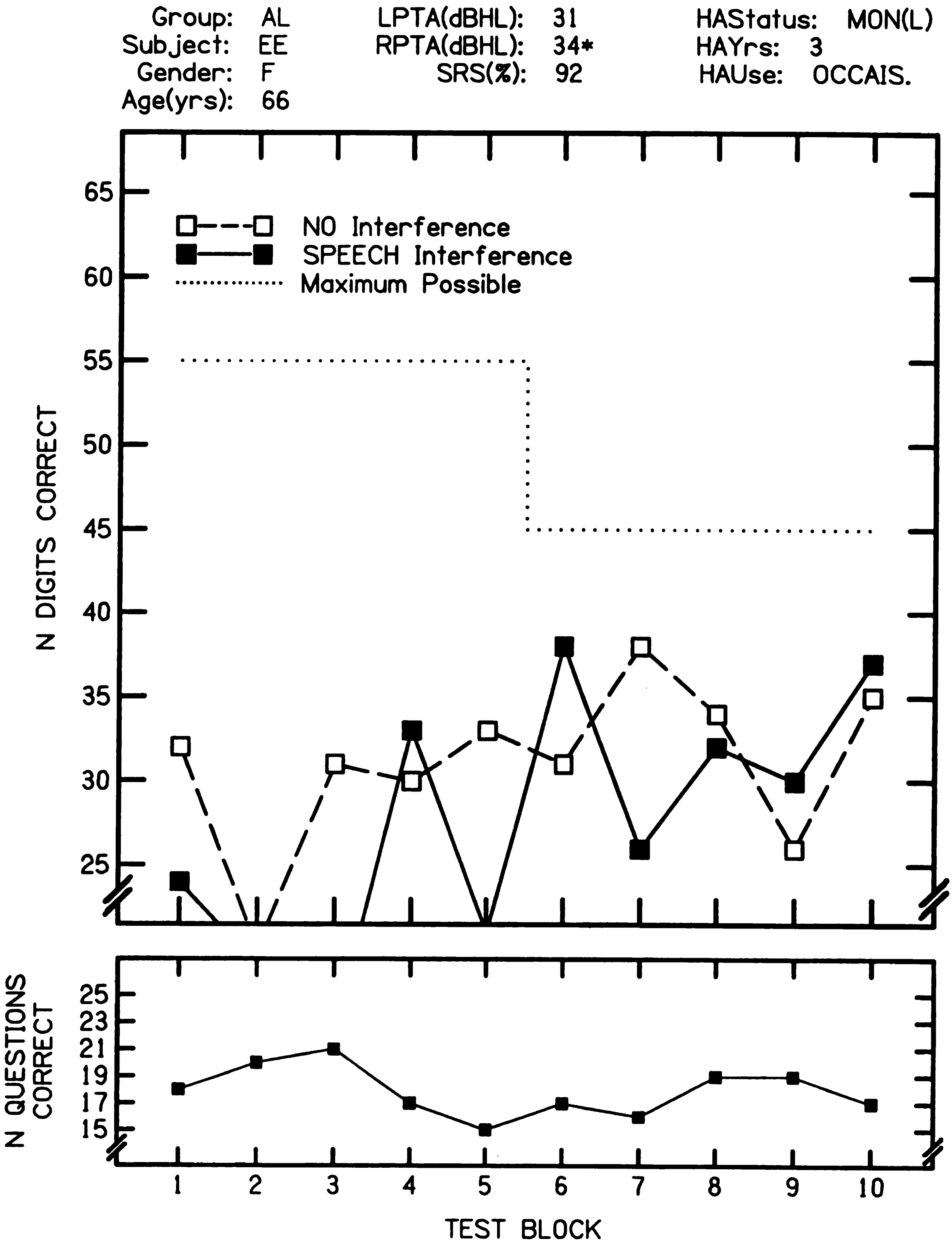
Group: AL
Subject: DD
Gender: M
Age(yrs): 65

LPTA(dBHL): 50*
RPTA(dBHL): 50
SRS(%): 84

HAStatus: BIN
HAYrs: 1.5
HAUse: OCCAS.



APPENDIX B


Group: AL
Subject: EE
Gender: F
Age(yrs): 66
LPTA(dBHL): 31
RPTA(dBHL): 34*
SRS(%): 92
HAStatus: MON(L)
HAYrs: 3
HAUse: OCCAIS.
NO Interference
SPEECH Interference
Maximum Possible
N DIGITS CORRECT
65
60
55
50
45
40
35
30
25
N QUESTIONS CORRECT
25
23
21
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17
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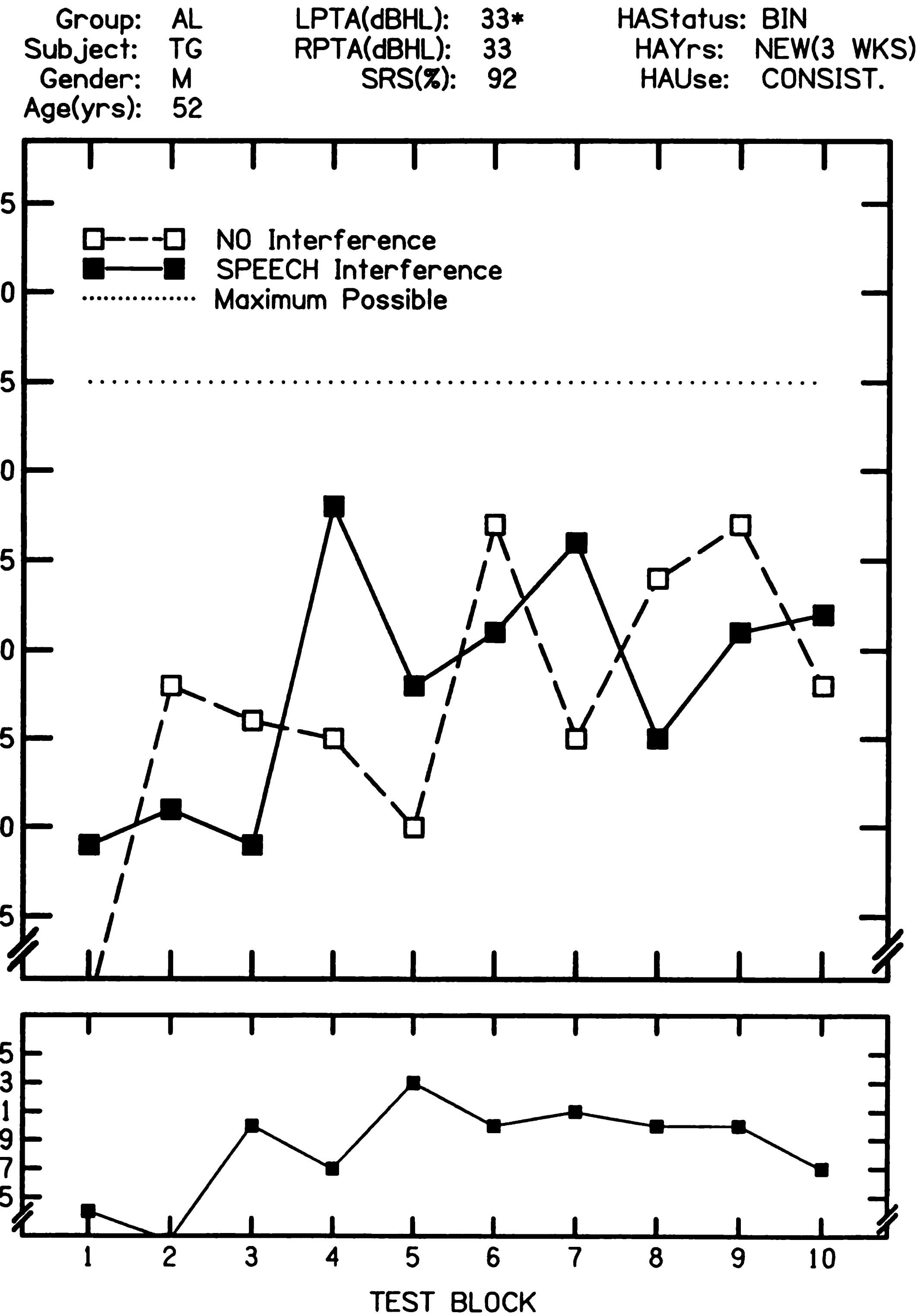
TEST BLOCK

APPENDIX B


Group: AL
Subject: TG
Gender: M
Age(yrs): 52
LPTA(dBHL): 33*
RPTA(dBHL): 33
SRS(%): 92
HAStatus: BIN
HAYrs: NEW(3 WKS)
HAUse: CONSIST.
NO Interference
SPEECH Interference
Maximum Possible
N DIGITS CORRECT
65
60
55
50
45
40
35
30
25
N QUESTIONS CORRECT
25
23
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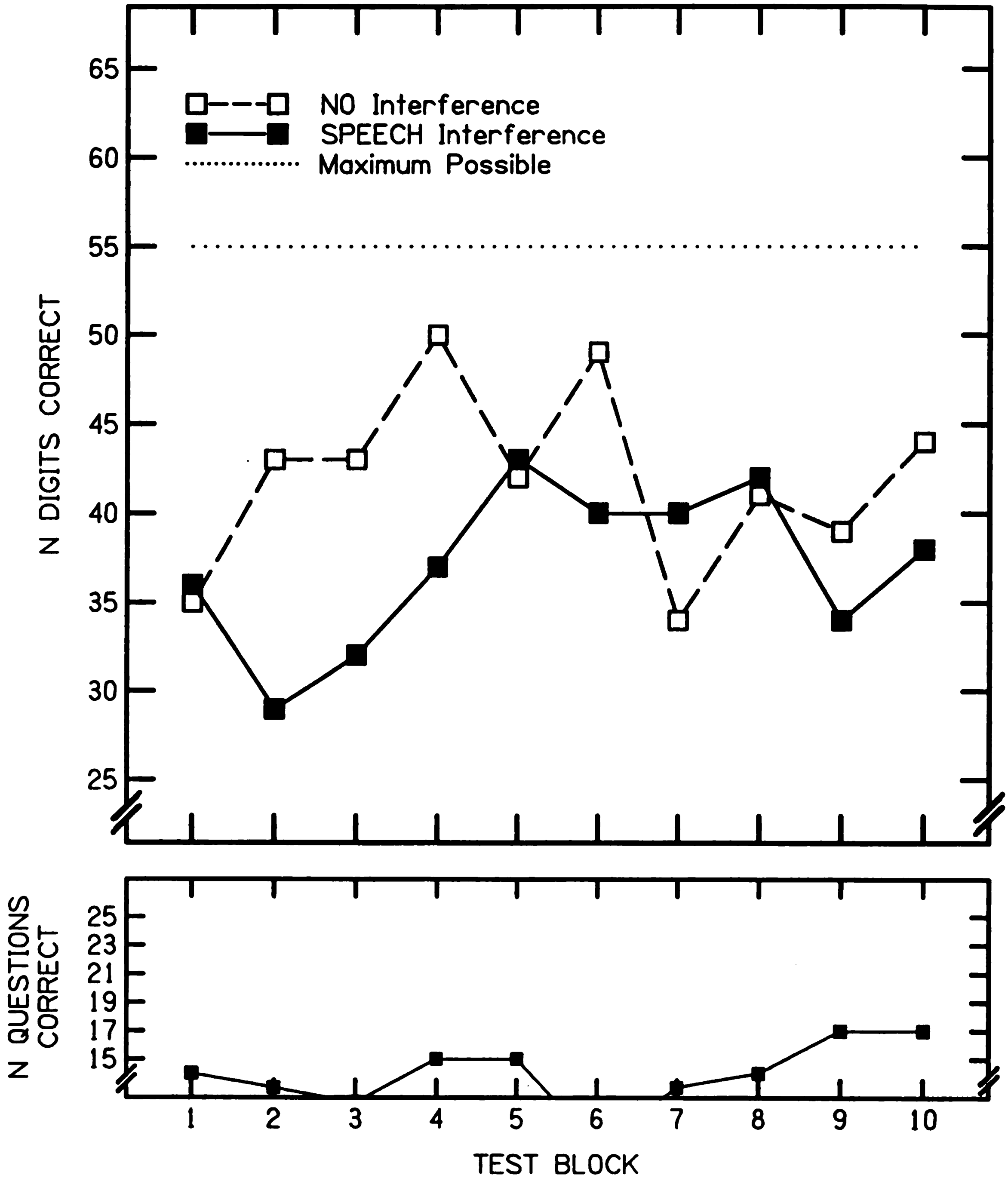
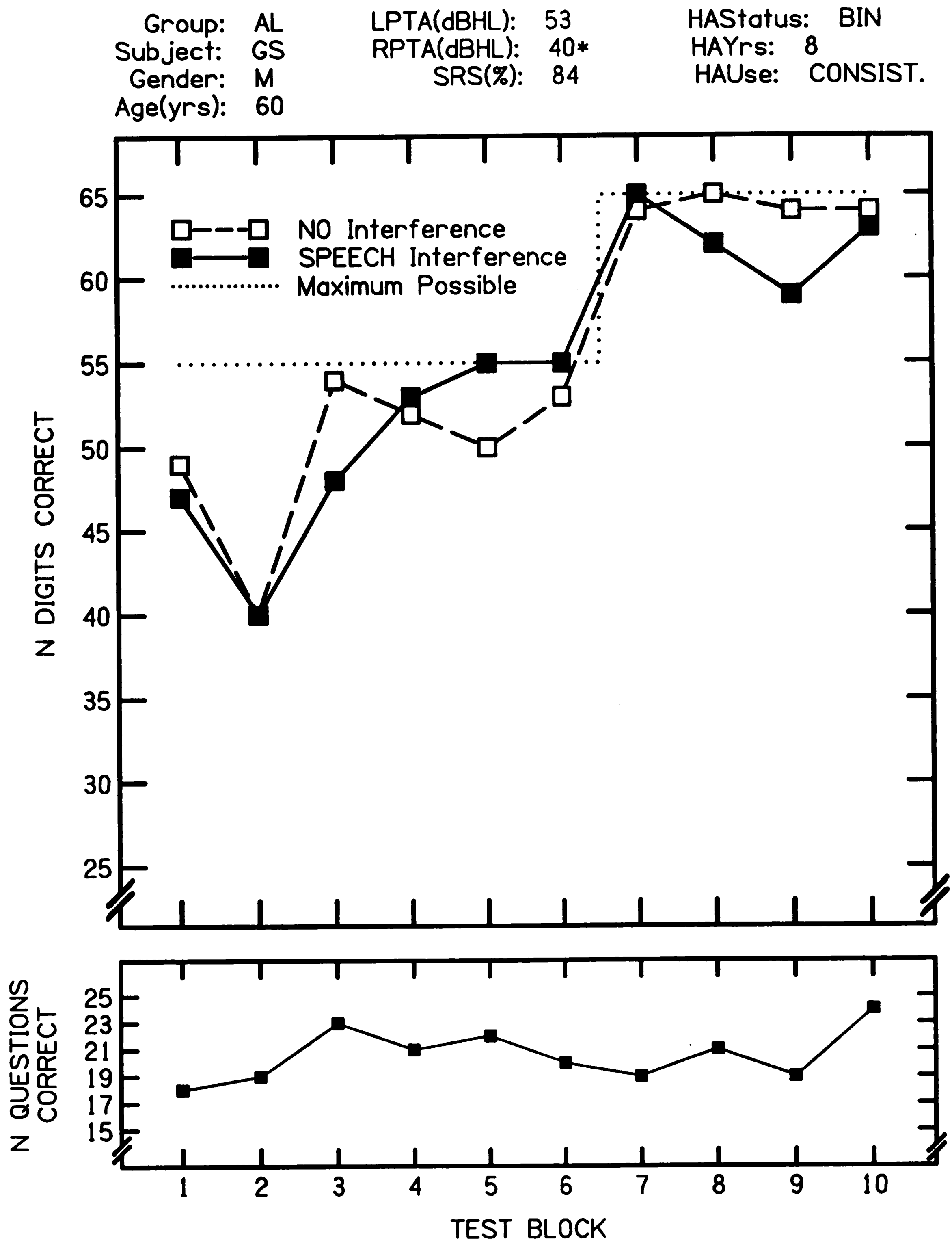
TEST BLOCK

APPENDIX B

Group:	AL	LPTA(dBHL):	42	HAStatus:	BIN
Subject:	DS	RPTA(dBHL):	42*	HAYrs:	0
Gender:	F	SRS(%):	100	HAUse:	CONSIST.
Age(yrs):	42				



APPENDIX B


Group: AL
Subject: GS
Gender: M
Age(yrs): 60
LPTA(dBHL): 53
RPTA(dBHL): 40*
SRS(%): 84
HAStatus: BIN
HAYrs: 8
HAUse: CONSIST.
NO Interference
SPEECH Interference
Maximum Possible
N DIGITS CORRECT
65
60
55
50
45
40
35
30
25
N QUESTIONS CORRECT
25
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TEST BLOCK

APPENDIX C

APPENDIX C

DIGIT RECALL

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SID:________________________ Date: ________________________

Block: ______________________ Condition: ____________________

Comments:____

APPENDIX C

ITEM #1 (1)______________________________

(2)______________________________

(3)______________________________

(4)______________________________

(5)______________________________

ITEM #2 (1)______________________________

(2)______________________________

(3)______________________________

(4)______________________________

(5)______________________________

ITEM #3 (1)______________________________

(2)______________________________

(3)______________________________

(4)______________________________

(5)______________________________

ITEM #4 (1)______________________________

(2)______________________________

(3)______________________________

(4)______________________________

(5)______________________________

ITEM #5 (1)______________________________

(2)______________________________

(3)______________________________

(4)______________________________

(5)______________________________

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