AUDITORY COMPREHENSION DEFICITS IN APHASIA: A HIERARCHY OF DIFFICULTY IN YES/NO QUESTIONS

THESIS

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Jason Carter, B.S.

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ABSTRACT

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By

Jason Carter, B.S.
Southwest Texas State University
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SUPERVISING PROFESSSOR: Barry L. Slansky, Ph.D.

The purpose of this study was to determine if a hierarchy of difficulty exists for yes/no questions. Participants in this study were 8 aphasic subjects (6 men and 2 women) and 8 control subjects (3 men and 5 women), ranging in age from 55 to 72 years. Five categories of yes/no questions were established, digitally recorded into the computer, and then presented randomly via loudspeaker. Data on accuracy of response and response time were recorded by the computer. Statistically significant differences were found between the question types and across experimental groups for accuracy rate and response times. Clinical implications of this study include providing speech-language pathologists a systematic approach to treating auditory comprehension deficits in aphasia.

CHAPTER I

INTRODUCTION

Auditory comprehension is “the mental process by which listeners take in the sounds uttered by a speaker and use them to construct an interpretation of what they think the speaker intended to convey (Clark & Clark, 1977, p. 43). This process involves many peripheral auditory and central nervous system transformations, with ongoing linguistic and cognitive functioning. The process of auditory comprehension has been explained in many ways. One model of comprehension is known as the bottom-up model (Massaro, 1975). This model is characterized as extremely signal-dependent, in that processing the acoustic speech signals occurs in a fairly linear manner. For example, listeners proceed through a series of stages beginning with perceiving the acoustic characteristics of speech. From this, listeners interpret those characteristics as phonemes, combine those phonemes into syllables and words, determine the meaning and relationship of those words, and eventually interpret a mental picture of the meaning of the original utterance (Brookshire, 1997).

Over the years, researchers realized that the listeners' knowledge base and experiences are highly influential on comprehension. No longer is comprehension just a series of binding or automatic judgments generated by listeners. It was found that listeners contribute personal experiences and information to relate to the information they hear. Not only do these experiences influence comprehension, but listeners also make decisions regarding what to listen to, based on their interpretation of what is important. Instead of listeners making linear judgments about the phonemes and syllables, the words were now the starting point in the comprehension process (Brookshire, 1997). This model became known as the top-down model of processing.

Factors Influencing Auditory Comprehension

Many factors that influence auditory comprehension in neurologically normal individuals also affect comprehension in aphasic individuals. These include factors such as linguistic complexity, message length, and the frequency of occurrence of the vocabulary contained in the message (Bacon, Potter, & Seikel, 1992; Marshall, 1981, 1986). It has been shown that as linguistic complexity increases, there is a corresponding decrease in the ability to comprehend auditory information (Goodglass, Gleason, & Hyde, 1970; Sarno, 1974; Schuell, Jenkins, & Landis, 1961; Shewan & Canter, 1971).

Message length is an especially important factor in subjects' ability to comprehend auditory information. According to Caramazza, Zurif, and Gardner (1978), people with aphasia tend to have a short auditory memory span. Because of this reduced working memory, they have difficulty retaining vital information necessary for subsequent processing. As a result, long strings are difficult to process. Another factor that influences subjects' ability to comprehend auditory stimuli is syntactic complexity. People with aphasia demonstrate reduced comprehension for syntactically complex stimuli. Subject's with aphasia can easily confuse information that is not straightforward. For instance, declarative sentences are easier to comprehend than passive sentences. Also, sentences with multiple clauses and negatives are difficult to comprehend (Marshall, 1986). Verb tense and word order in sentences also influences comprehension (Pierce, 1981, 1982). It is thought that processing more syntactically complex sentences requires listeners to generate initial processing decisions, then confirm or modify those decisions when provided the additional information contained in the sentence.

Word frequency can also influence comprehension. Words that are used frequently in English are more likely to be comprehended than words that occur less frequently (Schuell, Jenkins, & Jimenez-Pabon, 1964). Also, words that are more concrete in nature are easier to comprehend than abstract words (Brookshire & Nicholas, 1980).

Clinically, it is important to determine the effects of these factors on a subject's ability to comprehend auditory information. Without such information, it is difficult to monitor improved comprehension resulting from intervention. Furthermore, it is important to understand the effect of these factors as a means of manipulating the stimuli to provide maximal stimulation. One of the most functional tasks we perform every day is interpreting information that we hear, processing it and formulating an appropriate answer. Therefore, comprehending auditory information is crucial for verbal communication.

Impaired Auditory Comprehension in Aphasia

Rosenbek, LaPointe, and Wertz (1989) define an auditory comprehension deficit as a deficiency in the ability to process or understand spoken language that cannot be accounted for by a peripheral sensory deficit, generalized cognitive deficit, or primary disturbances in attention or arousal. Although no definition of auditory comprehension impairments is universally accepted, their definition is accepted by most clinical aphasiologists. Auditory comprehension deficits have been called the veiled disorders (Rosenbek et al, 1989), since the deficits are often manifested in covert features and are often overlooked due to the more overt symptoms that accompany aphasia (i.e. oral language impairments.).

Most people with aphasia demonstrate some degree of auditory processing impairment (Darley, 1982; DeRenzi & Vignolo, 1962; Schuell, Jenkins, & Jimenez-Papon, 1964; Weisenberg & McBride, 1935). Schuell and colleagues (1964, p. 277) suggested that "...because of the great dependence of language on the auditory system, there is almost always demonstrable impairments of auditory comprehension in aphasia." Those impairments vary in degree and some test instruments may not be sufficiently sensitive to capture mild impairments. Identifying the degree of impaired auditory comprehension is a difficult task because comprehension can only be inferred from an aphasic individuals' response to what is heard (Riedel, 1981). Because auditory comprehension cannot be directly measured, one must always evaluate comprehension based on the subjects' response to the stimuli. Therefore, comprehension scores may reflect not only processing abilities, but also the additional stages of response planning and execution skills. One possible explanation for the inefficiencies in measuring auditory comprehension deficits is offered by McNeil and Prescott (1978). They state that auditory processing deficits can occur at many different levels of processing or at any combination of the levels, stages, or components of auditory processing. As a result, comprehension in aphasia can be quite variable, both within and across individuals. Linguistic and nonlinguistic factors contribute to comprehension in various environments. Furthermore, comprehension performance is influenced by attention mechanisms relating to resource allocation, and may even be related to physiologic cycles (McNeil & Kimelman, 1986; McNeil, Odell, & Tseng, 1991, Slansky & McNeil, 1997).

Auditory comprehension is treated through various levels depending on the extent and primary area of auditory comprehension that is impaired. Treatment can extend from treating the comprehension of single words through picture matching tasks to comprehending simple sentences and following commands. Another method of treatment for auditory comprehension is responding to questions, in particular, yes/no questions.

Yes/No questions are used to treat a wide range of severity in aphasia. The questions can be formulated to be very simple or can be modified to become quite complex. They are also suitable for use in treating severe aphasics who cannot formulate the lengthy verbal responses needed to answer other types of questions (Brookshire, 1998). Yes/No questions can also be used with patients whose primary response modality is nonverbal. For example patients can gesture, write, or even point to respond to yes/no questions. Because verbal yes/no questions are used to explore aphasic subjects' auditory comprehension, they are of great practical and clinical importance (Bacon, Potter, &

Seikel, 1992; Goodglass & Kaplan, 1972; Gray, Hoyt, Mogil, & Lefkowitz, 1977; Kertesz & Poole, 1974; Schuell, 1965). Auditory yes/no questions are routinely used to assess the extent and severity of auditory comprehension deficits. These questions also are used to treat auditory comprehension because of their functional nature. These types of questions may be the only type of interaction that occurs between family and the person with aphasia. However, not all yes/no questions are of equal complexity based on question length, vocabulary, and syntax. Because these questions can assess such varied content, it is important to know what kinds of yes/no questions are more difficult for individuals with aphasia to understand. For these reasons, it was important to investigate how question type influences auditory comprehension of yes/no questions.

Statement of the Problem

Unfortunately, little research has been done to assess how aphasic subjects comprehend auditory yes/no questions. A study conducted by Bacon, Potter, and Seikel (1992) determined that a hierarchy of difficulty exists for several types of auditory yes/no questions for people with aphasia. In their study, they developed four question types that were classified into egocentric, environmental, pictorial, and relationship. Egocentric questions dealt with the subjects' current state. Environmental questions concerned the subject's' current environment. Pictorial questions addressed the content of the "Cookie Theft" picture from the Boston Diagnostic Aphasia Examination. Finally, relationship questions were based on physical relations between objects. Each of these groups contained twelve questions for a total of 48 questions.

The subjects for the Bacon et al. study were twenty aphasic adults, 13 men and 7 women, who ranged in age from 46 to 78 years with a mean age of 64. The subjects were divided into two experimental groups of ten. The first group was a consistent presentation group, receiving the treatment categories consecutively. The second group was the random presentation group, receiving the treatment categories randomized. All subjects were given a 30-second break after 12 questions to reduce fatigue.

The subjects responded nonverbally by pointing to a "yes/no" board. Responses were scored using a multidimensional system based on accuracy, response time, and cues. If subjects responded correctly and immediately, they received a 4. If subjects were correct but delayed, they received a 3. If subjects responded incorrectly but self-corrected, they received a 2. If the response was inappropriate or inefficient, but corrected when the clinician prompted the subjects, they received a 1. An incorrect response received a 0. Based on the scores obtained on this scale, Bacon et al. (1992) concluded that a hierarchy of difficulty did exist for their categories of auditory yes/no questions. They found that Egocentric questions were the easiest to comprehend followed by Environmental questions. Pictorial questions did not differ from Egocentric and Environmental questions in difficulty. Relationship questions were the most difficult for the aphasic subjects to comprehend. The authors also suggested that the categories selected may not have been broad enough to encompass all types of yes/no questions because of the sharp drop in accuracy rate between the Environmental questions and the Relationship questions. This sharp drop may have been due to the scoring system. The scoring system may not have been sufficiently sensitive to measure the slight differences between categories. Bacon et al. suggested more research be done to further validate and define the existence of this hierarchy.

Given the need to further delineate the hierarchy for yes/no questions, the present study modified the hierarchy described by Bacon et al. and developed additional question types to encompass a broader variety of questions. Also, other procedures were used to more discretely quantify the processing time required to answer yes/no questions. The following questions were posed to evaluate this hierarchy.

Experimental Question

Based on the limited available literature regarding yes/no questions and the limited findings of Bacon et al. (1992), the following questions were posed:

1. Is there a significant difference in accuracy rate and response time across the various question types in control subjects?
2. Is there a significant difference in accuracy rate and response time across the various question types in aphasic subjects?
3. Is there a significant difference between the control and aphasic groups within the same question types?

CHAPTER II

METHODS

Brief Overview

Five categories of yes/no questions were established. Twenty questions were developed for each category. The questions were digitally recorded, edited, and randomized for presentation to aphasic and non-aphasic control subjects. Their responses were recorded for accuracy rate and response time by the computer.

Stimuli Development

The present study used a modified version of the question types described by Bacon et al. (1992) to encompass a broader spectrum of yes/no question types. These included egocentric, immediate environment, factual, relational, and causal questions. The complete list of questions is included in Appendix A. Egocentric questions pertain to the subject's current state, (e.g., "Are you awake?"). Immediate environment questions refer to specific information about the immediate testing environment, (e.g., "Is the door closed?"). Factual questions (e.g., "Is the sky blue?") are based on information that is of a factual nature or are statements of fact. Relational questions are those that compare the relation between two objects (e.g., "Is a rock heavier than a feather?"). The final category of questions is conditional. Conditional questions are statements of fact with a condition applied to them, for example "Does it rain when it is cloudy?"

Once the categories were established, 10 sets of paired questions in each category were assigned for a total of 100 questions. The questions in each pair were identical except for a single word that was changed to manipulate the answer to the question. One question in each pair was written to elicit a "yes" response and the other a "no" response. Following procedures from standardized aphasia tests (Goodglass & Kaplan, 1972), the paired question procedure was used to reduce the probability of guessing a correct response. The questions were generated or adapted by the experimenters to conform to the established question categories. The adapted questions were those published in commercially available aphasia treatment workbooks.

Recording

The stimulus questions were digitally recorded using the Kay Elemetrics Computerized Speech Lab (CSL; 1994). A male voice with an average fundamental frequency of 118 Hz was used to record the questions. The questions were read using a normal speaking rate and normal inflection pattern. They were recorded using a sampling rate of 20,000 Hz. The questions were then digitally edited to remove unnecessary pause time at the onset of the recording. The end of each recording was carefully edited to assure that there was no more than 50 ms of silence at the end of each question. Each question was then coded and saved in an individual file on the computer. Backup copies of all stimulus files were saved on both floppy disks and a removable disk cartridge. Stimulus files were presented from the removable disk during the experiment.

In this manner, stimulus questions could be accessed directly for presentation.

Subject Selection

Participants in this study were 8 aphasic subjects (6 males and 2 females) and 8 control subjects (3 males and 5 females), ranging in age from 55 to 72 years. Subjects were recruited from several aphasia support groups, affiliated with the National Center for Neurogenic Communication Disorders. Control subjects consisted of non-brain injured members of the aphasia support group; some were spouses of the aphasic subjects.

To be included in this study, subjects were required to meet specific inclusion criteria. This testing was completed onsite by the thesis advisor prior to beginning the experiment. To meet inclusion criteria, all subjects passed a pure-tone, air-conduction, hearing screening in at least one ear at 500, 1000, 2000, 3000, and 4000 Hz at 35 dB HL (ANSI, 1996). Hearing testing was conduced in a sound-treated audiometric booth using a Grason-Stadler 1761 audiometer. They also were required to pass the speech discrimination portion of the Recent Memory Screening Test (Bayles & Tomoeda, 1998) with a score of at least 15 of 18 correct responses. Discrimination testing was also conducted in the same sound-treated booth. All subjects demonstrated adequate motor ability by responding to stimuli by pressing the designated yes or no button on a mouse and making 15 appropriate responses, each under 5 seconds during 20 practice trials of randomly selected questions from the experimental procedure. The aphasic and control subjects demonstrated intact cognitive function by scoring greater than 9.33 and having a delayed/ immediate recall ratio greater than 15.74% on the Recent Memory Screening Test (Bayles & Tomoeda, 1998). This score has been used to detect cognitive declines related to dementia (Bayles, Boone, Tomoeda, Slauson, & Kaszniak, 1989), independent of language abilities. All subjects were right handed for purposes of cerebral dominance. All aphasic subjects scored below the 85th percentile on the Aphasic Diagnostic Profile (ADP)(Helm-Estabrooks, 1992) as well as below the 85th percentile on the auditory comprehension subtest of the ADP. All control subjects scored above the 85th percentile on the ADP. The subjects spoke English as their first language and had no premorbid history of any learning or language difficulties. Complete biographic data for all subjects are included in Appendix B.

Procedures

All subjects were tested in a random order, based on availability. Each subject was seated in a quiet room that was designed to simulate a typical "living room" environment. The stimuli were presented in a random fashion using the ECO Sys/Win (1997) computer program through a single Labtec CS-550 loudspeaker placed one meter in front of the subject. The intensity of presentation was constant at 65dB SPL throughout the experiment and was monitored with a sound level meter. Randomized sets of questions were presented in blocks of twenty questions with a five-second pause between each question and a one-minute break between each question block. The randomization order for the questions is included as Appendix C. The entire set of questions was presented over a series of two trials with each question repeated once in the randomization order. In this way, a four-question set, consisting of the repeated question pair, was established. Experimental testing was completed in approximately 30 minutes per subject.

The rate of presentation and response collection was computer controlled using the ECO Sys/Win program. To record responses, each subject pressed the designated yes/no button on the mouse that was attached to a Compaq 133 MHz computer. All responses were made with the subject's left hand. This was to minimize the potential effects of right-sided weakness or paralysis that often accompanies left hemisphere brain damage.

Data Collection

The computer-controlled data collection was completed at the National Center for Neurogenic Communication Disorders by the thesis advisor. Accuracy rate and response time data for each question were recorded through the ECO Sys/Win program for later analysis. The computer program measured response time (in milliseconds) as the time between the end of the question and the subject's response. Accuracy rate data was also obtained. If the subject answered correctly, the question was assigned a value of "one." If incorrect, the question was assigned a "zero." To be included in the analysis, three out of four questions in the set had to be answered correctly. By using this criterion, the researchers reduced the probability of correctly guessing yes/no questions from 50% to 12.5%. Response data were stored in the ECO Sys/Win format, and were later transformed into a spreadsheet format. These data were stored on disk and made available for subsequent data preparation and statistical analysis.

CHAPTER III

RESULTS

This study provided a means for examining the complexity of yes/no questions by measuring both accuracy rate and response time. Data were collected from selected individuals with aphasia and from a group of control subjects. For each subject group, results will be presented for accuracy rate, then for response time.

Aphasia Group

Accuracy Rate

Table 1 presents the mean accuracy rate for each question type for each aphasic subject. As part of the experimental design, the question types initially were ranked according to the anticipated accuracy rates and response times. Initial inspection indicates several of the mean accuracy rates for the group corresponded to the predicted order for those question types. Results for the aphasic and control groups are illustrated in Figure 1 with the error bars representing one standard deviation.

A one-way repeated measures Analysis of Variance (ANOVA) was used to make comparisons between accuracy rates across the question types. All data passed a normality test ($p > .200$) and an equal variance test ($p = .061$). The ANOVA revealed

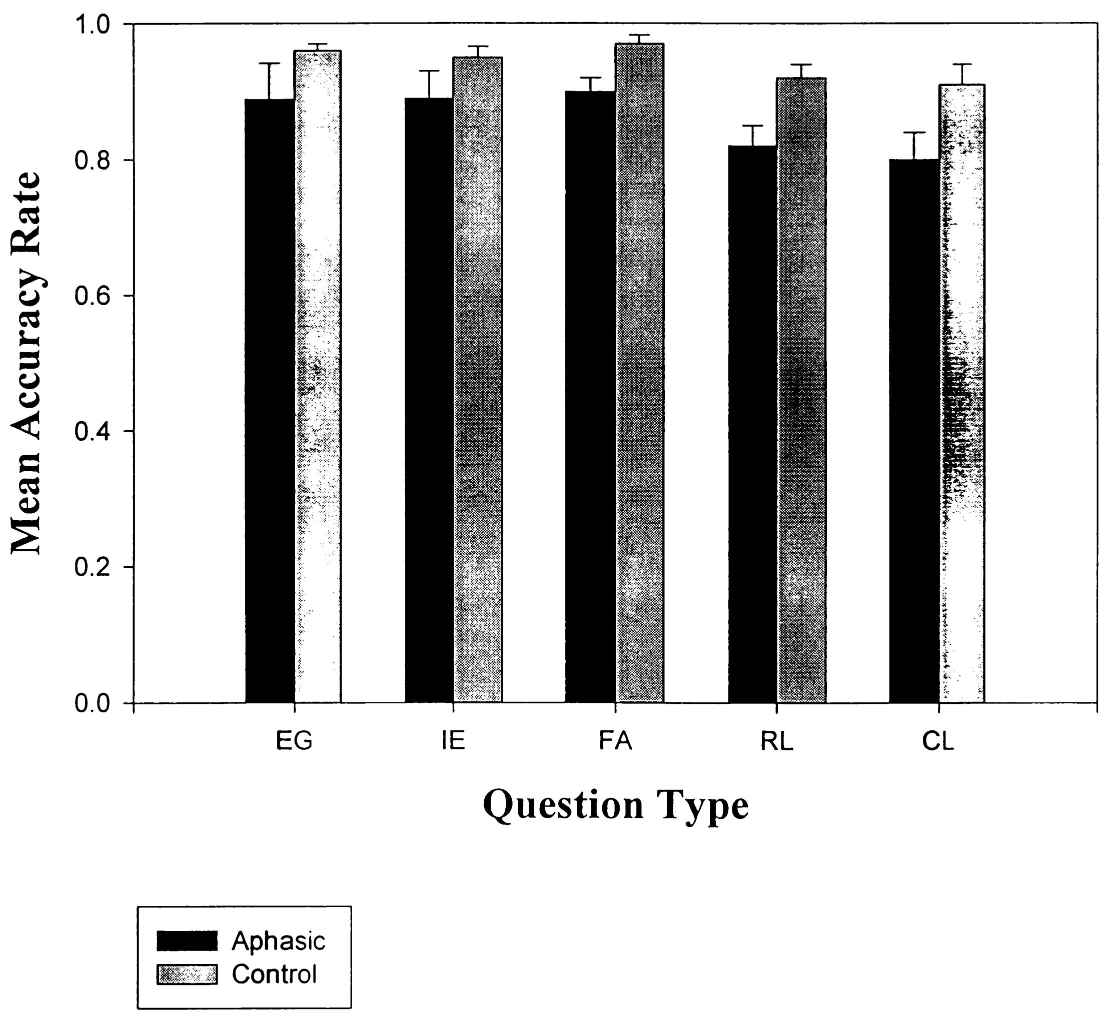
Table 1.

Mean Accuracy Rate and (Standard Deviation) for Aphasic Subjects by Question Type

Subject Code	EG	IE	FA	RL	CL
A01	.85 (.24)	.90 (.12)	.90 (.17)	.82 (.26)	.80 (.22)
A02	.80 (.22)	.92 (.23)	.90 (.21)	.87 (.13)	.82 (.20)
A03	.92 (.16)	.95 (.15)	.95 (.10)	.85 (.17)	.87 (.21)
A04	.85 (.17)	.90 (.17)	.87 (.17)	.85 (.12)	.82 (.20)
A05	.90 (.17)	.82 (.16)	.90 (.12)	.77 (.18)	.72 (.24)
A06	.92 (.12)	.87 (.24)	.92 (.12)	.80 (.22)	.82 (.16)
A07	.97 (.07)	.95 (.10)	.92 (.12)	.82 (.23)	.80 (.25)
A08	.90 (.12)	.87 (.17)	.90 (.17)	.80 (.25)	.77 (.21)

Note. EG = Egocentric, IE = Immediate Environment, FA = Factual, RL = Relational, and CL = Conditional.

Figure 1. Mean Accuracy Rate By Question Type



significant differences between treatments ($F(1, 7) = 15.278$, $p < .001$) for accuracy rate. A post-hoc, pairwise multiple comparison procedure (Tukey Test) was used to determine which question groups were significantly different. Although all comparisons were tested, only comparisons between adjacent question types (i.e., relative to the initial order) were of interest. A significant difference in accuracy rate was found between the factual and relational question types ($q = 6.954$, $p < .001$). Comparisons between all other adjacent question types were not significantly different. Therefore, accuracy rate alone was not a sensitive measure to detect differences between the question types.

Response Time

Response times were also recorded to detect differences in how subjects responded to questions of various types. Table 2 presents the mean response times for each question type for each aphasic subject. Initial inspection of the group response time data revealed that the mean response times for each question type increased in the order predicted. These results are illustrated in Figure 2 with error bars representing one standard deviation. A one-way repeated measures ANOVA was used to determine if the differences between the question types were statistically significant. For response times, all data passed a normality test ($p > .200$) and an equal variance test ($p = .172$). The ANOVA revealed significant differences between treatments ($F(1, 7) = 130.97$, $p < .001$) for response time. Post-hoc comparisons using the Tukey Test revealed which question types were significantly different in response times. Significant differences were found between the following question types: egocentric and immediate environment ($q = 5.99$, $p = .002$), factual and relational ($q = 10.69$, $p < .001$), and relational and conditional

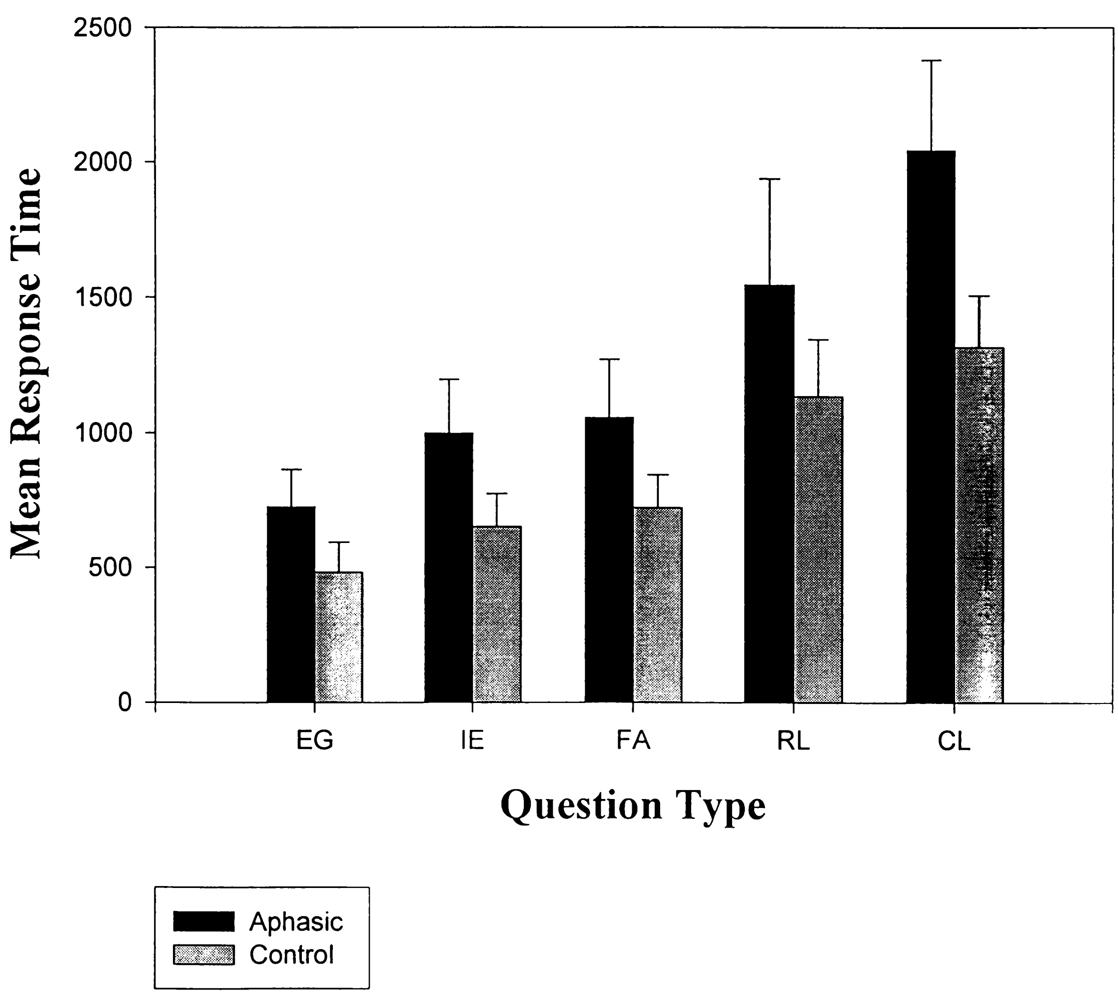
Table 2.

Adjusted Mean Response Times and (Standard Deviations) for Aphasic Subjects by Question Type

Subject Code	EG	IE	FA	RL	CL
A01	695 (63)	946 (69)	965 (181)	1472 (100)	1874 (113)
A02	931 (112)	1178 (89)	1188 (57)	1815 (113)	2249 (54)
A03	674 (64)	1069 (93)	918 (71)	1241 (95)	1837 (121)
A04	663 (41)	835 (87)	894 (76)	1201 (109)	1792 (96)
A05	805 (59)	1247 (109)	1290 (110)	2069 (78)	2387 (162)
A06	629 (53)	803 (108)	953 (148)	1338 (137)	2022 (87)
A07	514 (70)	720 (61)	824 (65)	1123 (111)	1591 (166)
A08	889 (100)	1187 (110)	1423 (68)	2093 (59)	2586 (82)

Note. EG = Egocentric, IE = Immediate environment, FA = Factual, RL = Relational, and CL = Conditional. Adjusted mean response times are shown in milliseconds.

Figure 2. Mean Response Time By Question Type



($q = 10.93$, $p < .001$). The only comparison that was not found to be significantly different was the response times between the immediate environment and factual questions. Therefore, response time was sensitive to differentiating between the complexity of the various question types for these aphasic subjects.

Control Group

Accuracy Rate

Table 3 presents the mean accuracy rate for each question type for each control subject. Initial inspection of the group data reveal that several of the mean accuracy rates corresponded to the predicted order for those question types. Group results are also illustrated in Figure 1.

A one-way repeated measures ANOVA was used to make comparisons between accuracy rates across the question types. All data passed a normality test ($p > .200$) and an equal variance test ($p = .239$). The ANOVA revealed significant differences between treatments ($F (1, 7) = 9.423$, $p < .001$) for accuracy rate. Post-hoc comparisons using the Tukey Test revealed which question types were significantly different in response times. A significant difference in accuracy rate was found between the factual and relational question types ($q = 5.807$, $p = .003$). Comparisons between all other adjacent question types were not significantly different. Therefore, for these control subjects, accuracy rate alone was not a sensitive measure to detect differences between the question types.

Table 3.

Mean Accuracy Rate and (Standard Deviations) for Control Subjects by Question Type

Subject Code	EG	IE	FA	RL	CL
C01	.95 (.10)	.92 (.12)	.95 (.10)	.95 (.10)	.95 (.10)
C02	.97 (.07)	.95 (.10)	.97 (.07)	.90 (.17)	.90 (.17)
C03	.97 (.07)	.95 (.10)	.97 (.07)	.90 (.12)	.90 (.12)
C04	.97 (.07)	.97 (.07)	1.0 (.00)	.95 (.15)	.87 (.13)
C05	.97 (.07)	.97 (.07)	.97 (.07)	.90 (.21)	.90 (.17)
C06	.95 (.10)	.97 (.07)	.97 (.07)	.95 (.15)	.95 (.10)
C07	.97 (.07)	.95 (.10)	.97 (.07)	.95 (.10)	.92 (.12)
C08	.95 (.10)	.95 (.15)	.97 (.07)	.92 (.12)	.95 (.10)

Note. EG = Egocentric, IE = Immediate Environment, FA = Factual, RL = Relational, and CL = Conditional.

Response Time

Table 4 presents the mean response times for each question type for each control subject. Initial inspection of the group response time data revealed that the mean response times for each question type increased in the order predicted. These results are also illustrated in Figure 2. To determine if the differences among the question types were statistically significant, an ANOVA was used. For response times, all data passed a normality test ($p > .200$) and an equal variance test ($p = .172$).

The ANOVA revealed significant differences between treatments ($F(1, 7) = 130.97$, $p < .001$) for response time. Post-hoc comparisons using the Tukey Test revealed which question types were significantly different in response times. Significant differences were found between the following question types: egocentric and immediate environment ($q = 5.99$, $p = .002$), factual and relational ($q = 10.69$, $p < .001$), and relational and conditional ($q = 10.93$, $p < .001$). The only comparison that was not found to be significantly different was the response times between the immediate environment and factual questions. Therefore, as was also discovered for the aphasic group, response time was sensitive to differentiating between the complexity of the various question types for these control subjects.

Aphasia Group vs. Control Group

Accuracy Rate

Initial inspection of the data between subject groups revealed some differences in accuracy rates. These data are also illustrated in Figure 1. Aphasic subjects tended to have lower accuracy rates for some question types when compared to control subjects.

Table 4.

Adjusted Mean Response Times and (Standard Deviations) for Control Subjects by Question Type

Subject Code	EG	IE	FA	RL	CL
C01	363 (44)	479 (45)	591 (28)	863 (71)	1286 (93)
C02	400 (51)	544 (56)	725 (73)	1092 (66)	1215 (52)
C03	552 (40)	761 (67)	614 (57)	1145 (61)	1457 (76)
C04	516 (54)	621 (45)	730 (48)	1258 (95)	1438 (96)
C05	622 (44)	766 (73)	836 (74)	1303 (87)	1365 (99)
C06	467 (45)	653 (79)	821 (55)	1251 (70)	1415 (124)
C07	608 (56)	824 (65)	892 (63)	1377 (104)	1461 (98)
C08	328 (54)	564 (39)	560 (45)	790 (66)	896 (119)

Note. EG = Egocentric, IE = Immediate environment, FA = Factual, RL = Relational, and CL = Conditional. Adjusted mean response times are shown in milliseconds.

To determine if these differences between the aphasic and control groups were statistically significant, an ANOVA was used. All data passed a normality test ($p > .200$). All data passed an equal variance test ($p = .170$).

The ANOVA revealed significant differences between groups ($F (1, 9) = 26.76$, $p < .001$). Post hoc analyses using the Tukey test revealed which differences between groups were significant. Significant differences were found between the aphasic and control groups for the following question types: egocentric ($q = 6.836$, $p < .001$), immediate environment ($q = 5.179$, $p = .017$), factual ($q = 5.869$, $p = .004$), and conditional ($q = 10.588$, $p < .001$). The only group difference that was not found to be significant was for relational questions. Therefore, for nearly all question types, there were clear differences in accuracy rate for the aphasic and control groups.

<u>Response Time</u>

Initial inspection of the data between groups revealed some differences in response times. These data are also illustrated in Figure 2. Aphasic subjects tended to have longer response times for some question types when compared to control subjects. Again, to determine if these differences between subjects were statistically significant, a one-way repeated measures ANOVA was performed. All data passed a normality test ($p = .173$) and an equal variance test ($p = .081$).

The ANOVA revealed significant differences between subjects ($F (1, 7) = 41.087$, $p < .001$). Post hoc analyses using the Tukey test revealed that significant differences were found between the aphasic and control groups for the following question types: immediate environment ($q = 4.711$, $p = .044$), relational ($q = 5.560$, $p = .008$), and conditional ($q = 9.862$, $p < .001$). The differences that were not found to be significant were between the egocentric and factual questions.

In summary, the question types increased in difficulty in the order predicted with the exception of two question types. An identical pattern was observed for both aphasic and control subjects for both accuracy rate and response time.

CHAPTER IV

DISCUSSION

Purpose

The purpose of this study was to determine if a hierarchy of difficulty exists for yes/no questions. The goals of this study were to determine if there was a significant difference in the accuracy rates and response times of aphasic and control subjects for the question types. Also, this study sought to determine if there was a difference between the accuracy rates and response times of aphasic and control subjects for similar question types.

Interpretation of Results

The results of this study clearly indicated the existence of a hierarchy of difficulty for yes/no questions based on response times primarily and accuracy rates to a lesser degree. An identical pattern in accuracy rates and response times was observed between the experimental group of aphasics and the control group. This suggested the hierarchy exists regardless of brain injury.

For both groups, accuracy rate was not a significant predictor of question difficulty. The only significant finding was the difference between factual and relational questions.

Reasons for this difference were attributed to length and differing syntactic complexity. Relational questions were longer than factual questions. They had a longer duration and those questions had a higher word count. The mean durations for the question types are illustrated in Table 5. The mean duration for relational questions was 2760 ms, whereas the mean duration of factual questions was 1791 ms. Also, relational questions contained an average of 7.0 words per question; only 3.1 words per question for factual. Therefore, it is likely that the higher word counts and longer durations made the questions more complex, thus requiring more in-depth processing. The longer overall duration of the relational questions placed greater demands on the subjects' working memory. Subjects had to retain more in memory before processing subsequent parts of the question. According to Just and Carpenter (1993), such demands on working memory increase the computational demands on sentence processing. Furthermore, the task for these two question types differed. The nature of relational questions required the subject to compare two entities or concepts, which may place greater demands on working memory than factual questions. Factual questions required attending to the value of a single entity or concept. These factors likely accounted for the significant decrease in accuracy rates between those questions types.

Response time was found to be the most significant predictor of question difficulty for both experimental groups. A steady increase in response time was observed across all question types. This increase was significant for all question types except for the difference between immediate environment and factual questions. As previously explained, question length has been shown to influence comprehension abilities; however, the results of this study indicated that not only question length influenced

Table 5.

Mean Duration and Standard Deviation for Each Question Type

Question Type	Mean Duration (ms)	Standard Deviation
Egocentric	1534.8	258.5
Immediate Environment	1909.9	345.7
Factual	1791.3	107.9
Relational	2760.6	437.9
Conditional	2755.3	299.7
Mean Duration =	2150.38	
Standard Deviation =	570.96	

comprehension, but also question type. In some cases, response times for some longer questions were faster than shorter questions, and response times differed for some questions of similar length. As illustrated in Table 5, the mean duration of immediate environment question ($\underline{M}$ = 1909 ms) was longer than that of factual questions ($\underline{M}$ = 1791 ms). The mean words per immediate environment question was 4.4 and the mean words per factual question was 3.1. Although, one would expect that factual questions would have had better response times than immediate environment questions based on question length, this was not the case. The lack of a significant difference between the two could be attributed to the presence of contextual support for the immediate environment questions, which facilitated the subjects' comprehension despite the increased question length. A contrary situation was the similar mean durations and words per question of relational and conditional questions. Relational questions had a mean duration of 2760 ms, and conditional questions had a mean duration of 2755 ms. The average number of words per question for relational questions was 7.0, and the average number for conditional questions was 7.7. Although, one could infer that these questions would have had similar response times, response times for conditional questions were significantly longer. This difference was attributed again to the varying content requiring differing degrees of processing. Relational questions required the comparison of two entities by one factor or description, while conditional questions required the comparison of one entity or concept against multiple factors. These two examples clearly indicated that question content also influences comprehension.

Aphasic vs. Control (by question type)

When comparisons were made between the two experimental groups, significant differences were found between the accuracy rates. All differences were significant except the difference for relational questions. It can be concluded that brain injury, such as a stroke, causes accuracy rates for responding to yes/no questions to decrease. However, these rates decreased along the same pattern as that of the control subjects. The brain injury itself did not result in a change of the hierarchy given that the pattern remained the same as that of control subjects.

Differences in response times were also found to be significant for most question types. The only differences that were not found to be significant were the differences in response times for egocentric and factual. It can be concluded that brain injury increases response times for some question types. As previously discussed, the response times increased along the same pattern as the normal group. The brain injury did not change the hierarchy or make one question type more difficult to comprehend than another.

Conclusions, Implications, and Future Studies

The results of this study clearly indicated that the type of yes/no question is important in predicting how well that question is comprehended. This study also demonstrated that changing the question length is not the only manner in which question difficulty can be altered. These conclusions were evident for both the control and aphasic subjects, as they exhibited the same pattern for accuracy and response time. Given the relative simplicity of the questions presented in this study and the level of comprehension abilities of the subjects tested, accuracy rate alone was not as reliable of a predictor of processing abilities as response time.

This study affirms that yes/no questions are an important method of evaluating auditory comprehension in aphasia. Clinically, the results of this study should assist speech language pathologists in developing materials for treating auditory comprehension deficits. Also, this study gives a systematic method of progressing treatment once patients have achieved their goals for a given question type.

Future studies are needed to further define this hierarchy, since several additional questions were unanswered. For one, the experimental group consisted of fairly mild aphasic individuals. Does this hierarchy change for more severe aphasics? What are the changes in accuracy and response times for people with more severe aphasia? Also, the results indicated a fairly large change in response times between factual and relational question categories. There may be an additional yes/no question category that would result in a more gradual transition between those question types. Factual questions can be easily altered to increase question length without changing the question type. Perhaps the introduction of the longer factual questions would make the transition between performance on factual and relational questions more gradual. Increased length, however, may not assume increased question complexity.

Another transformation to be investigated would be to maintain similar question types, yet increase the syntactic complexity. Increased syntactic complexity could be achieved by adding embedded clauses, using ambiguous referents, or by inserting negatives.

Temporal factors of the yes/no stimuli could also be manipulated in order to determine the effects on processing. In a study by Slansky (1998), it was demonstrated that auditory processing abilities for both aphasic and control subjects were adversely affected when the stimuli were temporally altered by extending the duration of specific segments of the acoustic signal. Although the linguistic task used in that study was a semantic decision task, the yes/no stimuli from this current study may be more realistic, and therefore, provide a better representation of subjects' functional auditory comprehension abilities. The yes/no stimuli could be acoustically altered by adding pauses within the question, or by extending the question length by using the acoustic expansion algorithm available on various acoustic instruments.

Another direction would be to evaluate this hierarchy in conditions that better represent typical listening environments. Individuals frequently communicate in environments in which noise and competing auditory stimuli are present. Therefore, these question types should be evaluated in the presence of competing linguistic stimuli. Such work is currently in progress (Broadbent & Slansky, 1999).

Finally, although the population studied in this investigation was adults with aphasia, one should determine if this hierarchy exists for individuals with other types of neurological impairments such as dementia or traumatic brain injury.

Appendix A.
Stimulus Questions Pairs Listed By Type and Durations

Code	Question	Duration (ms)
Egocentric		
EG01	Are you awake?	1346
EG02	Are you asleep?	1505
EG03	Are you sick?	1184
EG04	Are you well?	1215
EG05	Are you sitting?	1213
EG06	Are you standing?	1468
EG07	Are you a man?	1360
EG08	Are you a woman?	1469
EG09	Are you old?	1358
EG10	Are you young?	1438
EG11	Are you an adult?	1602
EG12	Are you a child?	1628
EG13	Are your eyes open?	1798
EG14	Are your eyes closed?	2083
EG15	Are you listening?	1468
EG16	Are you writing?	1536
EG17	Are you wearing clothes?	1900
EG18	Are you wearing gloves?	2084
EG19	Are you married?	1492
EG20	Are you single?	1549
	Mean =	1534.8
	Standard Deviation =	258.5

Appendix A (Continued).

Code	Question	Duration (ms)
Immediate Environment		
IE01	Is the door closed?	1811
IE02	Is the door open?	1731
IE03	Is the tester a man?	2008
IE04	Is the tester a woman?	2085
IE05	Is it day time?	1426
IE06	Is it night time?	1494
IE07	Is it morning?	1335
IE08	Is it afternoon?	1583
IE09	Is the window closed?	2032
IE10	Is the window open?	1943
IE11	Is the television off?	1959
IE12	Is the television on?	1998
IE13	Is the floor carpeted?	2135
IE14	Is the floor tiled?	1968
IE15	Is there a picture on the wall?	2574
IE16	Is there a picture on the door?	2591
IE17	Is the light on?	1543
IE18	Is the light off?	1626
IE19	Are you sitting on a chair?	2185
IE20	Are you sitting on a table?	2171
	Mean =	1909.9
	Standard Deviation =	345.7

Appendix A (Continued).

Code	Question	Duration (ms)
Factual		
FA01	Is the sky blue?	1747
FA02	Is the sky green?	1840
FA03	Do dogs bark?	1665
FA04	Do dogs whistle?	1697
FA05	Do birds fly?	1685
FA06	Do horses fly?	1869
FA07	Do plants grow?	1977
FA08	Do rocks grow?	1906
FA09	Do babies cry?	1594
FA10	Do houses cry?	1690
FA11	Are fires hot?	1634
FA12	Are fires cold?	1872
FA13	Are elephants big?	1781
FA14	Are elephants small?	1989
FA15	Are lemons sour?	1794
FA16	Are lemons sweet?	1797
FA17	Do scissors cut?	1853
FA18	Do scissors write?	1840
FA19	Do fish swim?	1774
FA20	Do fish dance?	1823
	Mean =	1791.3
	Standard Deviation =	107.9

Appendix A (Continued).

Code	Question	Duration
Relational		
RL01	Is a rock heavier than a feather?	2489
RL02	Is a rock lighter than a feather?	2527
RL03	Is a dime more than a nickel?	2354
RL04	Is a dime more than a quarter?	2498
RL05	Is driving faster than walking?	2883
RL06	Is driving slower than walking?	2890
RL07	Is a man older than a child?	2628
RL08	Is a man younger than a child?	2508
RL09	Is a minute longer than a second?	2689
RL10	Is a minute longer than an hour?	2659
RL11	Is a dog bigger than a mouse?	2466
RL12	Is a dog bigger than an elephant?	2673
RL13	Is a month shorter than a year?	2525
RL14	Is a month longer than a year?	2502
RL15	Is a skyscraper taller than a house?	3181
RL16	Is a skyscraper shorter than a house?	3200
RL17	Does the ocean have more water than a bathtub?	3735
RL18	Does the ocean have less water than a bathtub?	3942
RL19	Is a mile longer than a foot?	2481
RL20	Is a mile shorter than a foot?	2383
	Mean =	2760.6
	Standard Deviation =	437.9

Appendix A (Continued).

Code	Question	Duration
Conditional		
CL01	Does it rain when it is cloudy?	2108
CL02	Does it rain when it is sunny?	2089
CL03	Do you wear a coat when it is winter?	2720
CL04	Do you wear a coat when it is summer?	2887
CL05	Do you eat dinner when you are hungry?	2588
CL06	Do you eat dinner when you are thirsty?	2960
CL07	Do you sleep when you are tired?	2679
CL08	Do you read when you are tired?	2746
CL09	Do you make snowmen when it snows?	3020
	Do you make snowmen when it rains?	3174
CL11	Do you go swimming when it is hot?	2667
CL12	Do you go swimming when it is cold?	3079
CL13	Do you eat breakfast when it is morning?	2997
CL14	Do you eat breakfast when it is night?	2688
CL15	Do babies cry when they are sad?	2837
CL16	Do babies cry when they are happy?	2789
CL17	Do you use an umbrella when it is raining?	3054
CL18	Do you use an umbrella when it is sunny?	3036
CL19	Do you drink when you are thirsty?	2403
CL20	Do you drink when you are tired?	2586
	Mean =	2755.3
	Standard Deviation =	299.7

Appendix B.

Biographical Information and Test Scores for Control and Aphasic Subjects

Subject Code	Age	CVA MPO	ADP	ADP-AC	SRT D/I
A01	69	8	58	37	0.86
A02	64	12	77	25	0.93
A03	58	18	81	50	0.81
A04	64	12	75	50	0.93
A05	63	20	70	37	0.92
A06	72	21	77	63	1.00
A07	67	17	77	84	0.92
A08	63	19	68	50	1.00
C01	71	-	-	99	0.94
C02	55	-	-	95	1.00
C03	62	-	-	95	1.00
C04	63	-	-	84	0.88
C05	67	-	-	91	0.94
C06	57	-	-	91	0.88
C07	67	-	-	91	0.81
C08	61	-	-	95	0.93

Note. Subject codes beginning with an A are aphasic subjects. Subject codes beginning with a C are control subjects. CVA MPO = months post onset of most recent CVA, ADP = Aphasia Diagnostic Profile Severity Score Percentile Rank, ADP-AC = Aphasia Diagnostic Profile, Auditory Comprehension Subtest Percentile Rank, and SRT D/I = Delayed/Immediate Recall ratio on the Story-Retelling Test.

Appendix C.
Randomization Order for the Two Experimental Presentations

	Randomization A	Randomization B
Block 1	EG20	FA12
	FA03	FA17
	RL16	RL18
	FA10	CL19
	FA04	FA11
	CL20	RL14
	IE18	CL18
	FA08	EG12
	RL04	CL05
	CL09	CL14
	RL09	IE19
	FA07	EG03
	FA05	FA18
	IE09	CL07
	RL01	EG17
	EG02	FA13
	EG10	FA15
	CL04	RL02
	IE11	RL08
	CL13	IE03

Appendix C (Continued).

	Randomization A	Randomization B
Block 2	CL16	EG08
	FA16	RL15
	FA20	CL02
	EG09	CL11
	IE06	FA01
	RL10	RL17
	RL06	RL13
	IE01	CL06
	FA06	CL17
	EG05	CL03
	CL08	CL12
	FA14	RL20
	CL15	FA09
	IE16	RL03
	IE04	RL12
	RL07	RL19
	IE14	EG16
	EG04	RL05
	IE20	IE13
	EG19	IE02
Block 3	CL01	FA02
	IE07	IE17

Appendix C (Continued).

	Randomization A	Randomization B
	EG14	EG06
	IE12	IE10
	EG15	EG11
	IE08	IE15
	EG01	EG18
	IE05	EG13
	CL10	FA19
	EG07	RL11
	FA12	EG20
	FA17	FA03
	RL18	RL16
	CL19	FA10
	FA11	FA04
	RL14	CL20
	CL18	IE18
	EG12	FA08
	CL05	RL04
	CL14	CL09
Block 4	IE19	RL09
	EG03	FA07
	FA18	FA05

Appendix C (Continued).

	Randomization A	Randomization B
	CL07	IE09
	EG17	RL01
	FA13	EG02
	FA15	EG10
	RL02	CL04
	RL08	IE11
	IE03	CL13
	EG08	CL16
	RL15	FA16
	CL02	FA20
	CL11	EG09
	FA01	IE06
	RL17	RL10
	RL13	RL06
	CL06	IE01
	CL17	FA06
	CL03	EG05
Block 5	CL12	CL08
	RL20	FA14
	FA09	CL15
	RL03	IE16

Appendix C (Continued).

Randomization A	Randomization B
RL12	IE04
RL19	RL07
EG16	IE14
RL05	EG04
IE13	IE20
IE02	EG19
FA02	CL01
IE17	IE07
EG06	EG14
IE10	IE12
EG11	EG15
IE15	IE08
EG18	EG01
EG13	IE05
FA19	CL10
RL11	EG07

Note. EG = Egocentric, IE = Immediate environment, FA = Factual, RL = Relational, and CL = Conditional.

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