Effect of Exemplar Typicality on Naming Deficits in Aphasia

Swathi Kiran (s-kiran@northwestern.edu),
Department of Communication Sciences and Disorders, Northwestern University,
Evanston, IL 60208 USA

Cynthia K. Thompson (ckthom@northwestern.edu)
Department of Communication Sciences and Disorders & Neurology, Northwestern University,
Evanston, IL 60208 USA

Douglas L. Medin (medin@northwestern.edu)
Department of Psychology, Northwestern University
Evanston, IL 60208 USA

Abstract

The effect of typicality of category exemplars on naming performance was investigated using a single subject experimental design across participants and behaviors in four patients with fluent aphasia. Participants received a semantic feature treatment to improve naming of either typical or atypical examples, while generalization was tested on the untrained examples of the category. The order of typicality and category trained was counterbalanced across the participants. Results indicated that patients trained on naming of atypical examples demonstrated generalization to naming of intermediate and typical examples. Patients trained on typical examples demonstrated no generalization to naming of intermediate or atypical examples. Implications for models of typicality and rehabilitation of aphasia are discussed.

Introduction

Aphasia is a language disorder that results from damage (such as stroke or head trauma) usually to the left hemisphere of the brain. Naming difficulty is the most common form of language deficit noted in individuals with aphasia. One widely accepted model of naming (Dell, 1986; Stemberger, 1985) suggests that activation of a word during naming involves two closely interacting levels, activation of the semantic representation as well as activation of the phonological form of the target word. Naming deficits can therefore arise from difficulty in activation at either of the two levels. Patients with naming deficits arising from an impairment in activating semantic representations often present with impairments in accessing appropriate semantic fields within categories (Goodglass & Baker, 1976).

Numerous studies on normal individuals have found typical examples of a category to be accessed faster and more accurately than atypical examples, an effect labeled the typicality effect (Rips, Shoben, & Smith, 1973; Rosch, 1975). Evidence for the typicality effect exists through typicality ratings (Rosch, 1975), response times on category verification tasks (Larochelle & Pineu, 1994), and category production frequency (Rosch, 1975). Little evidence, however, exists regarding representation of typicality in individuals with aphasia, although some investigations have noted deficits (Grober et al., 1980; Grossman, 1981). The interpretation of these deficits with reference to theoretical models of typicality however has not been addressed.

In a connectionist account of relearning in neural networks, it was found that a lesioned computer network retrained on atypical examples resulted in improvements on typical items as well (Plaut, 1996). Training typical items, however, only improved the performance of those items while performance of atypical words deteriorated during treatment. While Plaut's findings have not yet been tested in individuals with aphasia, the prospect of such generalization effects is especially significant for treatment of naming deficits, since most naming treatments have found little generalization to untrained items (McNeil et al., 1997; Pring et al., 1993).

The present experiment aimed to investigate the effects of exemplar typicality on naming performance in individuals with aphasia. Specifically, the purpose of the experiment was to train naming of a set of typical or atypical examples of a superordinate category, and examine generalization to untrained examples of the category. The present experiment was motivated by prototypical/family resemblance models of typicality (Hampton, 1979; Rosch & Mervis, 1975). According to these models, on a multidimensional scaling of a category (e.g., bird) based on similarity of items, typical examples (e.g., robin, sparrow) are found to have more features similar amongst them and with the category prototype, and therefore are represented closer to the center of the semantic space. In contrast, atypical items (e.g., penguin, ostrich) have fewer features that are similar amongst them and the prototype, and are at the periphery of this semantic space. We hypothesized that training aphasic individuals to produce atypical examples from a category would result in generalization to more typical examples of the category. If indeed atypical examples are at the periphery of the category, then strengthening access to these examples by emphasizing the variation of semantic features across the category would strengthen the overall semantic category. Conversely, typical examples were hypothesized to represent little or no variation within the category. Therefore, training typical examples was predicted to improve only items at the center of the category, with no improvements expected for atypical examples.

Methods

Participants

Four individuals, ranging in age from 63-75 years, and presenting with aphasia resulting from a cebrebrovascular accident to the left hemisphere were selected for the experiment. All four patients presented with fluent aphasia, characterized by fluent circumlocutory speech, mild auditory comprehension deficits and severe naming difficulties. Based on standardized language testing, the locus of naming deficit was attributable to impairments in accessing the semantic representation of the target, and/or in accessing its phonological form.

Stimuli

Norms for typicality of category exemplars were developed prior to initiation of the experiment. One group of 20 normal young and elderly subjects constructed as many examples as possible for ten categories, while another group of 20 normal young and elderly subjects rated the typicality of these examples on a 7-point scale. Examples for each category were then divided into three groups, typical, intermediate and atypical, based on their average z scores. Based on several selection criteria, which included frequency, distinctiveness, number of syllables, unambiguity regarding category membership, two categories (birds and vegetables) with 24 examples each were selected for treatment. Each set of 24 items included a subset of eight typical and eight atypical items. The remaining eight in each set were determined to be intermediate in terms of typicality. For each of the selected examples, corresponding color photos printed on 4 x 6 inch cards were selected. In addition to the experimental photos, stimuli from three different superordinate categories (fruit, animal and musical instrument) were selected to serve as distracters for treatment.

Once the two categories and their 24 examples were selected, semantic features for each category were developed. For each category, a minimum of 20 features belonging to the category that were either physical, functional, characteristic or contextual attributes were selected. Additionally, a minimum of 20 distracter features to be used during the yes/no question tasks (see treatment), using the same four attribute types not belonging to the target category were developed. At least 10 features that were applicable to all examples in the category were selected (e.g., bird: has a beak, lays eggs), while obscure features (e.g., asian food for vegetable), and features that were salient only for a single example (e.g., hoots for owl, drills holes for wood pecker) were eliminated. Generally, features that were applicable to two or more items in the category were selected. Distracter features belonging to the categories sport, transportation, animal, insect, flower and weapon were selected using the same criteria as the target category features.

Design

A single subject experimental design with multiple baselines across behaviors and participants (Connell & Thompson, 1986) was employed. In such an experimental design, effects of treatment are assessed at regular intervals for each patient separately. In the present study, as treatment was extended to atypical or typical members of a superordinate category, generalization to the remaining examples was examined. The emergent naming patterns provided information regarding the re-organization and representation of semantic categories.

Prior to application of treatment, during the baseline phase, naming of all 48 examples of two categories (N = 24) was tested. Picture naming was then trained using selected examples of one superordinate category, with the order of categories and exemplar typicality counterbalanced across participants. During treatment, naming of all 24 examples in the category were assessed every second treatment session. These naming probes constituted the dependent variable in the study and naming accuracy over time was assessed. See table 1 for order of treatment for the four patients.

Criteria for acquisition of naming of trained items was 7/8 items named correctly on two consecutive naming probes. Generalization to naming of untrained examples was considered to have occurred when a 40% change over baseline levels was noted for untrained examples. If generalization to naming of untrained items was observed, treatment was shifted to the second category. If generalization to naming of untrained items was not observed, treatment was shifted to the next group (i.e., intermediate) within the same category.

Table 1: Order of treatment for the four participants

	P1	P2	P3	P4
Order of treatment				
1.	Birds	Birds	Vegetables	Vegetables
	1.Typical	1 Atypical	1.Typical	1.Atypical
	2. Inter	2. Inter	2. Inter	2. Inter
	3.Atypical	3.Typical	3.Atypical	3.Typical
2.	Vegetables	Vegetables	Birds	Birds
	1.Typical	1.Atypical	1.Typical	1.Atypical
	2. Inter	2. Inter	2. Inter	2. Inter
	3.Atypical	3.Typical	3.Atypical	3.Typical

Treatment

For each participant, one subset of items within a category (typical, intermediate or atypical) was trained at a time. In each treatment session, participants practiced the following steps for each of the eight examples of a subset: a) naming the picture, 2) sorting pictures of the target category (N=24) with three distracter categories (N=36), 3) identifying 6 semantic attributes applicable to the target example from a set of 35 features of the superordinate category, 4) answering 15 yes/no questions regarding the presence or absence of a set of semantic features about the target example. Distracters on this task included semantic features from the target category not applicable to the target, and features from unrelated superordinate categories.

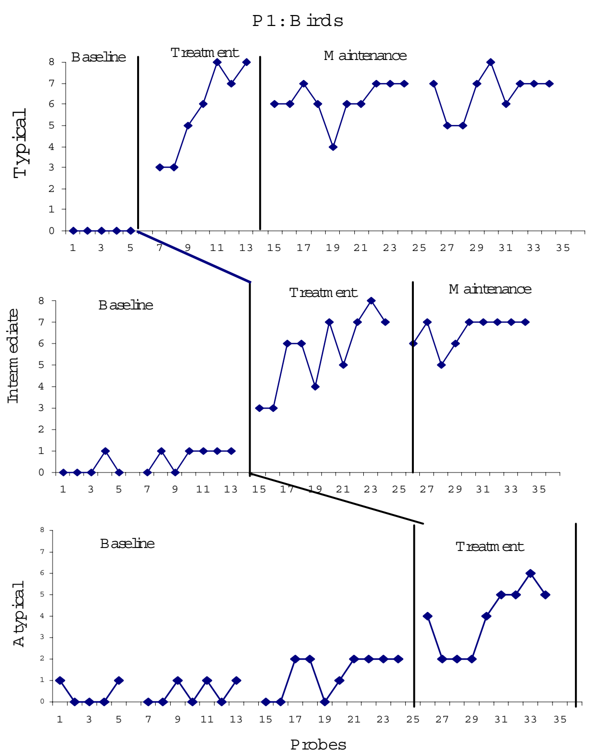

Figure 1. Naming accuracy on typical, intermediate and atypical items for the category birds for Participant 1

Results

Participant 1 Following five baseline sessions, treatment was initiated on typical items on the category birds. While naming of typical items improved to criterion (7/8 for two consecutive sessions), generalization to naming of intermediate or atypical examples was not observed. Treatment then was shifted to intermediate examples, following which improvement was observed on those items with no changes noted for atypical examples. Once criterion was achieved for intermediate examples, treatment was finally shifted to atypical examples and improvement was noted for the trained atypical items (see Figure 1). Administration of probes at phases denoting change of treatment set revealed no changes in items of vegetables.

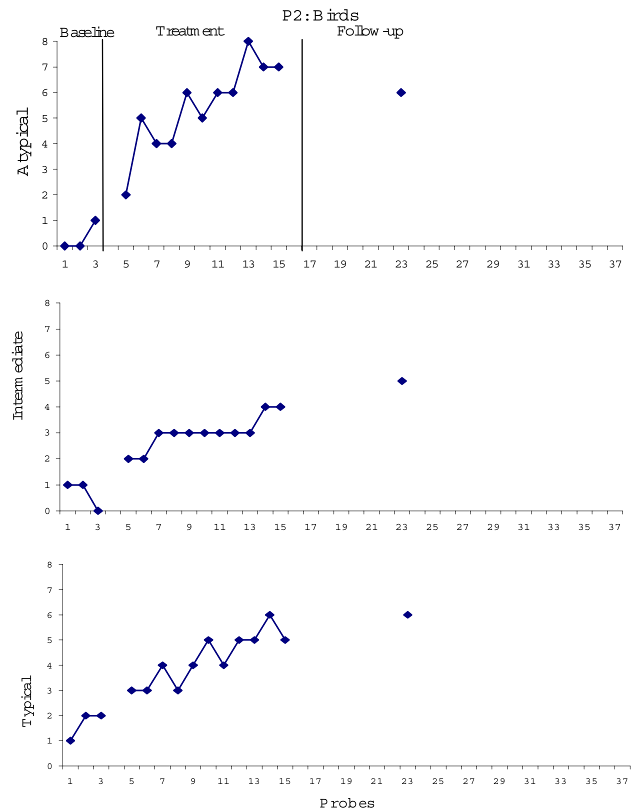

Figure 2. Naming accuracy on typical, intermediate and atypical items for the category birds for Participant 2

Participant 2 Following three baseline sessions, treatment was initiated for atypical examples of birds. Performance on naming of atypical examples improved to criterion (7/8 for two consecutive sessions), while generalization to naming of intermediate and atypical examples was noted (see Figure 2). Treatment then was shifted to vegetables. Following two baseline sessions, treatment was initiated on atypical examples of vegetables. Acquisition of atypical items for vegetables was observed, and once again, generalization was noted for intermediate and typical examples, denoting replication within the participant across categories. Follow up probes administered within six weeks of completion of treatment indicated maintenance levels comparable to treatment levels.

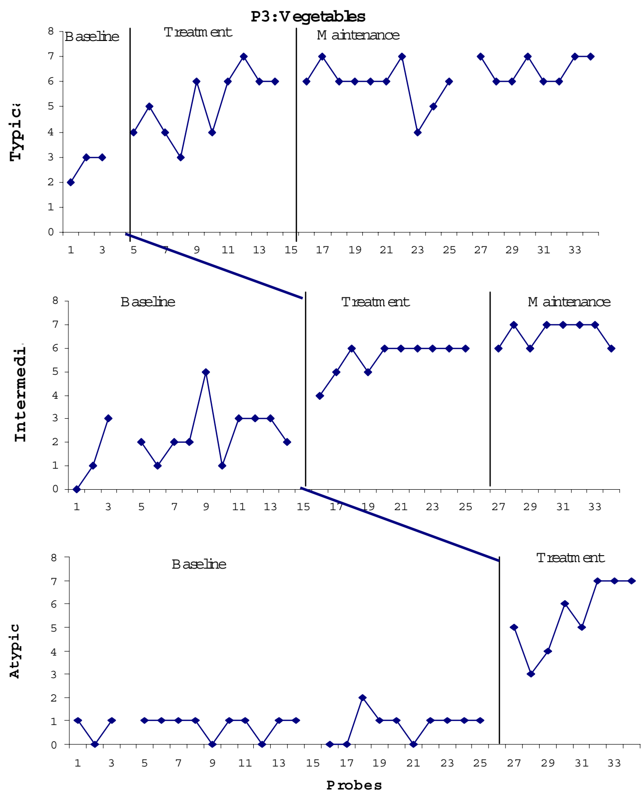

Figure 3. Naming accuracy on typical, intermediate and atypical items for the category vegetables for Participant 3

Participant 3 Following three baseline sessions, treatment was initiated on typical examples of vegetables. While an acquisition curve for typical items was discernible, criterion of 7/8 accuracy for typical examples was not achieved after 20 treatment sessions. Treatment was then shifted to intermediate examples, once again acquisition of trained items was noted but criterion was not achieved. Finally, treatment was shifted to atypical examples. Performance on those items reached criterion, while performance on typical and intermediate items was maintained (see Figure 3). Administration of probes at phase change revealed no changes in items of birds. For both participant 1 and participant 3, due to the extended duration, treatment was discontinued after completion of the first category.

Participant 4 Following five baseline sessions, treatment was initiated for atypical examples for vegetables. Performance on naming of atypical examples improved to criterion, with generalization noted on intermediate and atypical examples (see Figure 4) Treatment then was shifted to birds. Following two baseline sessions, treatment was initiated on atypical examples of birds. Acquisition of atypical items for birds was observed, while once again, generalization was noted for intermediate and typical example, once again providing a replication within participant across categories. Follow up probes administered within six weeks of completion of treatment indicated maintenance levels comparable to treatment levels.

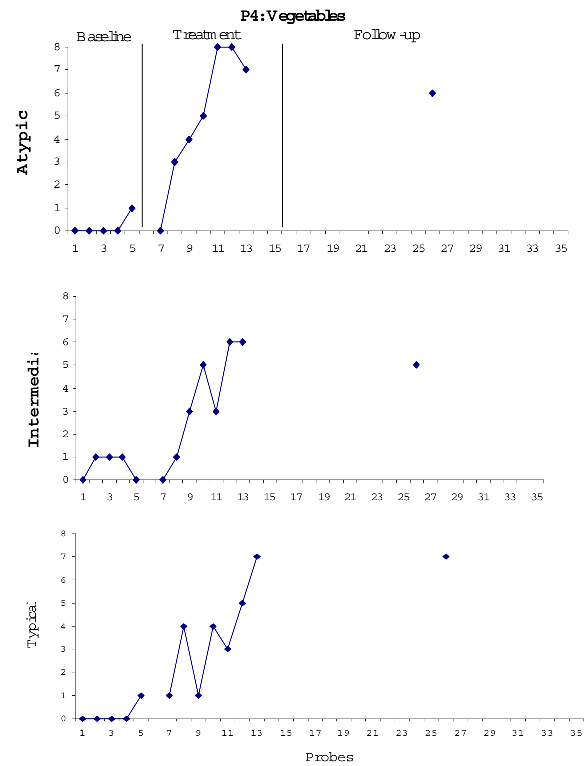

Figure 4. Naming accuracy on typical, intermediate and atypical items for the category vegetables for Participant 4

Discussion

The present experiment demonstrates that training atypical examples of a category and their semantic features results in generalization to naming of intermediate and typical examples of the category. This finding was observed in Participants 2 and 4 across two categories even when the order of categories was counterbalanced across the two participants. Training typical examples and their semantic features, however, did not result in generalization to the intermediate and atypical examples, as observed in Participant 1 and 3.

These findings suggest that because atypical examples are dissimilar to one another and to the category prototype, these examples collectively convey more information in terms of semantic features about the variation that can occur within the category than do typical examples. Heightening access to featural information relevant to semantic categories, therefore facilitate access to more typical items within a category. While it has been demonstrated that greater coverage of a category's features can lead to stronger inductive generalizations (Sloman, 1993), current models of typicality do not explain the treatment effects observed in the present experiment. For instance, findings of the present experiment cannot be explained by the two-stage feature comparison model (Smith, Shoben, & Rips, 1974), since this model only explains category membership and not exemplar access.

Similarly, prototype/family resemblance models (Hampton, 1979; Rosch & Mervis, 1975) suggest that categories are represented by a set of weighted semantic features as a function of typicality, but do not explicitly state the relation between these summary feature representations and the phonological representations of specific examples. Moreover, prototype models do not specify how the various examples in a category are connected to each other, an element crucial to the explanation of the present experiment.

Exemplar models (e.g., Heit & Barsalou, 1996) come closest to explaining the results of the present experiment in that typical and atypical examples are represented as specific instances in the category that have been previously encountered. Therefore, it can be assumed that these specific representations are associated with their phonological representations. However, if examples of a category are represented as abstractions of specific instances, the exemplar models do not explain why training semantic features of atypical examples would result in improvements in naming of typical examples.

In summary, although all models of typicality explain possible differences in the representation of typical and atypical examples, they do not predict why training semantic features of atypical examples would improve phonological access of not just atypical examples but of intermediate and typical examples as well. More importantly, these models do not predict why training semantic features of typical examples would result in <u>no</u> improvement in the phonological access of intermediate and atypical examples. Even Plaut's connectionist model (1996), which motivates the present experiment, does not explain the mechanism involved in accessing improved phonological forms. This model describes a reading via meaning task with four layers, orthographic input layer, intermediate layer, a semantic layer and clean up layer. To generate semantic features, the prototype represents a set of semantic features (or binary values) with a high probability of becoming active. Typical examples share most of their features with the prototype, while atypical examples share few features with the prototype. Therefore, while this model provides an explicit account on the extent of difference between typical, atypical examples and the prototype, the nature of these features (whether defining or characteristic), and the nature of the examples (whether summary representations or specific instances) are also unclear.

Any explanation for the present experiment should therefore account for the following: (a) effects of treatment on improvements in semantic feature representation, (b) influence of strengthened semantic representations on access to phonological forms, (c) selective strengthening of connections between atypical and typical phonological representations (and not the other way around). A combination of interactive activation models (Dell, 1986; Stemberger, 1985) and prototype models of typicality provide such an explanation. Two levels of representation are hypothesized, semantic and phonological, and the connections between the semantic and phonological levels are bi-directional and excitatory while connections within each level are inhibitory. Within the semantic level, each example of a category (e.g., <u>bird</u>) is a summary representation of weighted semantic features, which interfaces with the lexical representation of the example. Items that are typical exert greater lateral inhibition on other examples within the category, due to their similarity with the category prototype. Less typical items exert less lateral inhibition on corresponding examples. This is because less typical items are dissimilar from the category prototype and illustrate the variation of semantic features that can exist (e.g., <u>cannot fly</u>, <u>lives near water</u>). Training semantic features of atypical examples strengthens their corresponding lexical representation and by the nature of the weak lateral inhibition, strengthens the representations of intermediate and typical examples as well. These strengthened semantic representations exert an excitatory influence on their corresponding phonological representations, which are raised above a resting threshold level. It is hypothesized that items directly trained receive a greater unit of activation to cross the resting threshold than untrained items.

Training typical examples on the other hand, only strengthens the semantic representations of the typical examples, and since these features convey no information about the variation of semantic features that can occur in the category, they have no influence on the semantic representations of intermediate and atypical examples. Therefore, the lateral inhibition exerted by the semantic representations of typical examples on intermediate and atypical examples does not reduce following treatment. Consequently, only the strengthened typical representations can successfully raise their corresponding phonological representations above the resting threshold. The unchanged semantic representations for intermediate and atypical examples, can exert no excitatory influence on their corresponding phonological representations, and therefore have to be trained directly in treatment to be named successfully. These hypotheses are currently being tested using a connectionist network simulation.

Finally, results of the present experiment have significant implications for rehabilitation in aphasia. These results, although counter-intuitive to traditional treatment approaches, suggest that training naming of atypical examples is a more efficient method of improving naming items within a category than training typical items. Interestingly, training more complex items which encompass variables relevant to simpler items have been demonstrated in other language domains. Training complex syntactic structures results in generalization to simpler ones in agrammatic aphasic patients (Thompson, Ballard & Shapiro, 1998; Thompson et al., 1997) and training complex phonological forms results in improvements to simpler forms in children with phonological deficits (Geirut et al., 1996, 1999). These results also provide important insights into the mechanisms of relearning in patients with brain damage. In these individuals, it is assumed that language organization is fractionated following brain damage. The goal of language treatment is then to compensate and maximize the use of spared functions. The results of the present experiment suggest that relearning of category structure and corresponding phonological representations can be re-established in a more efficient way than previously thought.

References

Connell, P.K., & Thompson, C.K. (1986). Flexibility of single subject design. Journal of Speech and Hearing Disorders, 51, 214-225

Dell, G.S. (1986). A spreading activation theory of retrieval in sentence production. Psychological Review, 92, 283-321.

Geirut, J.A. (1999). Syllable onsets: clusters and adjuncts in acquisition. Journal of Speech Language and Hearing Research, 42 (3), 708-726.

Geirut, J.A., Morrisette, M.L., Hughes, M.T., Rowland, S. (1996). Phonological treatment efficacy and developmental norms. Language, Speech and Hearing Services in Schools, 27 (3), 215-230.

Goodglass, H., & Baker. E. (1976). Semantic field, naming and auditory comprehension in aphasia. Brain and Language, 10, 318-330.

Grober, E., Perecman, E., Kellar, L., & Brown, J. (1980). Lexical knowledge in anterior and posterior aphasics. Brain and Language, 10, 318-330.

Grossman, M. (1981). A bird is a bird: Making references within and without superordinate categories. Brain and Language, 12, 313-331.

Hampton, J.A. (1979). Polymorphous concepts in semantic memory. Journal of Verbal Learning and Verbal Behavior, 18, 441-461.

Heit, E., & Barsalou, L. (1996). The instantiation principle in natural language categories. Memory, 4, 413-451.

Larochelle, S., & Pineu, H. (1994). Determinants of response times in the semantic verification task. Journal of Memory and Language, 33, 796-823.

McNeil, M.R., Doyle, P.J., Spencer, K., Goda, A.J., Flores, D., & Small, S.L. (1998). Effects of training multiple form classes on acquisition, generalization and maintenance of word retrieval in a single subject. Aphasiology, 12 (7-8), 575-585.

Plaut, D.C. (1996). Relearning after damage in connectionists networks: Toward a theory of rehabilitation. Brain and Language, 52, 25-82.

Pring, T., Hamilton, A., Harwood, A., & McBride, L. (1993). Generalization of naming after picture/word matching tasks: only items appearing in therapy benefit. Aphasiology, 7 (4), 383-394.

Rips, L.J., Shoben, E.J., & Smith, E.E. (1973). Semantic distance and the verification of semantic distance. Journal of Verbal Learning and Verbal Behavior, 12, 1-20.

Rosch, E. (1975). Cognitive representation of semantic categories. Journal of Experimental Psychology: General, 104, 192-233.

Rosch, E., & Mervis, C. (1975). Family resemblances: Studies in internal structure of categories. Cognitive Psychology, 7, 573-604.

Sloman, Steven A. (1993) Feature-based induction. Cognitive Psychology, 25 (2), 231-280

Smith, E.E., Shoben, E.J., & Rips, L.J. (1974). Structure and process in semantic memory: A featural model of semantic association. Psychological Review, 81, 214-241.

Stemberger, J.P. (1985). An interactive model of language production. In A.W. Ellis (Ed.) Progress in the psychology of language Hillsdale, NJ: Lawrence Erlbaum.

Thompson, C.K, Shapiro, L., Ballard, K.J., Jacobs, J. J. Schneider, S.L., & Tait, M.E. (1997). Training and generalized production of wh- and NP movement structures in agrammatic speakers. Journal of Speech, Language and Hearing Research, 40, 228-244.

Thompson, C.K., Ballard, K., & Shapiro, L. (1998). Role of syntactic complexity in training wh-movements structures in agrammatic aphasia: Order for promoting generalization. Journal of International Neuropsychological Society, 4, 661-674.