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Treating agrammatic aphasia within a linguistic framework: Treatment of Underlying Forms

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Abstract

Background—Formal linguistic properties of sentences—both lexical, i.e., *argument structure*, and syntactic, i.e., *movement*—as well as what is known about normal and disordered sentence processing and production, were considered in the development of Treatment of Underlying Forms (TUF), a linguistic approach to treatment of sentence deficits in patients with agrammatic aphasia. TUF is focused on complex, non-canonical sentence structures and operates on the premise that training underlying, abstract, properties of language will allow for effective generalisation to untrained structures that share similar linguistic properties, particularly those of lesser complexity.

Aims—In this paper we summarise a series of studies focused on examining the effects of TUF.

Methods &Procedures—In each study, sentences selected for treatment and for generalisation analysis were controlled for their lexical and syntactic properties, with some structures related and others unrelated along theoretical lines. We use single-subject experimental designs—i.e., multiple baseline designs across participants and behaviours—to chart improvement in comprehension and production of both trained and untrained structures. One structure was trained at a time, while untrained sentences were tested for generalisation. Participants included individuals with mild to moderately severe agrammatic, Broca's aphasia with characteristic deficits patterns.

Outcomes & Results—Results of this work have shown that treatment improves the sentence types entered into treatment, that generalisation occurs to sentences which are linguistically related to those trained, and that treatment results in changes in spontaneous discourse in most patients. Further, we have found that generalisation is enhanced when the direction of treatment is from more to less complex structures, a finding that led to the Complexity Account of Treatment Efficacy (CATE, Thompson, Shapiro, Kiran, & Sobecks, 2003). Finally, results of recent work showing that treatment appears to affect processing of trained sentences in real time and that treatment gains can be mapped onto the brain using functional magnetic resonance imaging (fMRI) are discussed.

Conclusions—These findings indicate that TUF is effective for treating sentence comprehension and production in patients who present with language deficit patterns like those seen in our patients. Patients receiving this treatment show strong generalisation effects to untrained language material. Given the current healthcare climate, which limits the amount of treatment that aphasic patients receive following stroke, it is important that clinicians deliver treatment that results in optimal generalisation in the least amount of time possible.

This paper summarises a linguistic approach to treatment of sentence production and comprehension deficits found in individuals who have agrammatic Broca's aphasia. The programme, “Treatment of Underlying Forms”, is labelled as such for good reason: the

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underlying, abstract, properties of language are seriously considered, with the assumption that training such properties will allow for effective generalisation to untrained structures that share similar linguistic properties.

The effects of this treatment approach have been studied extensively in a series of studies by Thompson, Shapiro, and colleagues (Ballard & Thompson, 1999; Jacobs & Thompson, 2000; Thompson, Ballard, & Shapiro, 1998; Thompson & Shapiro, 1994; Thompson, Shapiro & Roberts, 1993; Thompson, Shapiro, Ballard, Jacobs, Schneider, & Tait, 1997b; Thompson, Shapiro, Kiran, & Sobecks, 2003; Thompson, Shapiro, Tait, Jacobs, & Schneider, 1996). Our treatment investigations use a single subject experimental design in order to allow us to directly examine generalisation as it emerges during treatment, while experimental control is maintained. From this work we have learned the following: (a) treatment improves production (and comprehension) of the sentence types entered into treatment, (b) generalisation to untrained sentences occurs to those that are linguistically similar to those trained, (c) generalisation is enhanced when the direction of treatment is from more to less complex structures, (d) treatment results in substantial changes in spontaneous discourse in most patients,[1] (e) treatment appears to affect processing of trained sentences in real time, and (f) treatment gains can be mapped onto the brain using functional magnetic resonance imaging (fMRI).

THEORETICAL FRAMEWORK

Treatment of Underlying Forms considers both lexical, i.e., *argument structure*, and syntactic, i.e., *movement*, aspects of sentences that become the focus of treatment. In most theories of grammar there is an intimate relationship between these properties. In addition, they have been the focus of much work in psycholinguistics and neurolinguistics. Here we briefly review these properties (see Shapiro & Thompson, in press; Thompson, 2001, for a more complete discussion).

Argument structure is a lexical property of verbs that characterises the number and types of participants in an event described by the verb. This property interacts with the syntax and thus places constraints on the well-formedness of sentences. There are several different types of verbs determined (a) by the number of participants (i.e., arguments) that go into the action described by the verb, (b) by the number of different argument structure arrangements that are possible given a certain verb, and (c) by the semantic (*thematic*) roles that the arguments play. Verbs such as *sleep*, *snore*, and *laugh* are one-place (intransitive, unergative) verbs, requiring only a single external argument assigned the thematic role of “Agent of the action”. Verbs such as *chase*, *cut*, and *tickle* are two-place verbs, which assign the Agent role to the external argument and the Theme role to the internal argument. Verbs such as *give*, *put*, and *send* have three arguments, Agent, Theme, and Goal.

Sentences are derived from the output of two operations: *Merge*, which combines syntactic objects selected from the lexicon to form higher-order categories, e.g., a selected verb combines with its arguments to form a verb phrase (VP), and *Move*, which displaces a category to another position in the syntactic tree. It has long been recognised that there are several types of movement (Chomsky 1991, 1993). The most relevant to our work are wh-movement (or A′ movement) and NP-movement (A movement). These operations are crucial for deriving non-canonical sentence forms.

[1]We note that this treatment has been shown to result in different generalisation patterns in patients with fluent aphasia (Murray, Ballard, & Karcher, 2004).

In English, object-extracted wh-questions, clefts, and object relatives are formed via wh-movement. Consider the following, an object-extracted wh-question:

1. Who did the thief chase?

Formation of sentences of this type involves movement of a direct object argument from its base position, occurring after the verb, to a position higher in the syntactic tree as shown in Figure 1.

The complement of *chase* moves from the direct object position after the verb to the specifier position of CP, a non-argument (A′) position. This operation leaves behind a copy or trace of the moved complement. Once moved, the displaced constituent is linked (co-indexed) with the position from which it was derived and the thematic role, originally assigned to the complement, is inherited by the moved constituent.

NP-movement is involved in formation of English passives and subject raising constructions. Consider the following passive sentence:

2. The artist was chased by the thief.

In formation of the passive, the complement of the verb, i.e., *the artist*, is moved from its canonical, post-verbal position to the specifier position of TP, an argument (A) position, as shown in Figure 2. Once again, a copy or trace of the moved complement is left behind, and the thematic role of the moved constituent, assigned prior to movement, is retained.

Processing and production implications

Verb argument structure—The sentence-processing literature indicates that the lexical entries for verbs are available for some, if not all, Broca's aphasic subjects. In a series of on-line experiments it has been shown that individuals with Broca's aphasia and anterior brain damage activate the argument-taking properties of verbs when they are encountered in sentences, as do normal listeners (e.g., Shapiro, Gordon, Hack, & Killackey, 1993; Shapiro, Nagel, & Levine, 1993; Shapiro, Zurif, & Grimshaw, 1987, 1989; Tanenhaus, Carlson, & Trueswell, 1989; Trueswell & Kim, 1998). Once active, these properties are used by the processing system, perhaps during a secondary routine, to establish thematic relations among the arguments in the sentence, allowing for final interpretation. Interestingly, however, individuals with Wernicke's aphasia, resulting from damage to posterior perisylvian regions, do not show normal on-line sensitivity to these argument structure properties, suggesting that the conceptual-semantic aspects of these lexical properties influence the types of "semantic-like" deficits observed in these individuals.

The results of recent neuroimaging studies coincide with these patterns, i.e., verb argument structure processing relies heavily on posterior regions of the brain (Ben-Shachar, Hendler, Kahn, Ben-Bashat, & Grodzinsky, 2003; Thompson, Bonakdarpour, Fix, Parrish, Gitelman, & Mesulam, 2004). Thompson et al., for example, in a study comparing activation patterns for verbs controlled for their argument structure found that verbs with a greater number of arguments, e.g., three-argument versus two- or one-argument verbs, yield bilateral posterior, superior temporal gyri/sulci activation.

Verb argument structure also influences production. Several studies with Broca's aphasic patients have shown that verb production becomes more difficult as the number of argument structures entailed within the verb's representation increases. This has been shown in English and also across languages, including Dutch, German, Italian, and Hungarian (DeBleser & Kauschke, 2003; Jonkers & Bastiaanse, 1996, 1998; Kegl, 1995; Kemmerer & Tranel, 2000; Kim & Thompson, 2000, 2004; Kiss, 2000; Luzzatti, Raggi, Zonca, Pistarini, Contardi, & Pinna, 2002; Thompson, Lange, Schneider, & Shapiro, 1997), i.e., three-argument verbs are more difficult to produce than two- or one-argument verbs. Further, verbs with even greater argument structure complexity, i.e., complement verbs such as *know*, which entail a clausal argument or proposition within their representation, present difficulty for Broca's aphasic patients (Thompson et al., 1997a), and intransitive unaccusative verbs such as *melt*, and *amuse*-type psychological (psych) verbs, which involve syntactic movement, are more difficult to produce than intransitive unergatives such as *run*, and *admire*-type psych verbs which do not (Lee & Thompson, 2004; Thompson, 2003).

Complex sentences—There is a large body of evidence suggesting that normal listeners show sensitivity to the movement operations involved in non-canonical sentences (see Swinney & Osterhaut, 1990, for an example). This shows up in sentences like “The policemen saw the boy *who* the crowd at the party accused _[trace/copy]_ of the crime”. When processing such sentences, the complement of *accused* (the moved element) is “reactivated” at the trace/copy site for processing, perhaps to satisfy the thematic requirements of the verbs. Importantly, agrammatic Broca's aphasic patients do not show this normal processing pattern. That is, they have difficulty in properly assigning thematic roles to arguments that have been moved out of their canonical position (Grodzinsky, 1995; Schwartz, Linebarger, Saffran, & Pate, 1987; Zurif, Swinney, Prather, Solomon, & Bushell, 1993). On the production side, these patients use primarily simple sentence structures, avoiding complex sentences in which binding relations are essential.

Treatment of Underlying Forms exploits these patient strengths and weaknesses. The facts that Broca's aphasic individuals retain access to verb argument structure during on-line processing, yet show deficits in verb and verb argument structure production, are central to the approach. In addition, the rules that govern non-canonical sentence formation are exploited to help patients overcome their difficulty with both comprehension and production of these structures. That is, the representational similarities and differences underlying the surface realisations of sentences that are the focus of our work are considered.

TREATMENT OF UNDERLYING FORMS

Treatment of Underlying Forms (TUF) considers both the lexical and syntactic properties of (a) the sentences entered into treatment and (b) the sentences selected for generalisation analysis. Treatment begins with tasks concerned with establishing and improving knowledge of and access to the thematic role information around verbs,[2] using the active, declarative form of non-canonical sentences. Then instructions concerning the movement of various sentence constituents are provided and subjects are taken through the proper movement to derive the surface form of target sentences. In essence, the procedures involve “meta-linguistic” knowledge of verb properties and movement. Additional morphemes required in the surface form of various sentences are provided and inserted into sentence frames.[3] Throughout treatment, we examine generalisation to sentences that are similar to those trained in terms of their semantic and syntactic properties.

Participant characteristics

Patients who have participated in experiments examining the effects of TUF show profiles on the *Western Aphasia Battery* (WAB, Kertesz, 1982) consistent with a diagnosis of mild to

[2]We note that other available treatments are similar to Treatment of Underlying Forms in this regard, i.e., “verb as core” (Loverso, Prescott, & Selinger, 1986) and “mapping therapy” (see Schwartz, Saffron, Fink, Myers, & Martin, 1994) focus on the thematic roles of sentence NPs. Our approach, however, departs from these in that we focus on both comprehension and production of the verb and its arguments as well as adjuncts contained in target sentences. Additionally, we exploit the movement operations involved in creating grammatically correct non-canonical sentences and emphasise how thematic roles are retained in the surface string of complex sentences in which NPs have been moved out of their canonical positions.

[3]See Thompson (2001) for detailed treatment protocols.

moderately severe agrammatic, Broca's aphasia with Aphasia Quotients (AQs) ranging from around 65 to 85.[4] Our agrammatic subjects demonstrate a characteristic pattern of comprehension: (a) lexical comprehension of both nouns and verbs is superior to overall sentence comprehension, (b) semantically reversible sentences are more difficult to understand than non-reversible sentences, and (c) comprehension of canonical sentences (i.e., actives and subject relatives) is superior to non-canonical sentences (i.e., passives and object relatives).

In production, greater difficulty in producing verbs as compared to nouns is the typical pattern, and a verb argument structure production hierarchy is common, with verbs with a greater number of arguments more difficult to produce than those with fewer. Greater impairments in producing complex sentences (i.e., passives, object relatives, object clefts, object-extracted wh-questions) as comparedto simple, active sentences, is also characteristic of our patients. These production patterns show up in both constrained sentence production tasks[5] and in narrative discourse samples.[6]

Training and generalisation of wh-movement structures

Training and generalisation of wh-questions—Our treatment approach evolved from early work concerned with training agrammatic patients to produce wh-questions (e.g., Wambaugh & Thompson, 1989) in which we foundno generalisation from *what* to *where* questions. In keeping with our theoretical framework, we surmised that this lack of generalisation across wh-questions that are roughly analogous in their surface form could have resulted because of differences in the lexical properties of the verbs utilised by the two question types as well as differences in movement operations required. The what-questions trained included two-place verbs such as *cook*, and therefore deriving the surface question form involved argument movement. Conversely, the where-questions trained includedone-place verbs such as *sleep*. To derive a question form, *adjunct* movement was required. Adjuncts, unlike arguments, are phrases contained within sentences that are not a part of the verb's lexical representation; thus they are not assigned a thematic role by the verb and they are not obligatorily present in sentences.

We therefore theorised that the lack of generalisation from *what*- to *where*-questions was related to the distinction between argument and adjunct movement. We further conjectured that, if this postulate were correct, wh-questions that are alike not only in surface form, but also in their underlying linguistic representation, would be better candidates for generalisation. For example, we predicted generalisation from *what*- to *who*-questions that are identical in both phrase structure and in argument structure, i.e., both constructions involve verbs that select a direct object. Both questions also rely on argument movement.

Training and generalisation of argument movement—In a follow-up study, we (Thompson et al., 1993) investigated generalisation across wh-questions that involve argument movement, i.e., *what* and *who*-questions—as in *What is the boy fixing?* and *Who is the boy helping?* Note that the verbs *help* and *fix* are both two-place verbs, which assign the thematic role of Theme to the direct object argument. To derive both question types, the direct object DP is replaced by a wh-morpheme, and moved to the sentence initial position. Wh-questions were trained using NP^V^NP^PP sentences in which the PP was either an argument or an adjunct.

[4]We note that patients with lower AQs, i.e., below 50, have not responded successfully to treatment (see Ballard & Thompson, 1999).
[5]We use the *Northwestern Assessment of Verbs and Sentences* (NAVS) (Thompson, 2005) to detail both comprehension and production patterns.
[6]Narrative samples are collected by asking subjects to tell the story of Cinderella and describe a Charlie Chaplin silent film. Samples are analysed using a coding system developed by Thompson, Shapiro, Tait, Jacobs, Schneider, & Ballard (1995).

Results were encouraging. Training *who*-questions resulted in generalisation to untrained *who*- and untrained *what*-questions (and vice versa), and in addition, training wh-questions in the more complex phrasal configuration resulted in generalised wh-question production in less complex ones. We attributed this successful generalisation to our controlling the lexical properties of verbs as well as the movement operations required for *what* and *who* questions.

Training and generalisation of argument vs adjunct movement

To further establish the distinction between training wh-questions that utilise argument movement versus those that utilise adjunct movement we (Thompson et al., 1996) trained an additional seven agrammatic aphasic individuals to produce *who*, *what*, *where*, and *when* questions. As previously noted, *who* and *what* questions require similar movement of the direct object argument, whereas *when* and *where* questions require adjunct movement. As in our other treatment work, the primary outcome of interest was generalisation across wh-question types. We predicted that training sentences derived from movement of an argument (e.g., *who*-questions) would only generalise to untrained wh-questions that also rely on movement of an argument (e.g., *what*-questions), but not to sentences derived from movement of an adjunct phrase (e.g., *when*- and *where*-questions). Similarly, we predicted that training sentences derived from movement of an adjunct would not generalise to those derived from movement of an argument. Using a set of 20 two-place verbs, 80 active sentence stimuli (NP^V^NP^PP) were developed to depict the underlying form of the four question constructions trained as in (3) – (6).

3. The soldier is pushing the woman into the street. Who is the soldier pushing into the street?

4. The boy is kicking the cow in the barn. What is the boy kicking in the barn?

5. The student is helping the doctor during the evening. When is the student helping the doctor?

6. The guard is protecting the clerk at the store. Where is the guard protecting the clerk?

Results supported our previous work. When treatment was applied to wh-questions requiring movement of the direct object argument (e.g., *what*-questions), generalised production of untrained wh-questions was restricted to those also involving direct object argument movement (e.g., *who*-questions). Similarly, when treatment was applied to wh-questions requiring adjunct movement (e.g., *where*-questions), generalisation occurred to untrained wh-questions relying on adjunct movement (e.g., *when*-questions). Importantly, argument movement did not generalise to adjunct movement constructions, and vice versa.

Training and generalisation of wh-movement vs NP-movement structures

As described previously, a distinction can be made between two types of movement. One type is Wh-movement, which displaces a complement from its underlying position after the verb (in English) to Spec-CP, a non-argument (A′) position. The other is NP-movement, which moves elements into the subject argument (A) position (Spec-TP). Given this theoretical distinction—and our premise and earlier findings that generalisation should occur only among constructions that have like-structural properties—we addressed the following question: Will training sentences that rely on one type of movement generalise only to those constructions also relying on that type of movement, or, alternatively, will any type of movement generalise to any other type of movement? This is a much stronger test of our underlying forms premise than the argument/adjunct distinction, since the spell-out forms of sentences generated from Wh-movement (e.g., wh-questions, object clefts, and object relatives) cannot be said to be similar in any analogical way to each other, or to sentences generated by NP-movement (e.g., passives, subject raising).

In Thompson et al. (1997b), we trained agrammatic aphasic subjects to produce sentences derived from Wh-movement—i.e., either wh-questions (7) or object clefts (8)—and tested generalisation to NP-movement structures—i.e., passive (9) and subject raising structures (10)), and vice versa.

7. Who did the girl hit? (wh-question)

8. It was the boy who the girl hit. (object cleft)

9. The boy was hit by the girl. (passive)

10. The girl seems to have hit the boy. (subject raising)

The data revealed the following patterns: the sentences entered into treatment were acquired very quickly once treatment began, and remained significantly above baseline performance levels throughout the study. Observed generalisation patterns aligned with our predictions: Participant 1 who was trained on wh-movement structures showed increased performance on both trained and untrained wh-movement sentences. Training object clefts resulted in generalisation to *who*-questions. Yet this training did not influence production of passives or subject-raising constructions. For Participant 2, training on passives yielded improved performance on subject-raising constructions, but no generalisation to untrained object clefts or wh-questions was noted. These patterns corroborated and extended the results from our studies examining argument and adjunct distinctions in wh-movement; that is, generalisation occurred only to constructions that have similar underlying properties as those trained. In follow-up studies, we have found similar constraints on generalisation across sentence types (Ballard & Thompson, 1999; Jacobs & Thompson, 2000).

Complexity effects

One other pattern noted in our work is that training more complex but related structures yields more wide-ranging treatment effects than using simpler structures as a starting point for treatment. As noted above, in Thompson et al. (1993) we found that training wh-questions that relied on “denser” underlying phrase structure configurations generalised to wh-questions based on less dense structures. In addition, in a closer analysis of response patterns from our previous studies that examined wh-questions and object clefts (Thompson & Shapiro, 1994; Thompson et al., 1997b) we found that several of our participants evinced better generalisation when first trained on object clefts relative to when first trained on wh-questions. Considering the differences between these two structures, the syntax of object cleft constructions involves movement within an embedded relative clause; the maximal projection (CP) of this clause is dominated by another TP in the matrix clause. In simple object extracted wh-questions, movement to Spec-CP is also involved, but movement is within the matrix clause. The CP dominates all other nodes in the construction. Thus, the syntax of a simple wh-question forms a subset of the entire phrasal configuration of an object-cleft construction. Therefore, object clefts can be considered to be more complex than wh-questions.

Given this complexity metric, and assuming that such a notion can be transferred to the processing routines underlying sentence production and comprehension, we conducted some formal tests of this complexity hypothesis. In one of our efforts (Thompson et al., 1998) we tested three agrammatic Broca's aphasic individuals who were trained on object clefts (e.g., *It was the artist who the thief chased*) and wh-questions (e.g., *Who did the thief chase?*). Using, again, a single-subject experimental design, participants were trained to produce either object clefts or simple object extracted wh-questions in counterbalanced order, while generalisation to untrained structures was assessed.

Results showed that when treatment was first appliedto object clefts, object cleft production increased significantly above baseline levels, and so too did wh-question production, with similar learning curves noted for both constructions. Conversely, the two participants who received initial treatment focused on wh-questions, showed no generalised effect to object clefts. Both showed improved wh-question production (and comprehension), which did not influence object clefts. Rather these structures required direct treatment. For all three participants, the production of passives, generated from NP-movement, did not increase above initial baseline levels during treatment of wh-movement structures, replicating our earlier work.

These patterns aligned with our complexity predictions: treatment effects are more pronounced when treatment is initiated on complex structures; in such a case simpler structures emerge without direct treatment. The reverse approach, while espoused in traditional language intervention approaches, i.e., beginning treatment with simpler structures and progressively increasing the complexity of material entered into treatment, appears to be less efficacious, and indeed, other similar treatment experiments have indicated this as well.

In our most recent effort (Thompson et al., 2003) we replicated and extended this work by adding an additional structure, i.e., object relative constructions as in (11) below.

11. The man saw the artist that the thief chased. (object relative)
12. It was the artist who the thief chased. (object cleft)
13. Who did the thief chase? (wh-question)

Note that object relatives and object clefts are similar to one another, yet there are crucial differences between the two (see Figure 3). In the matrix clause of object relatives (e.g., *The man saw the artist* …), the subject is base-generated in the verb phrase, as per the VP internal subjects hypothesis (Koopman & Sportiche, 1991) and moves to Spec-TP (the subject position). Furthermore, the subject (*the man*) acquires the Agent role from the verb (*saw*). In the matrix clause of object cleft constructions (e.g., *It was the artist* …), however, the subject is represented by a pronoun (*It*) that lacks semantic content, as no thematic role is assigned. Further it is base generated in its subject position, thus subject movement is not required. These differences indicate that object relatives are more complex than object clefts, i.e., the material in the matrix clause of object clefts is more complex than that in object relatives. Matrix wh-questions as in (13) are less complex than both object relatives and object clefts, as discussed above.

Given these complexity differences, we predicted that training patients to produce complex object relatives would result in generalisation to both object clefts, and object extracted wh-questions, but that training simpler forms wouldnot result in improved production or comprehension of the more complex ones. Results showed that this is the case: training object relatives resulted in generalisation to untrained object clefts and wh-questions, while training wh-questions did not show generalisation to untrained object relatives or clefts. Furthermore, when object clefts were entered into treatment, generalisation was not observed to object relatives.[7] Consideration of these findings as well as our earlier observations led us to coin the Complexity Account of Treatment Efficacy (CATE) (Thompson et al., 2003).

The complexity account is buttressed by mounting evidence from multiple sources. For example, Eckman and colleagues showedthat teaching relative clauses to L2 learners of English generalises to untrained canonical structures (actives and subject relatives) (Eckman, Bell, & Nelson, 1988), much like what we have foundwith our Broca's aphasic participants. Gierut and

[7]We note that sentence length cannot be a serious contender for contributing to our complexity effects, given that our object relatives and clefts were controlled for length. Furthermore, the number of propositions expressed in the sentences cannot explain the observed patterns, since both matrix wh-questions and object clefts could be argued to entail only one proposition, yet object clefts and wh-questions did not pattern together. Nevertheless, we take it as an open question as to the set of factors that might contribute to a complexity metric.

colleagues, in numerous studies, have shown that unmarked phonological structures replace marked structures in the error patterns observed in children with phonological disorders. Furthermore, training marked structures (e.g., defined in terms of sonority or cluster formation) results in greater system-wide changes than training unmarked structures (see, for example, Gierut, 1998; Gierut & Champion, 2001; see also Archibald, 1998; Barlow, 2001, for evidence from L2 phonological acquisition). We have also observed such complexity training effects with adult individuals with apraxia of speech (Maas, Barlow, Robin, & Shapiro, 2002) and those with fluent aphasia and naming deficits (Kiran & Thompson, 2003). Finally, evidence for the complexity hypothesis also comes from domains outside language (e.g., in maths learning, Yao, 1989; and in motor learning, Schmidt & Lee, 1999).

EFFECTS OF TREATMENT ON DISCOURSE PATTERNS

Changes in discourse characteristics have been noted in several of the aforementioned treatment studies. The most important changes noted across participants include (a) increases in mean length of utterance (MLU), (b) increases in the proportion of grammatical sentences, and (c) increases in the proportionate number of verbs as compared to nouns produced. Notably, subjects have also shown improvements in verb argument structure production with increases in correct usage of Agents, Themes, Goals, and even sentential complements seen following treatment. The proportion of adjuncts produced correctly has also increased with treatment. These findings are encouraging and suggest that treatment gains are not restricted to improvement on targeted sentence structures. Rather, they suggest that treatment results in improved access to a variety of language structures that are encountered when sentences become the focus of treatment.

EFFECTS OF TREATMENT ON SENTENCE PROCESSING

Importantly, we note that in a recent study using an auditory anomaly detection paradigm (Dickey & Thompson, 2004), we showed that agrammatic patients, who were successfully trainedto comprehend and produce Wh-movement structures using TUF, evinced normal-like on-line processing of these structures. Treated patients were more successful than untreated patients in detecting the anomalies, rejecting anomalous sentences reliably more often than non-anomalous sentences, as did normal participants. This effect was not noted for untreated patients, i.e., there was no statistically significant difference between their rejection of anomalous or non-anomalous structures. These findings suggest that treatment can improve patients' ability to process movement constructions. We are currently following up on these findings by examining the eye-tracking patterns of patients as they listen to such sentences. These data will help us to understand whether or not patients begin to engage “normal” processing routines when off-line abilities improve, or whether they use abnormal processing strategies to solve the sentences that they encounter.

THE NEURAL CORRELATES OF TREATMENT EFFECTS

Finally, we note that treatment gains can be mapped onto the brain using fMRI. In a recent study (Thompson, Fix, Gitelman, Parrish, & Mesulam, 2000) we examined the neural correlates of treatment-induced (TUF) improvements in patients with agrammatism. Six agrammatic patients participated in the study. Three patients were provided with treatment and underwent pre–post treatment behavioural testing and fMRI scans. Under scanning conditions, patients performed a sentence verification task for both syntactically complex object clefts and simpler subject cleft constructions. One of these subjects (OJ) also served as a control subject, receiving repeat behavioural testing and fMRI scans at 5-month intervals prior to undergoing treatment and post-treatment scanning. The remaining three subjects served as control subjects for the behavioural tasks only. Results showed significant changes in behavioural tests administered pre- and post-treatment for the treated subjects only. Concomitant changes were noted in activation patterns in the right hemisphere homologue of Wernicke's and surrounding areas for all treated subjects (BA 22, 21, and 37) and the right hemisphere homologue of Broca's area for two patients (HR and MK) for sentences as compared to words. Two patients (MK and OJ) also showed post-treatment recruitment of spared left hemisphere areas (see Figure 4). These findings show that the neural networks underlying language processing can be modified even in patients who are several years post-stroke. Indeed, our patients ranged from 1 (MK) to 10 years post-stroke (HR). However, further work is needed comparing the effects of various treatments on the ways in which the language network can be modified.

CONCLUSIONS

The findings from our research indicate that treatment for sentence production deficits in patients with agrammatic aphasia appears to be efficacious when the lexical and syntactic properties of (a) the language deficit exhibited by the aphasic individuals, (b) the sentences selected for treatment and generalisation analysis, and (c) the treatment strategy utilised, are considered and controlled. This approach results not only in improvement on trained structures, but also on linguistically related untrained structures. In addition, treatment influences spontaneous language usage; in particular improvements are seen in access to language structures involved in sentence production in general. Conversely, when linguistic underpinnings are not considered, generalisation effects are considerably diminished, or are absent, resulting in little or no discernible improvement in sentence production beyond the kind of constructions trained.

We also find that consideration of the complexity of material entered into treatment is important, i.e., generalisation is enhanced when the direction of treatment is from more to less complex structures. Once again, however, the linguistic relationship between trained and untrained items is important to consider, i.e., the relation must be grounded in what is known about language representation and processing.

Finally, we find that Treatment of Underlying Forms appears to affect on-line sentence processing, i.e., trained patients show more “normal” patterns of sentence processing than untrained patients, and the improvements resulting from treatment affect the neural network recruited to support language. While we have only begun our work in these areas, the results to date are encouraging.

In conclusion, our linguistic approach to treatment of sentence deficits as seen in agrammatic aphasia has been shown to be effective, perhaps more so than any other treatment designed for this purpose. While we are far from fully understanding the effects of brain damage on the language processing/production system or the full effects of treatment, we strongly suggest that this approach is the right one at least for some patients. Indeed, the more we learn about the linguistic and psycholinguistic underpinnings of sentence production and comprehension in normals and how these processes are affected by brain damage, the more detailed we can be about the design of treatment.

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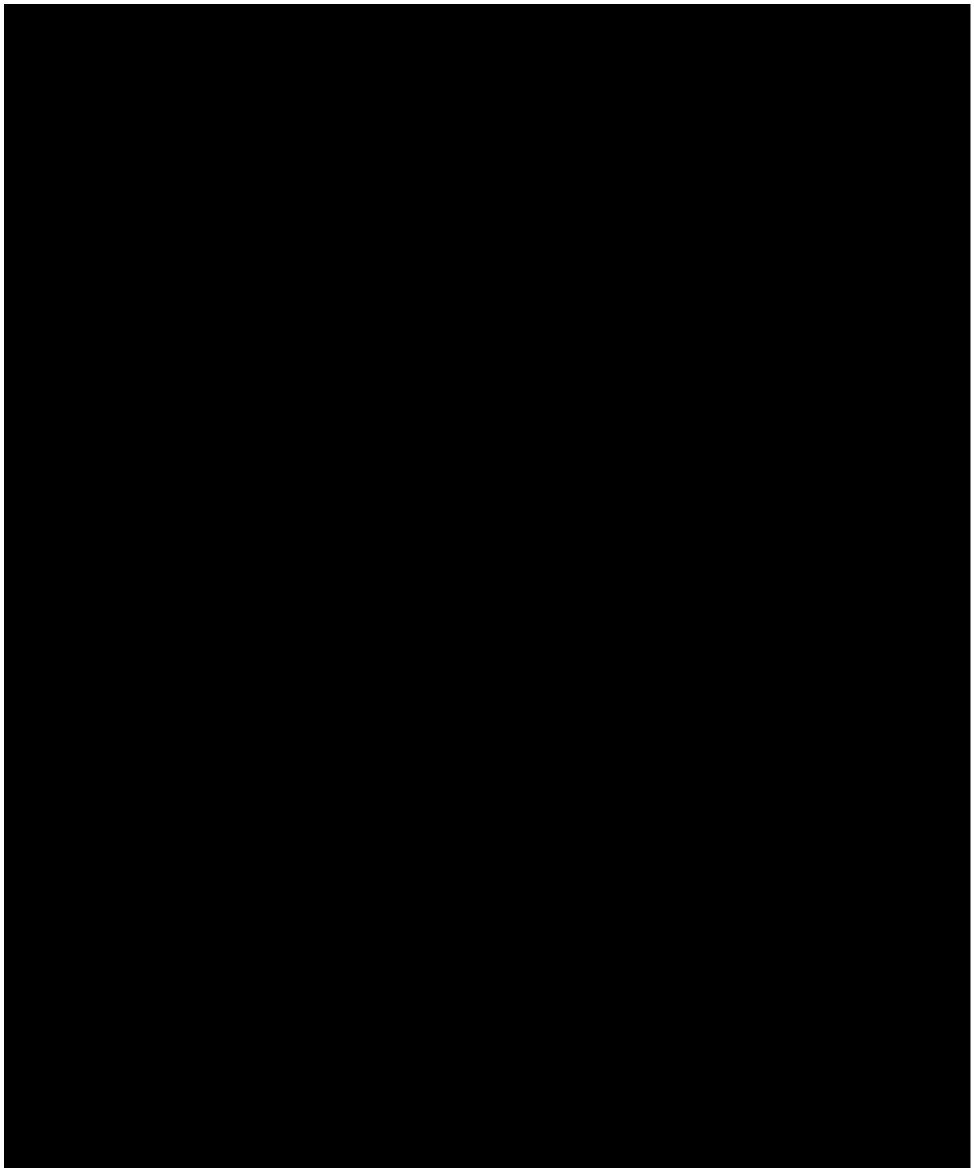

Figure 1.
Tree structure denoting Wh-movement (A′ movement) in an object extracted wh-question construction. Movement occurs from the direct object position to the specifier position of the complementiser phrase (CP), a non-argument occupied position. A copy or trace is left behind in its original position.

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Figure 2.
Tree structure depicting NP-movement (A movement). Here, the complement of the verb *chase* is moved to the subject position—the specifier position of the Tense Phrase (Spec-TP) —leaving a copy or trace. Thus, an argument is moved to another argument position.

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Figure 3.
Tree diagram showing object cleft (left) and object relative (right) constructions. Note that the material in the matrix clause (circled) in the two structures is different i.e., subject movement from Spec of VP of Spec of IP is shown for object relatives. Such movement is not seen in object cleft constructions. However, both structures involve identical wh- movement in the embedded clause.

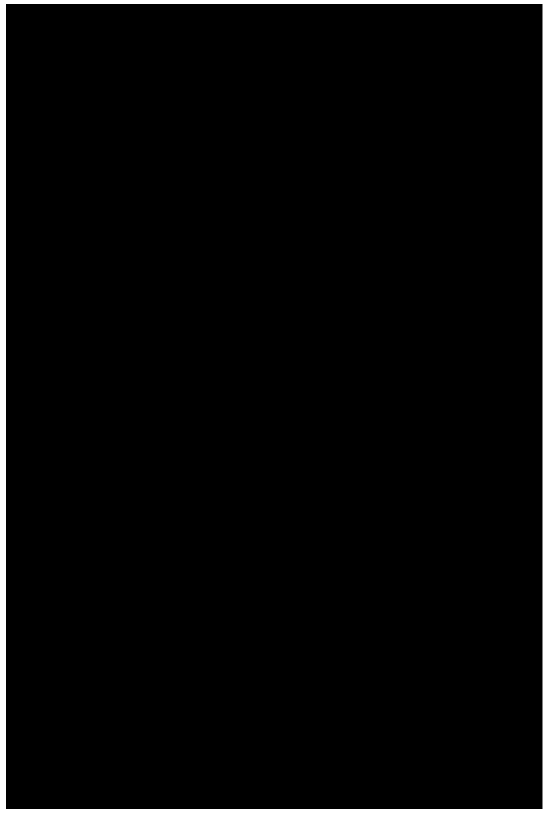

Figure 4.
Areas of significant activation in three agrammatic aphasic patients' post-treatment scans as compared to pre-treatment scans.