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Recombinative Generalization: Relationships Between Environmental Input and the Linguistic Repertoires of Miniature Linguistic System Learners[1]

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Running Head: Recombinative Generalization

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Abstract

Experimental research on the environmental conditions that promote generative language learning is reviewed. Recombinative generalization is introduced as a process that enables individuals to express and to comprehend novel utterances. This review focuses on the use of a miniature linguistic system paradigm to explore how recombinative generalization can be efficiently established. How the necessary stimulus conditions vary depending upon the linguistic repertoires of individuals who are learning a new syntactic construction are discussed. Examples of learners who have no knowledge, partial knowledge, and near complete knowledge of the lexical constituents included in language systems are used to illustrate differences in the necessary conditions that can yield generative language learning. Also mentioned are implications for understanding normal language acquisition and for developing efficient language intervention programs.

Recombinative Generalization: Relationships Between Environmental Input and the Linguistic Repertoires of Miniature Linguistic System Learners

I will be discussing some of the experimental evidence that supports the claim that systematic environmental input can account for the acquisition of generative language repertoires. Much of this research has employed miniature linguistic systems (see Wetherby, 1978), hereafter referred to as MLS. The MLS has provided a convenient way to systematically investigate functional relationships between environmental conditions and developing language, and it has proven particularly useful for conceptualizing the conditions responsible for generative language use. By generative language, I am referring to individuals' ability to express and to comprehend novel or untrained utterances. First, I would like to discuss generalization within a MLS context and describe what may be the principal process responsible for the development of generative language. After I describe this process, which I will call recombinative generalization, I will summarize some data and offer some speculations on the stimulus conditions that yield recombinative generalization. We will see that the stimulus conditions that are necessary for the occurrence of recombinative generalization vary depending upon the linguistic repertoire of the individual who is learning a new syntactic construction.

Insert Figure 1 About Here

Figure 1 depicts a basic MLS, which was taught to a number of preschoolers. Puppets were presented by moving them across a stage according to the particular action patterns shown. This matrix consists of combinations of four agent stimuli (rows) and four action stimuli (columns). Notice that the response words are eight nonsense words. These words are combined into two-word utterances according to a particular word order rule. The rule may be stated as follows: The first word refers to the agent and the second word refers to the action. Of course, one can easily generate similar MLSs with other referential stimuli that combine stimulus components such as colors, sizes, shapes, locations, and spatial prepositions. Also, we could use English or foreign language words and rule systems.

In one of the first experimental analyses of verbal behavior, Esper (1925) taught a similar 4 x 4 MLS to adults. Subjects were first taught to label 14 colored shapes. After they could label 14 of 16 stimuli without error, the two untrained stimuli were slipped in, which subjects were then able to label accurately. This is the crux of much of the MLS research. Subjects must be able to accurately label untrained recombinations of the stimulus components in the system in order to show that generalization has occurred.

As I mentioned, I view recombinative generalization as a process that describes the functional relationship between environmental features and this sort of generative language behavior. Recombinative generalization can be defined as differential responding to novel combinations of stimulus components that have been included previously in other stimulus contexts. In these contexts, the stimulus components have been associated with particular linguistic responses. Thus, language learners are able to arrange linguistic constituents, such as morphemes, words, and phrases, according to specific syntactic rules, such as word order rules. For example, linguistic constituents can be recombined when words comprising two different semantic classes, such as agents and actions, are rearranged to make up novel two-word utterances. Recombinative generalization can thus be accomplished, when stimulus components that have been discriminated and responded to correctly are subsequently put together in a novel arrangement.

A brief review of research that has involved attempts to further specify the environmental conditions under which recombinative generalization can occur follows.

In the first and most typical case, MLS experiments have been conducted with subjects who have no prior knowledge of the vocabulary or lexicon being used (Foss, 1968; Horowitz & Jackson, 1959; Whitehurst, 1971; Wolfle, 1931; 1933). Researchers have determined that particular stimulus conditions must be instituted before recombinative generalization can be expected.

Insert Figure 2 About Here

A 6 x 6 color-shape MLS adapted from a study by Foss (1968) is shown in Figure 2. Subjects were taught the labels designated by "A" or the labels designated by "B." The "A" labels are six color-shape stimuli selected from the diagonal of the matrix. The "B" labels are 10 stimuli selected by progressing down the diagonal of the matrix in a stepwise fashion with the addition of two more diagonal stimuli in the lower righthand corner of the matrix. After subjects were able to label their respective training stimuli errorlessly, they were asked to label each of the 36 colored shapes in the matrix.

The distinction between these two training strategies is an important one. Not only do the strategies differ in the number of training items included, but more importantly, the inclusion of non-diagonal training items provides overlap among color and shape components. Overlap results when the color or shape words occur in more than one two-word combination. Notice that the "B" training items share color and shape stimulus components. In the diagonal or non-overlap training condition, on the other hand, each color and shape word occurs in only one of the two-word combinations designated by "A". Training the diagonal items does not ensure that subjects will learn to respond to both words in the utterance. Attention to only the color or the shape components alone would be sufficient for accurate responding to the training stimuli. Foss (1968) found that none of the subjects who were trained on the six diagonal stimuli produced novel recombinations to label the untrained stimuli. In contrast, overlapping four color and four shape components when 10 stimuli were trained, forced subjects to discriminate among both the color and the shape components in order to provide the correct responses to training items. Foss found that this group of subjects demonstrated recombinative generalization. And not only did they generalize within the 4 x 4 matrix for which overlap among stimulus components was explicit, they also extended their generalization to the larger 6 x 6 matrix. One might argue that this was possible because subjects had induced and extended their use of a word order rule.

In studies conducted by Palermo and Parrish (1971) and by Goldstein, Wetherby, and Siewert (Note 1; 2) further evidence of a lack of recombinative generalization following the training of diagonal or nonoverlapping stimuli has been found. Thus, overlap among stimulus components is vital, apparently because it requires subjects to make the critical discriminations necessary for recombinative generalization to occur.

Children are not limited to two-word language productions for long. Consequently, it is important to consider how principles can be applied to more complex language systems. Consider the example of a three-term MLS shown in Figure 3. We have developed this language system for a study that we will be conducting with severely mentally retarded subjects. Therefore, we find it appropriate to use the English language, which these subjects have yet to acquire fully. A three-term utterance from this language system might take the form "the blue candle is on the book."

Insert Figure 3 About Here

If subjects do not have the modifier-, object-, and location-words found in Figure 3 in their linguistic repertoires, it is apparent that overlap among these stimulus components would be necessary to establish recombinative generalization. Whether this would be sufficient and how one might most efficiently provide such overlap is open to question, however. One way of providing overlap, which is analogous to the stepwise training condition described earlier, would entail introducing stimuli as training items according to the numbers shown in various cells of this language system. Notice that Cells 1 and 2 overlap the modifiers, green and red, with the same object, airplane and the same location, house. Cells 2 and 3 overlap the objects, airplane and truck, with the same modifier, red, and the same location, house. Cells 3 and 4 overlap the locations, house and drawer, with the object, truck, and the modifier, red.

Many of you may be thinking that it would seem reasonable to simplify this task. Indeed, providing overlap among three stimulus dimensions is a bit confusing. One option would be to teach one portion of the language system first, for example, modifier-object utterances and then we could recombine the modifier-object phrases with the locations.

This brings us to our second general case. Under what stimulus conditions might recombinative generalization occur if part of the language system is known by the language learner? Researchers have only begun to delineate the minimal stimulus conditions necessary for generative language use once subjects have been first taught a portion of a MLS (Goldstein, 1980; Striefel, Wetherby, & Karlan, 1978). If, for example, subjects have knowledge of part of the lexicon, overlap is not necessarily required for (recombinative) generalization to occur. Let me illustrate with data from one of seven preschoolers who participated in some of my own research (see Figure 4).

Insert Figure 4 About Here

Preschoolers were first taught to label four agent puppets. When they were subsequently trained to label agent-action stimuli, recombinative generalization was demonstrated in predictable manner. Notice that the subject whose data is shown in Figure 4 received training (designated by T) for only four agent-action stimuli, which were drawn from the diagonal of the matrix. Plus and minus symbols represent responses to untrained agent-action probe stimuli. Recombinative generalization was demonstrated sequentially. Each time this subject generalized, generalization was evident for the three untrained stimuli that recombined the agents with the newly trained action component. The children never responded correctly on the initial trial with a new diagonal training stimulus. Although three of the seven preschoolers required training on more than one stimulus that included the first action, mep, this same pattern of experimentally predictable generalization was shown for all seven children.

We can contrast the first general case in which subjects had no lexical knowledge of the language system with this second case in which subjects had lexical knowledge of one of two semantic classes. Only in the latter case is recombinative generalization possible when no overlap among the stimulus components is provided. By extending these findings to more complex language, we might be expected to efficiently bring about recombinative generalization in response to untrained modifier-object-location stimuli, the example which I mentioned earlier. If responses to modifier-object stimuli were already part of an individual's linguistic repertoire, the addition of each new location within a single modifier-object-location stimulus might result in extensive recombinative generalization.

I will briefly discuss a third general case in which the language learner has a lexical repertoire that encompasses all the content words of a novel language system. In this case, subjects who have knowledge of the complete lexicon used in a MLS should require minimal training. In fact, one example of the new syntactic construction may be sufficient for (recombinative) generalization to be demonstrated. I have extended the agent-action MLS that I discussed earlier to an agent-action-obbject MLS in which the agent puppets also served as objects (Goldstein, 1980). Consequently, the children had prior training with the complete lexicon.

Although training procedures were not set up to maximize this occurrence, a number of children have indeed demonstrated recombinative generalization after training on only one of 64 agent-action-object stimuli.

To take such a language system one step further, this minimal amount of environmental input may still result in recombinative generalization even if new function words or morphemes without any visual referents are included. Let's consider a language system roughly equivalent to the passive sentence structure. In response to agent-action-object stimuli, utterances similar to "John was chased by the dog" can be generated. However, when translated into a language system using nonsense words, utterances can be somewhat amusing, such as <u>tek</u> <u>foba</u> <u>wum</u> <u>ik</u> <u>la</u> <u>bup</u> (see Goldstein, 1980). The preschoolers I mentioned earlier readily learned and generalized their labeling according to this syntax: "object-foba-action-ik-la-agent." Six preschoolers each demonstrated recombinative generalization after receiving training on four of 64 such utterances.

In summary, while there is a paucity of research in many areas, I view the MLS paradigm as a valuable asset to the <u>experimental</u> analysis of language behavior. In particular, MLSs provide a parsimonious conceptual base for viewing the environmental circumstances that account for the development of generative language use. In addition, we have been able to identify how these stimulus conditions might vary depending on the prior learning histories of individuals.

Let me conclude by stating some general implications. In the natural environment, parents may inadvertently promote recombinative generalization, (especially of words already present in children's lexical repertoires) by modeling the recombination of words from the same semantic (response) classes. Of course, the child's language is not limited to two- and three-term relations for long. Based on the studies I have discussed, though, one can hypothesize that the modeling of more complex utterances using words in the child's repertoire and the correcting or reinforcing of relatively few of the child's attempted productions may be sufficient for the child to learn to generate numerous syntactic constructions.

MLS research also has implication for second-language teaching and has already proven useful as a basis for formulating efficient language intervention programs (Striefel, Wetherby, & Karlan, 1976, 1978; Wetherby & Striefel, 1978). Although the minimal environmental circumstances that have resulted in recombinative generalization for normal children and adults can be specified with a fair degree of surety, this set of circumstances may not always be sufficient for other subjects. Indeed, much research is needed to delineate the stimulus conditions that are not only necessary, but also sufficient for recombinative generalization to be demonstrated by language-deficient individuals. Thus far, this research has been quite promising. But the efficiency of language intervention could potentially be enhanced further by programming so as to maximize the effects of a history of lexical learning, for example. Moreover, we have only touched on the benefits that may accrue as a function of a history of semantic-syntactic learning.

The implications of recombinative generalization are most significant when we think of how we might establish increasingly complex language. As syntactic rules get progressively more complex and more linguistic repertoires can be integrated within a larger language system, the potential savings in direct training time increase tremendously. Future experiments should help to delimit the conditions that would result in this "rampant" generalization and would thus further our understanding of how the impressive diversity in developing language can be accounted for by environmental variables.

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2. Goldstein, H., Wetherby, B., & Siewert, L. An experimental analysis of receptive language and its relationship to expressive language. In preparation.

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Figure Captions

Figure 1. An example of stimuli and responses for an agent-action miniature linguistic system.

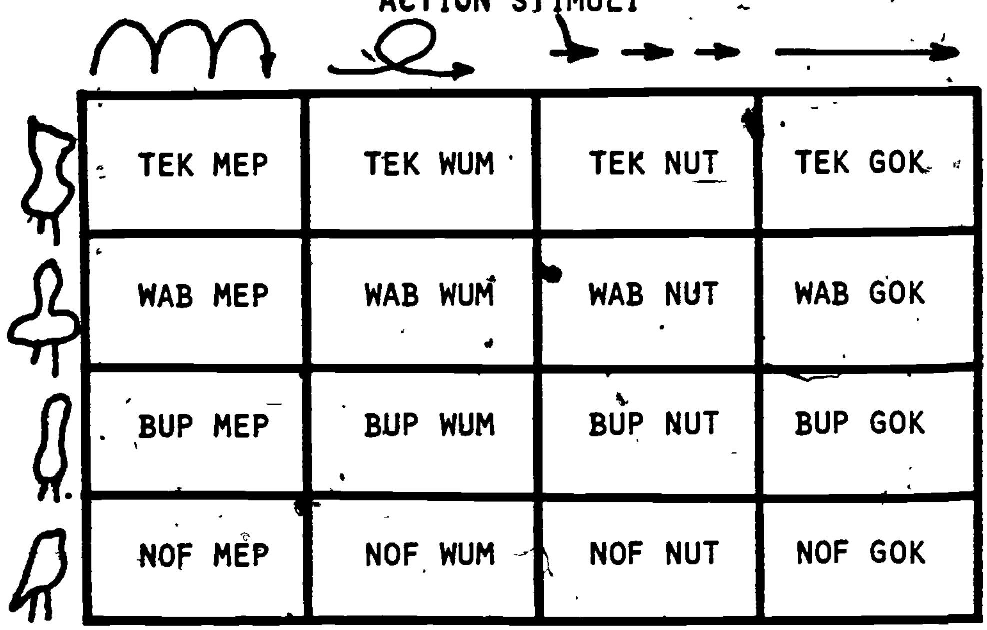
Figure 2. A 6 x 6 color-shape miniature linguistic system adapted from Foss (1968). The six diagonal training stimuli designated "A" each combine a different color with a different shape. The ten training stimuli designated "B" include recombinations of four of the color constituents and four of the shape constituents. All blank cells represent untrained color-shape recombinations.

Figure 3. An example of a 4 x 4 x 4 modifier-object location MLS. Numbers in the cells of the matrix denote the order of introduction of stimulus items into training.

Figure 4. An example of generalization probe data during the acquisition of an agent-action MLS. Training (T) was initiated across stimuli in a multiple baseline fashion. Performance on generalization probes is shown with probe trials scored either as correct (+) or incorrect (-).

ACTION STIMULI

AGENT STIMULI



TEK MEP	TEK WUM	TEK NUT	TEK GOK
WAB MEP	WAB WUM	WAB NUT	WAB GOK
BUP MEP	BUP WUM	BUP NUT	BUP GOK
NOF MEP	NOF WUM	NOF NUT	NOF GOK

Figure 1

SHAPE

COLOR	1	2	3	4	5	6
1	AB	B				
2		AB	B			
3			AB	B		
4	B			AB		
5					AB	
6						AB

Figure 2

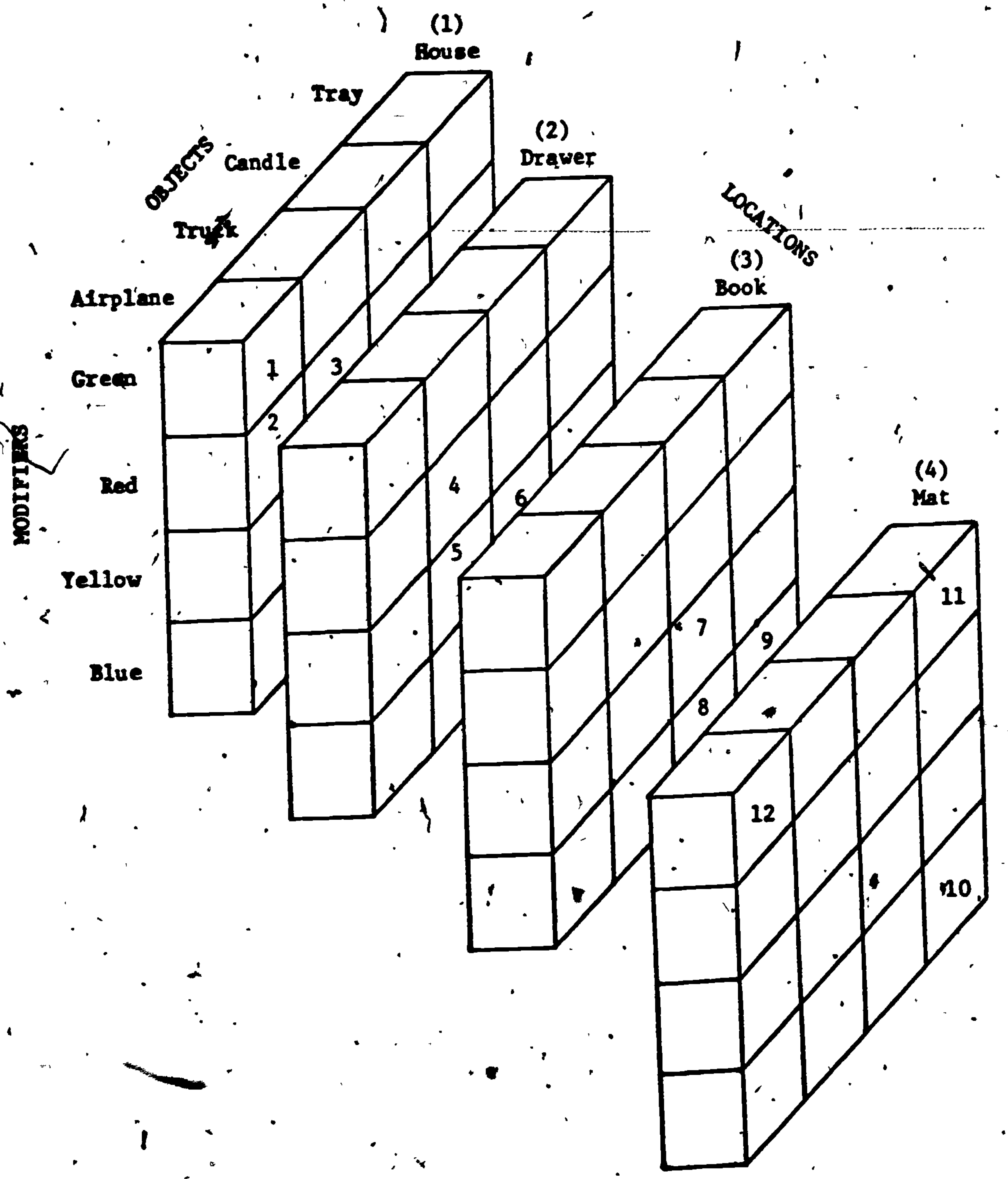

(1)
House
Tray
Candle
OBJECTS
Truck
Airplane
(2)
Drawer
LOCATIONS
(3)
Book
(4)
Mat
MODIFIERS
Green
Red
Yellow
Blue
1
2
3
4
5
6
7
8
9
10
11
12

Figure 3

Figure 4

SUBJECT: TOM

STIMULI	SESSION 6	7	8	9	10	11	12	13	14	15
TEK/MEP	- T									
WAB MEP		+	+ + +	+ +	+ +	+ + +	+ +	+ +	+ +	+ +
BUP MEP		+	+ + +	+ +	+ + - +	+ + +	[illegible]	+ +	+ +	+ +
NOF MEP		+	- + +	+ - +	- - + +	+ + +	+ + +	+ +	+ +	+ +
WAB WUM				- T						
BUP WUM				+	+ + +	+ + +	+	+ +	+ +	+ - +
NOF WUM				+	+ - +	+ + +	+ +	+ + +	+ +	+ +
TEK WUM				+	+ + +	+ + +		+ + +	+ +	+ +
BUP NUT					- T					
NOF NUT						+ + +	- -	- -	+ + +	+ +
TEK NUT					+	+ + +	+ -	- +	+ -	+ +
WAB NUT					-	+ + +	+ -	+ +	+ -	+ +
NOF GOK							- T			
TEK GOK							+	+ +	+ +	+ +
WAB GOK							+	+	+ - +	+ +
BUP GOK							+	+ +	+ -	+ +