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Training Sentence Production in Agrammatism: Implications for Normal and Disordered Language

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This paper presents an overview of our work concerned with treatment of sentence production deficits seen in agrammatic (Broca's) aphasic individuals. Using a single-subject experimental research paradigm, we examined emergent sentence production patterns in a subset of Broca's subjects who evinced sentence production (and comprehension) deficits involving "complex" sentences in which noun phrases (NPs) have been moved out of their canonical positions. We used aspects of Chomsky's Principles and Parameters approach of Government Binding (GB) Theory (Chomsky, 1986, Chomsky & Lasnik, 1991), as well as findings from the psycholinguistic and neurolinguistic literature as a basis for selecting sentences entered into our experiments and for designing our intervention approach, in general. Subjects were trained to produce sentences which rely on NP-movement (i.e., passives) or WH-movement (i.e., wh-questions, object clefts)—sentences formed by applying the rule "Move-alpha" in which moved constituents leave behind a "trace" or "gap" of their movement. Training emphasized the lexical and syntactic properties (e.g., thematic role assignment, NP-movement) of target sentences. Throughout this training we carefully measured generalization to untrained sentences relying on similar movement operations and

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error patterns were examined as they evolved over time. Results of our work indicated not only improved sentence production abilities in all subjects under study, but also—in many cases—generalization of sentence production across linguistic lines. That is, training WH-movement structures (e.g., object clefts) improved production of untrained WH-movement constructions (e.g., wh-questions) that are very different in their s-structure representation; however, no effect of this training on NP-movement structures occurred. In addition, within the class of wh-questions, generative production across questions relying on argument (direct object NP) movement (i.e., *what*- and *who*-questions) occurred in the absence of generalization to wh-questions requiring movement from adjunct position (i.e., *where*- and *when*-questions) for some subjects. For others, generalized production occurred only when wh-morphemes were the focus of treatment, indicating that at least two processes must be completed for successful wh-question production to take place: movement of the wh-item itself and control of sublexical features that determine wh-morpheme selection. These data are discussed in terms of the contribution that detailed recovery data, controlled for lexical and syntactic properties of sentence production, can make both to understanding the nature of sentence production deficits and to issues regarding normal sentence production.

This paper describes a series of experiments designed to examine sentence production in agrammatic aphasia by studying emergent production patterns occurring during the course of controlled treatment trials. Our purpose is to link linguistic and psycholinguistic issues with a proper research design so that generalization from trained to untrained structures can be assessed. We focus on a subset of aphasic patients—agrammatic Broca's patients—who are well known to produce primarily simple, incomplete sentences (Bates, Friederici, Wulfeck, & Juarez, 1988; Gleason, Goodglass, Obler, Green, Hyde, & Weintraub, 1980; Saffran, Berndt, & Schwartz, 1989). That is, they use primarily S-V and S-V-O structures (Christiansen, Goodglass, & Gallagher, 1993), and they evince difficulty in producing (and comprehending) "complex" sentences—sentences in which noun phrases (NPs) have been moved out of their canonical positions (e.g., wh-questions, passives, object relatives), i.e., sentences in which the order of thematic roles is noncanonical. We train subjects to produce these noncanonical sentences by taking them through a series of steps emphasizing the thematic roles of NPs, the movement of NPs required to derive the s-structure of complex sentences, and the insertion of grammatical elements in the surface sentence string. We use single-subject experimental designs (e.g., McReynolds & Kearns, 1983) to examine the effects of this sentence production training on both linguistically similar and linguistically dissimilar sentences. In this manner, the relation among the various sentence types used in our experiments is examined. If our hypotheses are correct concerning the need to consider the underlying representation of aberrantly produced

sentences, then generalization across sentences relying on the same representational mechanisms, but with different surface realizations should be noted. Furthermore, if learning and generalization patterns follow predictions gathered from linguistic theory, we might also be able to evaluate how well such theories can predict breakdown and recovery patterns in aphasia.

Our research program is based on the premises that (a) theories concerned with mentally represented linguistic knowledge can and should be used to deduce how normal sentence processing operates; that (b) aspects of normal sentence processing may serve a crucial role in determining what goes awry in the aphasias; and that (c) careful examination of emergent sentence production patterns occurring during treatment—controlled for lexical and syntactic properties that underlie normal sentence comprehension and production—can yield important data concerning sentence production operations.

Like Grodzinsky (1990), who has used Government Binding Theory (GB; Chomsky, 1981, 1986; Haegeman, 1992; van Riemsdijk & Williams, 1986) as a framework for discussing the sentence comprehension (and production) performance of agrammatic Broca's aphasic subjects (see also Hickok, Zurif, & Canseco-Gonzalez, 1993; Mauner, Fromkin, & Cornell, 1993), we use aspects of Chomsky's Principles and Parameters approach to GB Theory (Chomsky, 1981, 1986; Chomsky & Lasnik, 1991), as well as findings from the psycholinguistic literature as a basis for our treatment approach. The main motivation for Grodzinsky's theory has been the quest for a formal description of agrammatics' noted difficulty with the comprehension of sentences in which noun phrases (NPs) have been moved out of their canonical positions, leaving behind a "trace" or "gap" of that movement. Our work seeks to investigate the difficulty that agrammatics have with production of these noncanonical sentences.

The work that we describe in this paper examined production of both NP-movement derived sentences (i.e., passive sentences) and WH-movement derived sentences (i.e., object cleft and wh-questions). We selected passives, object clefts, and wh-questions because GB theory is quite explicit about how such constructions are derived (see below for a formal description of NP- and WH-movement). In addition, within the class of wh-questions, certain subsets of wh-constructions can be formed based on lexical-semantic as well as syntactic distinctions. For example, *what* and *where* questions—while they appear similar in their s-structure representation since both contain referential dependencies—are different when their underlying representations are considered. *What*-questions are derived by argument (direct object NP) movement; whereas *where*-questions are formed by adjunct movement.

TREATMENT OF SENTENCE PRODUCTION IN AGRAMMATIC APHASIA

Several approaches to training sentence level deficits in agrammatic aphasic individuals have been advanced in the aphasia literature—some of which focus directly on sentence production (e.g., Doyle, Goldstein, & Bourgeois, 1987; Helm-Estabrooks & Ramsberger, 1986; Loverso, Selinger, & Prescott, 1979; Thompson & McReynolds, 1986; Wambaugh & Thompson, 1989) and others which focus on aspects of sentence comprehension, testing sentence production as a byproduct of training (e.g., Byng, 1988; Jones, 1986; LeDorze, Jacobs, & Corderre, 1991; Schwartz, Saffran, Fink, Myers, & Martin, 1994). Interestingly, results of this work have shown that aphasic subjects respond well to treatment in that they improve in their ability to produce trained sentences; however, less impressive results have been reported regarding generalization across sentence types. That is, little or no generalization from trained to untrained sentence types has been reported. For example, production treatments focused on instruction and practice in producing notably aberrant sentence types have failed to improve production of sentences other than those trained (Doyle et al., 1987; Thompson & McReynolds, 1986; Wambaugh & Thompson, 1989). Further, even when more theoretically based treatments have been applied—for example, Mapping Therapy which exploits the meaning relations existing around verbs—improvement has been constrained largely to the types of sentences entered into treatment. For example, Schwartz et al. (1994) trained canonical (S-V-O) sentences with action verbs and various "padding" (additions of modifying words and phrases to the subject and/or object NP) using their Mapping Therapy and found improved canonical sentence comprehension (and production); however, little effect of this training was noted on noncanonical sentences (e.g., passives, object relatives, and subject relatives)—a finding consistent with the sentence production training literature.

We suggest that the lack of noteworthy generalization resulting from treatment of sentence deficits in aphasia can be explained by the following: The sentences selected for treatment have not been, for the most part, considered in terms of their lexical and syntactic properties, and, in addition the treatment provided for these agrammatic subjects has not focused explicitly on the lexical and syntactic processes underlying sentence production. Our work departs from previous work in that aspects of language representation and processing are considered. That is, we consider theories of grammar in our treatment of agrammatism. Recognizing the role of lexical and syntactic properties involved in normal sentence processing, we claim that application of treatment in which linguistic properties are manipulated and controlled may lead not only to improved production of certain sentences, but also to generalization

within and across linguistically related responses presumed to be influenced/subserved by similar rules and principles. We take seriously the lexical properties of verbs and their influence on sentence interpretation and production. As we discuss below, experimental evidence has indicated that agrammatic Broca's aphasic subjects appear to have normal access to verbs and thematic information (Shapiro & Levine, 1990; Shapiro, Gordon, Hack, & Killackey, 1993; Tyler, 1994; Kegl, 1994); however, they evince impoverished verb production (Miceli, Silveri, Villa, & Caramazza, 1984; Zingeser & Berndt, 1990) and they do not always fill the thematic grids around verbs in their sentence productions (Thompson, Shapiro, Li, & Schendel, 1995; Thompson, Shapiro, Tait, & Schneider, 1994; see also Neal & Caplan, 1994). Further, these patients do not appear to retain knowledge concerning trace-antecedent relations in sentences with moved constituents (Zurif, Swinney, Prather, Solomon, & Bushell, 1993), and it is likely that such binding relations also are not established in production (Thompson et al., 1994). Because Broca's subjects do not appear to "fill the gap" when it is encountered in the temporal unfolding of sentences, they too may not have access to coreferenced sentence constituents when attempting to produce sentences. In this regard, their simple sentence productions could be explained not only by limitations in access to verbs and verb-argument structure, but also by limited access to knowledge concerned with the ways that certain sentence constituents refer to each other when placed in sentence frames. We explore this postulate in our experiments concerned with production of sentences in which NPs have been moved out of their d-structure position in s-structure representations, leaving behind a *trace* or *gap* of that movement.

Because of the importance of verbs and thematic information in sentence production, our treatment begins with tasks concerned with establishing and improving access to the proper thematic role information around verbs produced.[1] Next we exploit processes involved in establishing trace-antecedent relations in complex sentences. We select sentences that rely on either WH-movement or NP-movement processes, enter some into treatment, and reserve the remaining sentences for generalization testing. Careful study of sentence production patterns emerging when treatment is applied, then, yields information not only concerning

[1] It is important to note that Mapping Therapy (Schwartz et al.) also is focused on the thematic role of sentence NPs. Our approach, however, departs from Mapping Therapy in that we require production (vs. strictly comprehension) of the verb and its arguments as well as adjuncts contained in target sentences. Importantly, we also exploit the movement operations involved in creating grammatically correct noncanonical sentences, emphasizing how thematic roles are retained in the s-structure of complex sentences in which NPs have been moved out of their canonical positions.

the most efficacious ways to approach sentence production treatment, but also data concerning the relation between sentences trained and the processes involved in sentence production.

SINGLE-SUBJECT EXPERIMENTAL ANALYSIS

We approach our investigations using a treatment research paradigm in which single-subject experimental designs are utilized (Connell & Thompson, 1968; Kearns, 1986; McReynolds, & Kearns, 1983; McReynolds & Thompson, 1986). Treatment research, like any other experimental research, requires use of experimental designs that allow examination of the effects of treatment on dependent measures while ruling out the effects of extraneous variables. Both group designs and single-subject experimental designs allow such control to be established. However, because of the potential heterogeneity among individuals with agrammatism (or, perhaps, because of the wide range of definitions of agrammatism and subject selection criteria applied by investigators), studying groups of patients even with apparently similar symptom patterns may not lead to the most important outcomes of treatment research—discovering the treatments that derive the best results for individual patients and discovering functional relations among and between language responses. That is, a major advantage of single-subject designs is concerned with the inherent requirement of these designs that the dependent variables under study be repeatedly measured throughout the course of experimentation, thereby allowing close examination of both trained and untrained language responses as they emerge. In this manner, covariance among and between linguistic structures can be studied.

Importantly, single-subject experimental research stands in contrast to single-case studies. Single-subject experimental designs used properly always require study of more than one subject for replication purposes and internal validity or experimental control is demonstrated through arrangement of design components. The only thing in common between the two approaches is their detailing of an individual subject's responsiveness to treatment. In single-subject experimental research, this is accomplished through repeated measurement of carefully specified dependent measures throughout the course of the study; in single-case studies repeated measurement is not required.

Single-subject experimental designs, therefore, are appealing in that they adhere to requirements of empirical research and still allow examination of individual patterns of responding such that relations between language structures may be experimentally tested. In this regard, single-subject experimental analysis can be thought of as a novel approach to research in agrammatism. By experimentally manipulating certain sentence structures, while at the same time repeatedly testing others, the

relation among sentence constructions can be examined. Further, by detailing sentence production error patterns and how these change over time, the operations involved in approximating grammatically correct sentence productions can be gleaned.

LINGUISTIC FRAMEWORK

Before we discuss our experimental findings, we present a review of relevant linguistic issues; we follow with a brief discussion of sentence processing in both normal and disordered populations.

The Lexicon and Theta Theory

In this section we consider, briefly, the lexical properties of verbs (and prepositions) and how such information interacts with the structure of sentences.

Predicate-argument structure. From a logical standpoint, most sentences can be considered representations of relations between a predicate and its arguments, hence the term argument structure. An NP (or sentential clause (CP/IP))[2] in a sentence can be an argument of the verb if it occupies an argument position (i.e., subject and complement positions) in the sentence. While strict subcategorization supplies information about the syntactic form (and ordering) of arguments, argument structure characterizes how many arguments a verb selects. In effect, argument structure specifies how many participants occur in the "action" described by the verb. Consider the verbs *kiss* and *put.* The transitive verb *kiss* requires two participants, a "kisser" and a "kissee"; thus, it selects for two arguments and hence a two-place argument structure. The verb *put* selects for a three-place argument structure. Arguments and argument structures are often represented as variables:

1. [Joelle $_x$] [$_{VP}$ kissed [Zack $_y$]]
2. [Dillon $_x$] [$_{VP}$ put [the toy $_y$] [on the shelf $_z$]]

(1) shows that *kiss* selects for a two-place (x, y) argument structure,where the NP *Joelle* is the x-argument and the NP *Zack* is the y-argument; (2) shows that *put* selects for three-place (x, y, z) argument structures, where the NP *Dillon* is the x-argument, the NP *the toy* is the y-argument, and the PP *on the shelf* contains the z-argument.

Thematic roles, assignment, and traces. Each argument can also have a unique "semantic" status (e.g., Agent, Theme, Goal).[3] That is, each

[2] We adopt a notation introduced by Chomsky (1986). CP (Complementizer Phrase) is equivalent to S'; IP (Inflection Phrase) is equivalent to S.

[3] It may turn out that one or another of these lexical properties are predictable from other information and thus are not really representational primitives. For example, Jackendoff

verb selects sets of thematic roles (theta roles) assigned to its arguments; each set of roles is called a thematic grid. Like subcategorization and argument structure, thematic grids are part of the lexical representation of the verb. The verb *kiss*, for example, allows a two-place (x, y) argument structure; assigned to these arguments from one thematic grid is both an Agent and a Theme:

3a. [Dillon $_{\text{AGENT}}$] kissed [$_{\text{NP}}$ Joelle $_{\text{THEME}}$]
3b. kiss: V → lexical category
(x y) → argument structure
(Agent Theme) → Thematic grid

(3a) shows that the verb *kiss* allows a two-place argument structure with Agent and Theme assigned to the arguments; the partial representation in (3b) reflects these lexical properties.

Consider now the following sentences:

4. Joelle kissed Zack (active)
5. Zack was kissed by Joelle (passive)
6. It was Zack who Joelle kissed (object cleft)
7. Who did Joelle kiss (wh-question)

Despite appearing in different grammatical positions, the NP *Joelle* is assigned the role of Agent and the NP *Zack* is assigned the role of Theme in each of these sentences [in (7) *who* serves the role of the moved direct object and, therefore, is assigned the thematic role of Theme].

Consider (7) in a bit more detail: The lexical properties of *kiss* require two argument positions; *Who* is co-indexed with the direct object argument position and assigned the theta role of Theme:

8. [$_{\text{CP}}$ Joelle kissed who]

To derive s-structure, *who* is moved into the Specifier position of COMP, leaving behind a trace in the direct object argument position:

9. [$_{\text{CP}}$ who$_i$ [$_{\text{C'}}$ did [$_{\text{IP}}$ Dillon kiss t$_i$]]]

Who is coindexed (represented by subscript i) with the trace (t), forming a theta chain. The wh-element receives its thematic role indirectly via this chain.

Sentences (5) and (6) receive a similar analysis, shown by the (partial) s-structures in (10) and (11):

(1987; 1990) makes a strong case that thematic roles are derived from lexical-conceptual structure and thus thematic roles are to be considered as "mnemonic devices" that stand for a more richly specified, and primitive, set of conceptual representations (e.g., CAUSE, PATH, etc.).

10. $[_{IP}$ Zack$_i$ was kissed t_i [by Joelle]]
11. It was Zack$_j$ [CP who$_{i,j}$ [IP Joelle kissed t_i]]

Details aside, in (10) the Theme role is assigned by the verb to the chain headed by the displaced argument *Zack* via the trace in direct object position. In (11) the situation is similar to example (9), with Wh-movement of *who* from direct object position; however, an additional co-indexation relation holds between *Zack*, NP head of the relative clause, and the coreferential wh-item (i.e., *who*).

"Move-alpha": NP- and WH-Movement

The examples supplied in (10) and (11) show two major types of movement (subsumed under Move-alpha): NP-movement and WH-movement. In NP-movement, a noun phrase is moved from an argument position (e.g., in the passive, the direct object position) to another argument position (e.g., the subject position), leaving behind an NP-trace. NP-movement occurs in the derivation of the passive (10) and so-called NP-raising structures (e.g., *Zack$_i$ seems t_i to be crying*). Unlike NP-movement, WH-movement involves displacement of wh-phrases from argument positions (e.g., direct object) to nonargument positions (e.g., Specifier of COMP), leaving behind a wh-trace. WH-movement derives wh-questions, relative clauses, and relative clefts.

Another difference between the passive and WH-movement involves the distance between the trace and its antecedent. Consider the simplified structures in (12) and (13):

12. $[_{IP}$ the boy$_i$ was hit t_i by the girl]
13. $[_{CP}$ It was the boy $[_{CP}$ who$_i$ $[_{IP}$ the girl hit t_i]]]

Note that (12) shows that no IP node intervenes between the trace and its antecedent in the passive, yet in the object cleft (13) *who* has moved out of IP into the specifier position of CP.

Arguments and Adjuncts

We need to make one more distinction before we move on to a description of the relevance of these linguistic notions to normal and disordered language processing. Implicit in this organization of lexical entries is the distinction between arguments and adjuncts. An argument is idiosyncratically selected by the verb; it forms part of the verb's entry in the lexicon, is usually obligatorily present, and is protected from deletion by the Projection Principle. An argument is thus assigned its thematic role by the

verb. An adjunct is not as rigidly selected by the verb, is never obligatorily present, and is not covered by the Projection Principle. Consider

14. Mary sent the book to the library
15. Mary read the book in the library

In (14) the three-place predicate (ditransitive or "dative" verb *send*) assigns three thematic roles to its arguments—an Agent to the NP *Mary*, a Theme to the NP *the book*, and a Goal to the NP *the library*. The two-place transitive verb *read* in (15) assigns only two thematic roles to its arguments—an Agent to the NP *Mary* and a Theme to the NP *the book*. The PP *in the library* is considered a locative adjunct; its "meaning" is not inherent in the verb's representation. Indeed, locative PPs like *in the library, under the tree*, etc. can occur fairly freely. Phrasal geometry also distinguishes between arguments and adjuncts. Adjunct PPs frequently show attachment ambiguities. For example, (15) can mean something like "*it was the book that was in the library* (not the book outside the library) *that Mary read*" in which case the adjunct PP—*in the library*—is attached to (i.e., modifies) the Noun Phrase *the book*. But it can also mean something like "*it was in the library* (not outside the library) *where Mary read the book*." In this case the PP modifies and is attached to the VP—*read the book*. Unlike the adjunct PP in (15), the argument PP in (14) is unambiguous; it carries one and only one possible interpretation—the Goal of the "action" described by the verb.

SENTENCE PROCESSING IN NORMAL AND NEUROLOGICALLY IMPAIRED POPULATIONS

Recent psycholinguistic work has shown that virtually all of these theoretical constructs have implications for accounts of sentence processing. For example, the thematic representations of verbs appear to be accessed in the verb's temporal vicinity in both normal listeners (e.g., Shapiro, Brookins, Gordon, & Nagel, 1991; Boland, 1991; Tanenhaus, Carlson, & Trueswell, 1989) and agrammatic Broca's aphasic patients (Shapiro & Levine, 1990; Shapiro et al., 1993a). Nevertheless, Broca's aphasic patients have difficulty properly assigning thematic roles onto arguments that have been moved out of their canonical positions (Caplan & Futter, 1986; Grodzinsky, 1990; Schwartz, Linebarger, Saffran, & Pate, 1987). Preferences for a verb's complements (or argument structures) appear to help guide the initial parse of a sentence (Shapiro, Nagel, & Levine, 1993; Trueswell, Tanenhaus, & Kello, 1993). Arguments and adjuncts affect sentence processing differentially: Adjuncts yield increased processing load relative to arguments in normal listeners (Shapiro et al., 1993a) and increased errors in sentence production in brain-damaged amnesic pa-

tients (Shapiro, McNamara, Zurif, Lanzoni, & Cermak, 1992). It also appears that NP- and WH-movement constructions each may have their own processing routines: More "work" needs to be done to attach an antecedent to a wh-trace than to an NP-trace since a wh-trace and its antecedent are separated by more clausal boundaries (e.g., Berwick & Weinberg, 1984).

Finally, work concerned with describing the production defict noted in Broca's aphasic patients with agrammatism has shown not only that these aphasic patients use shorter and less complex sentences than do normal subjects, but also that they produce fewer verbs than normal or aphasic subjects of other types (Miceli et al., 1984; Saffran et al., 1989; Zingeser & Berndt, 1990). Additionally, we (Thompson et al., 1994) found in a recent analysis of the production patterns of agrammatic aphasic subjects using a coding system developed with respect to the structure of the grammar that our agrammatic subjects did not use the full range of lexical properties available given a particular verb. That is, aphasic speakers produced significantly more one- and two-place verbs than did normal speakers; conversely, normal speakers produced more three-place and complement verbs than did aphasic subjects. Also, aphasic speakers often used complex verbs in their "simplest" form relative to normal speakers. This restriction, we surmised, was not due to any simple length or "economy of effort" consideration, but was due to a complex mixture of verb and sentence variables that affects the computational complexity of producing sentences. We suggested that this limitation may partially explain the short utterance length that is prevalent in agrammatic aphasia.

EXPERIMENTAL MANIPULATIONS

We exploited these findings in our experimental manipulations concerned with sentence production in agrammatic aphasic subjects. Investigating sentences that require application of the rule 'Move-alpha' (i.e., NP- and WH-movement) to derive noncanonical sentences, we taught subjects to recognize the verb and their argument structures in the active form of sentences and we instructed them to perform the movement required to derive s-structure representations of target sentences (importantly, we do not claim that active sentences are, in fact, the d-structure or underlying form for the derived noncanonical sentences; they simply contain the same thematic properties and thus can be used to help train such notions).

Subjects

A total of 17 aphasic subjects who presented with language profiles consistent with a diagnosis of Broca's aphasia (based on performance on the *Western Aphasia Battery* [WAB; Kertesz, 1983]) have been studied to date. All subjects evinced aphasia secondary to a single left-hemisphere neurological insult and were at least 12 months post onset of infarction. For the majority of our subjects, aphasia resulted from thromboembolic events in the distribution of the left middle cerebral artery (MCA); however, some subjects sustained aphasia secondary to ruptured aneurysm, tumor, and gun shot wounds; and one subject experienced

aphasia of unknown etiology carrying a diagnosis of Primary Progressive Aphasia (PPA). All subjects were native English speakers and premorbidly right-handed and had at least a high school education. All subjects passed pure-tone audiological screenings at 40 dB HL (ANSI, 1969) at 500, 1000, and 2000 Hz in at least one ear.

Language testing. The language disruption patterns noted in our subjects were consistent with agrammatism. Aphasia quotients derived from the WAB ranged from 56 to 93 across subjects with a mean of 74.5. Auditory-verbal comprehension, while impaired, was superior to verbal expressive abilities; WAB comprehension subtest scores ranged from 6.5 to 10.0 with greater difficulty noted in comprehension of sequential commands than yes/no questions or auditory word recognition. Fluency scores were 4.0 or 5.0, reflecting production of primarily short phrases and simple sentences. Subjects presented with varying degrees of naming, repetition, and reading comprehension difficulties.

We tested sentence comprehension quite extensively in our studies using the *Philadelphia Comprehension Battery for Aphasia* (PCBA; Saffran, Schwartz, Linebarger, Martin, & Bochetto, unpublished) and other measures. The PCBA contrasts lexical comprehension with sentence comprehension, comprehension of semantically reversible and nonreversible sentences, and comprehension of canonical and noncanonical sentences using a sentence-picture matching paradigm. Our subjects exhibited lexical comprehension superior to overall sentence comprehension with semantically reversible sentences compromising comprehension more greatly than nonreversible sentences. Further, our subjects showed relatively spared comprehension of canonical sentences (i.e., actives and subject relatives), but performed at chance or below on complex sentences in which NPs are moved out of their canonical positions (i.e., passives and object relatives).

Our subjects showed evidence of agrammatism in both elicited discourse and in constrained sentence production tasks. Narrative discourse samples were collected and analyzed using a coding system developed by Thompson et al. (1994) which details both lexical and morphosyntactic aspects of production. Narrative samples were obtained by asking subjects to tell the story of *Cinderella* using the method delineated by Saffran et al. (1989). On this task, as well as in conversational discourse, our agrammatic subjects produced primarily short utterances composed of few grammatical sentences. Most sentence productions were grammatically simple—that is few, if any, sentences contained moved sentence constituents or embeddings. Calculation of noun/verb ratios and open/closed class ratios showed that our agrammatic subjects produced more open class compared to closed class words; notably, within the open class, the agrammatic subjects produced more nouns than verbs.

Further, in terms of verb and verb argument structures produced by our subjects (see Appendix A for a detailing of verb and verb-argument coding), we found that our agrammatic subjects produced primarily obligatory one- and two-place verbs, few optional two-place verbs, and still fewer three-place verbs. Some agrammatic subjects also produced a sizable proportion of complement verbs; however, few of these verbs were produced with sentential complements—most were produced in direct object NP form. Our agrammatic subjects also produced more one- and two-place verbs with correct argument structure as compared to the other verb types. Too, our subjects produced Agents, Themes, and predication phrases correctly more often than third arguments (e.g., Goals) or sentential complements. It is important to note, additionally, that these subjects produced adjuncts correctly in less than 50% of their attempts.

To test constrained sentence production a sentence production priming task was used in which semantically reversible action pictures were presented in pairs and target sentence types were primed using one picture in the pair. Following the sentence prime, subjects were expected to produce the primed sentence type using the semantically reversed picture in the pair. We found that our subjects were able to produce active sentences, but not passives, object clefts, or Wh-questions.

PRODUCTION OF MOVED SENTENCE CONSTITUENTS: WH-MOVEMENT AND NP-MOVEMENT

As discussed previously, there are two kinds of phrasal movement subsumed under the general rule "Move-alpha": WH- and NP-movement. Our experiments examining these two forms of "Move-alpha" involved teaching agrammatic aphasic subjects to produce sentences derived by either WH-movement (i.e., wh-questions and object clefts) or NP-movement (i.e., passive sentences); we tested generalized production both within and across sentence types. Consider the following sentences:

16. Who did the girl hit? (wh-question)
17. It was the boy who the girl hit. (Object-cleft)
18. The boy was hit by the girl. (Passive)

In one of our experiments using a multiple baseline design, we (Thompson & Shapiro, 1994) trained aphasic subjects to produce wh-questions such as (16) and tested for generalization to object-cleft (17) and passive sentences (18). At the same time, we trained other subjects to produce object-cleft sentences and tested for generalization to wh-questions and passives.

Of interest here was analysis of the generalization patterns resulting from treatment. We postulated, for example, that because both wh-questions and object clefts are derived from WH-movement, we might observe improved production of wh-questions when object clefts were trained and vice versa, even though these sentences are very different from their surface form. Further, we predicted that neither training production of wh-questions or object clefts would affect production of passives, as passives are derived through NP-movement.

In this experiment, treatment was focused on the active form of sentences trained, since the active form contained the same thematic properties as the derived constructions. For example, when training production of either (16) or (17), the sentence form as shown in (19) was presented:

19. The girl hit the boy. (Active form)

Three agrammatic subjects were trained to recognize the verb, its arguments, and their thematic role assignments using this active sentence form. Then instructions concerned with movement of arguments to—in this case—nonargument positions were given to derive the surface form of targeted sentences. Subjects then were instructed to produce the derived surface representation of target sentences. Additional morphemes required in the surface form also were provided and inserted into sentence frames. Throughout the training period, production of both trained and untrained WH- and NP-movement-derived sentences were tested us-

ing our sentence production priming task; emergent production patterns were recorded.

Results of this experiment indicated that, indeed, the distinction between WH-movement and NP-movement processes is evident in sentence production in brain-damaged subjects. That is, two of our three agrammatic Broca's aphasic subjects readily learned to produce sentences derived from WH-movement, and with this learning, generalized production of other WH-movement-derived sentences was seen; no change in production of passive sentences (NP-movement) was observed. That is, training on wh-questions generalized to production of object clefts, but not to passives; similarly, training of object clefts resulted in generalized production of wh-questions, but again no effect of treatment was noted in production of passive sentences.

In another related study involving four agrammatic Broca's aphasic subjects, we (Jacobs & Thompson, 1994) replicated the previously noted distinction between WH- and NP-movement derived sentences. In this study object cleft and passive sentences again were selected for analysis. Following a baseline period in which production (and comprehension) of both sentence types was tested, treatment (similar to that provided in Thompson & Shapiro, 1994) was applied to one of the two sentence types and the effects of this training were measured by repeatedly testing production of both sentence types on generalization probe tasks. Results were similar to those found by Thompson and Shapiro (1994): While all subjects learned to produce the sentence types trained, no generalization to untrained sentence types was noted. That is, when subjects were taught to produce passive sentences, production of object-cleft sentences was not influenced. Similarly, when subjects were trained to produce object-cleft sentences, no change in production of passive sentences was noted. It appears from our data that once the movement operations required for one type of sentence relying on a particular type of movement is exploited, other sentences relying on similar processes emerge. These data then suggest that perhaps common mentalistic operations are required for sentences that are linguistically similar. Clearly, the current production data support the separation between NP- and WH-movement operations that shows up in both sentence processing and production work.

PRODUCTION OF SENTENCES INVOLVING ARGUMENT VS. ADJUNCT MOVEMENT

Another distinction in linguistic theory, also noted in sentence processing work, concerns the difference between arguments of the verb and adjuncts. We, too, have studied this distinction in sentence production experiments with agrammatic subjects. Our first attempt (Wambaugh &

Thompson, 1989) examined the effects of training wh-question productions in four agrammatic aphasic subjects. Using a multiple baseline design across behaviors and subjects, *what* and *where* questions were trained, while generalization within and across structures was examined. Results indicated that, although generalization within structures occurred (i.e., from *what* constructions to untrained *what* constructions), generalization across structures (i.e., from *what* to *where* constructions) was negligible. In keeping with our current theoretical framework, we surmised that this lack of generalization across wh-questions that are notably analogous in their s-structure representation (e.g., phrase structure is exactly the same) could have resulted because of the difference in argument structures for the two wh-construction types. For example, consider the following sentences trained by Wambaugh and Thompson:

20. What is he cooking?
21. Where is he sleeping?

Importantly, the verbs *cook* and *sleep* have different lexical properties. *Cook* is a two-place transitive verb allowing a direct object NP (e.g., *He is cooking the dinner*) and an Agent, Theme thematic grid, whereas, *sleep* is a pure intransitive verb—not taking a direct object NP. Here the focus of the wh-question is, in fact, a locative adjunct. To appreciate the structural distinction between these two verb types, consider the following:

22. he is $[_{VP}[_{V'}$ cooking the dinner]]
23. he is $[_{VP}[_{V'}$ sleeping] in the bed]

As discussed earlier in this paper, the direct object in (22)—*the dinner*—occurs as sister to the lexical head of VP; that is, it is directly theta-marked by the verb. However, in (23), the locative—*in the bed*—occurs as sister to V′ in an adjunction structure and is, thus, outside of the V′ containing the head verb. Therefore, in *what*-questions, derived from argument (object NP) movement, a theta chain consisting of a trace in the object NP position and its co-indexed antecedent (the wh-complementizer) is established and the trace is properly governed by the verb. A similar chain is established in *where*-questions, but the trace is crucially not properly governed by the verb.

Given the differences in *what*- and *where*-question formation, we theorized that the lack of generalizaton noted in the subjects studied by Wambaugh and Thompson resulted from distinctions between argument and adjunct movement—distinctions resulting from verb properties and thematic role assignment. If this postulate were correct, wh-questions that are alike not only in s-structure, but also in their underlying linguistic representation (i.e., questions using verbs with similar argument structures/thematic grids) would be better candidates for generalization.

For example, we predicted generalization from *what*-questions to *who*-questions—identical in both argument structure and in phrase structure—because verbs that enter into both kinds of questions take a direct object NP.

In a follow-up study, we (Thompson, Shapiro, & Roberts, 1993) investigated this possibility and reported the results for two agrammatic aphasic subjects trained to produce *what*- and *who*-questions. Consider the following:

24. Zack is helping $[_{NP}$ a friend $_{THEME}]$
25. Zack is fixing $[_{NP}$ the toy $_{THEME}]$

In (24) and (25) both the verbs *help* and *fix* take a direct object NP which falls within the domain of the VP. To derive a wh-question, the direct object NP (which has received the thematic role of Theme in the d-structure) is replaced by a trace co-indexed with the wh-morpheme in sentence initial position ([SPEC, CP], as in (26) and (27):

26. $[\text{Who}]_i$ is Zack helping $[t]_i$
27. $[\text{What}]_i$ is Zack fixing $[t]_i$

In our experiment we used sentences like those in (24) and (25) to train *who*- and *what*-questions like those in (26) and (27). In addition, we used sentences with ditransitive or dative verbs like *give*, embedded in NP-V-NP-PP sentences (as in (28 below)) to train *who*- and *what*-questions such as that in (29) below:

28. The man is giving money to the boy
29. What_i is the man giving t_i to the boy?

Results of the study indicated, as predicted, that training of selected examplars of *who*-questions resulted not only in improved production of both trained and untrained *who*-questions, but also of untrained *what*-questions for one of the two subjects. Interestingly, both subjects showed generalization from more to less "complex" structures. That is, when sentences like (28) were used to help derive productions of sentences like (29), generalized production of sentences like those in (26) and (27) was observed without direct treatment of these structures. Findings from this study, again, supported the distinction between arguments and adjuncts. However, given the limited number of subjects as well as the heterogeneous results derived, we undertook a final study investigating this distinction.

In this final study, we (Thompson, Shapiro, Tait, Jacobs, & Schneider, in press) selected not only wh-questions that rely on WH-movement from argument position, but also those that rely on WH-movement from an adjunct position. That is, our agrammatic Broca's aphasic subjects were trained to produce either *who*- or *what*-questions which require movement of the argument NP (direct object) or *when*- and *where*-questions

which required adjunct movement; generalizaton was measured within and across these four wh-questions.

Using a set of 20 optionally transitive verbs, 80 active sentence stimuli (NP-V-NP-PP) were developed. For example, consider

30. The soldier is pushing the woman into the street.
31. The boy is kicking the cow in the barn.
32. The student is helping the doctor during the evening.
33. The guard is protecting the clerk at the store.

These sentences were used to help derive production of wh-questions that contained similar lexical properties (as indicated in (34)–(37)). Recall that these *who*- and *what*-questions are formed by displacement of a direct object argument, whereas, these *where*- and *when*-questions showed movement from an adjunct position:

34. Who_i is the soldier pushing t_i into the street? (the woman)
35. What_i is the boy kicking t_i in the barn? (the cow)
36. When_i is the student helping the doctor t_i? (during the evening)
37. Where_i is the guard protecting the clerk t_i? (at the store)

Using stimuli such as those in (30) to (33), wh-questions as in (34)–(37) were elicited in the following manner: A stimulus sentence (e.g., (30) above) was presented for the subject to read and the following instructions were given: "You want to know the person the soldier is pushing, so you ask?." The word "person" was emphasized, rising inflection was used, and a question mark card was placed above the sentence. To elicit *what*-questions using the stimulus sentence in (31) above, the examiner instructed: "You want to know the thing the boy is kicking, so you ask?." This time, the word "thing" was emphasized. To elicit *when*- and *where*-questions, the same procedure was used except that subjects were instructed to ask about the time or the place, respectively. Using this procedure during baseline testing indicated that none of the subjects was able to produce any of the wh-questions under study.

Seven agrammatic aphasic subjects were trained (a) to recognize the verb and verb-argument structures of the active sentences, (b) to move the proper sentence constituent to formulate wh-questions, and (c) to produce the surface form of targeted wh-questions. In keeping with the multiple-baseline design across behaviors, subjects received this training using only one wh-question form at a time (e.g., *who*), while the remaining wh-question forms (i.e., *what, where, when*) as well as untrained exemplars of the trained form (i.e., untrained *who*-questions) were tested for generalization using procedures identical to those used in baseline testing. The emergent sentence production patterns, then, provided information regarding the organization of sentence production operations within and across subjects.

Results indicated two patterns of emergent sentence production across subjects under study. The first pattern was noted in three of the subjects who demonstrated acquisition and generalization patterns as expected. That is, when treatment was applied to wh-questions requiring movement of the argument NP (i.e., direct object; e.g., *what*-questions), generalized production of untrained wh-questions was restricted to those also relying on argument movement (e.g., *who* questions). Similarly, when treatment was applied to wh-questions linked to adjuncts (e.g., *where*-questions), generalization occurred to untrained wh-questions relying on similar adjunct movement (e.g., *when*-questions). Importantly, argument movement did not generalize to adjunct constructions, and vice versa, supporting the findings derived by Wambaugh and Thompson (1989). These data indicated, then, that the argument/adjunct distinction found in both the linguistic and the psycholinguistic literature extends to the cross-generalization distinction found between arguments and adjuncts with our aphasic patients.

A second pattern of sentence production was noted in the other four agrammatic subjects. While treatment resulted in improved production of trained wh-question forms as well as a generalized decrease in errors of co-referencing in untrained question forms, these subjects consistently misselected the *Specifier*—producing any one of the four wh-morphemes at random. Therefore, for these subjects, discrimination/production training (of wh-morphemes) was instituted, which resulted in correct wh-question production of all four question types.

Based on the results of our studies investigating wh-question production, we suggest that there may be separate processes underlying the production (and perhaps comprehension) of WH-movement constructions, specifically regarding control of syntactic features of wh-question formation (i.e., movement of the NP itself) and control of sublexical features of wh-questions (i.e., wh-morpheme selection). Three of our agrammatic patients presented primarily with a syntactic deficit which influenced their wh-sentence production—they had difficulty selecting the proper NP to be moved. The other four subjects presented with an additional selection deficit involving the nonlexical (i.e., closed class) wh-word—they misselected, randomly, among the corpus of wh-morphemes under study. We note that this latter finding supports Grodzinsky's (1990) misselection hypothesis of agrammatic sentence production.

EFFECTS OF SENTENCE PRODUCTION TREATMENT ON DISCOURSE

Of particular interest to us is the effect of sentence production treatment on discourse; such an analysis is important in order to yield informa-

tion regarding how far the benefits of training extend. To this end, our most recent work carefully detailed lexical and morphosyntactic aspects of narrative and conversational discourse both prior to and following application of treatment (see Thompson et al., in press, for details). Results indicated important differences in the discourse data on post-testing compared to pretesting samples. To summarize, we found (a) statistically significant changes in the proportion of simple and complex sentences produced prior to and following treatment, reflecting a decrease in simple sentence productions and a concomitant increase in complex sentence productions, (b) decreases in noun/verb ratios, indicating an increase in the proportionate number of verbs as compared to nouns produced, (c) increases in the proportion of verbs produced with correct verb argument structure, with notable increases in correct usage of both x (Agents) and y (Themes), and (d) statistically significant changes in the proportion of adjuncts produced correctly. These data indicated that the benefits of our sentence production treatment extended beyond our experimental probe task to discourse.

We attributed the changes noted in spontaneous discourse to the nature of the treatment provided—which focused explicitly on the linguistic and psycholinguistic underpinnings that we hypothesized would influence production of sentences. Indeed, the current observation that sentence production treatment influenced lexical and syntactic properties that apply to sentence production in general attests to the efficacy of this treatment approach. If such improvements had not been forthcoming as a result of our intervention, the efficacy of this approach to treatment could be questioned. As we have pointed out elsewhere (see, for review, Thompson, 1988), it is the generalization of treatment effects that indicates the efficacy of treatment.

CONCLUSIONS

The data that we have gathered to date indicate that our treatment approach is successful; all subjects have shown improved sentence production on trained forms, regardless of the sentence type entered into treatment. Additionally, generalization from trained to untrained sentences has been noted consistently across our studies—with predictable patterns. We suggest, then, that when the linguistic underpinnings of (a) the language deficits exhibited by aphasic individuals, (b) the sentences selected for treatment, and (c) the treatment strategy applied are considered, treatment appears to be efficacious. When linguistic underpinnings are not considered, generalization effects are considerably diminished—or are absent—resulting in little or no discernible improvement in sentence production beyond the kinds of constructions trained.

Our findings attest to the contribution that detailed recovery data can

make both to understanding the nature of sentence production deficits and to issues regarding normal sentence production. We have shown that our program—although successful in its treatment application—can also be thought of as a novel experimental paradigm for examining various types of lexical and syntactic relations. We find our results to be compelling in terms of the use of treatment research paradigms for investigating theoretical issues relevant to both normal and agrammatic language. Because agrammatism appears to be a linguistically selective impairment, studying the relation among and between structures through analysis of generalization patterns provides information relative to the nature of the disorder and to the "usability" of the linguistic constructs upon which our analyses are based. We conclude that the generalization effects we have observed, both in our probe and discourse analyses, can be at least partially attributed to the nature of the treatment provided.

APPENDIX A

Verb, Argument, and Adjunct Codes Used for Analysis of Discourse in Aphasic and Normal Subjects

Obligatory one-place verbs (ob1): intransitive verbs, requiring an external argument only (Agent),

e.g., the verb *work*. [The men]$_{\text{Agent}}$(x) work(ob1).

Obligatory two-place verbs (Ob2): transitive verbs, requiring two arguments (an external Agent [x] and a Theme [y] or a Theme [y] and a Predication Phrase [p]—Noun Phrase, Prepositional Phrase, or Adjectival Phrase) (x, y; y, p),

e.g., the verb *fix*. [Zack]$_{\text{Agent}}$(x) fixed(ob2) [the radio]$_{\text{Theme}}$ (y) and
the verb *look*. That looks(ob2) [good]$_{\text{Adjectival Phrase}}$ (p).

Obligatory three-place verbs (ob3): requiring three arguments (an external Agent [x], Theme [y], Goal [z]). Includes both alternating and nonalternating datives (x, y, z; x, z, y).

e.g., the verb *give*. [Joelle]$_{\text{Agent}}$(x) gave(Ob3) [the ball]$_{\text{Theme}}$ (y) [to Zack]$_{\text{Goal}}$ (z). [Joelle]$_{\text{Agent}}$(x) gave(Ob3) [Zack]$_{\text{Goal}}$(z) [the ball]$_{\text{Theme}}$ (y).

Optional two-place verbs (op2): also known as optional transitives, must take an Agent [x], but the Theme [y] is optional. Therefore, they may take two possible argument structure arrangements (x) and (x,y),

e.g., the verb *eat*. [We]$_{\text{Agent}}$(x) eat(op2) and
the verb *read*. [John]$_{\text{Agent}}$(x) read(op2) [the book]$_{\text{Theme}}$ (y).

Optional three-place verbs (op3): must take an external argument and a theme, but the goal is optional; therefore, three-argument structure arrangements are possible (x, y) (x, y, z), and (x, z, y). Includes both alternating and nonalternating datives,

e.g., the verb *send*. [John]$_{\text{Agent}}$(x) sent(op3) [the paper]$_{\text{Theme}}$ (y), [John]

$_{Agent}$(x) sent(op3) [the paper]$_{Theme}$ (y) [to Joan]$_{Goal}$ (z), and [John]$_{Agent}$(x) sent(op3) [Joan]$_{Goal}$ (z) [the paper]$_{Theme}$(y).

Complement verbs (c): may be produced with three argument structure arrangements, requiring an external argument (x) and (a) a theme [y] (x, y), (b) a sentential complement [s'] such as a Wh-clause, that-clause, or an infinitive clause (x, s'), or (c) a predication phrase [p] (x,p),

e.g., the verb *accept*. [Zack]$_{Agent}$(x) accepted(c) [the money]$_{Theme}$ (y). [Zack]$_{Agent}$(x) accepted(c) [that the money was for research](s') and

the verb *feel*. [Zack]$_{Agent}$(x) felt(c) tired(p).

Copulas (cop): a form of be, serving as the matrix verb in a sentence, takes a Theme [y] and (a) a predication phrase (Noun Phrase, Prepositional Phrase, or Adjective Phrase) [p] (y,p) or (b) a sentential clause [s'] (y,s'),

e.g., the verb *is*. [John](y) is(cop) [a boy](p) and [John](y) is(cop) [who I want](s').

Argument/adjunct codes: x, Agent; y, Theme, Patient; z, Goal; s', Sentential Complement; p, Predication Phrase (NP, PP, AP); j, Adjunct (optional to the verb structure).

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