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A computerized procedure for teaching the relationship between graphic symbols and their referents

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Introduction

Augmentative and alternative communication (AAC) is a transdisciplinary field consisting of special educators, speech-language pathologists, and other professionals that has the improvement of communication in individuals with little or no functional speech as its primary objective. Many AAC users rely on graphic symbols as their primary means for communication (Lloyd, 1976; Lloyd, Fuller, & Arvidson, 1997; Vanderheiden & Grilley, 1976; Vanderheiden & Lloyd, 1986). Efficient communication with symbols depends on the relationship between symbols and their referents (the words represented by symbols) being learned to such a degree that the communicator is not consciously employing retrieval processes to recall the meanings of symbols. Learning to this degree is known as the development of automaticity. By reducing load on the finite capacity active memory processes (Schneider & Chein, 2003), automaticity promotes fluent communication and allows a greater capacity of active memory to be used for higher order processing and abstraction.

Drill and practice activities are one way to promote development of automaticity. These activities can be time and labor intensive endeavors. The development of a large symbol-referent vocabulary with retrieval automaticity may require a considerable amount of time, a scarce and finite teaching resource. It is unlikely that most educators have sufficient time to develop such a vocabulary. However, a well established phenomenon from the cognitive sciences known as the “generation effect” in which memory is facilitated by having participants generate to-be-remembered items has potential for the development of instructional software for use in AAC devices that would automate symbol-referent learning. This would reduce the direct instructional time and ultimately would allow educators and other AAC professionals to more efficiently and thoroughly teach symbols and their referents.

Briefly, the generation effect, a phenomenon in which items generated by participants are better remembered than items supplied by the experimenter for study, became popular in the cognitive sciences during the late 1970s with the publication of studies by Jacoby (1978), and Slamecka and Graf (1978). In the Slamecka and Graf study, college students in the generation condition were either asked to generate words that were synonyms, antonyms, rhymes, associatives (e.g., LAMP-LIGHT), or categorically similar (e.g., RUBY-DIAMOND) to a cue word. In the control condition, the students were given complete

identical pairs of words and were simply asked to read them aloud. In subsequent memory tests using forced recognition, free recall, and cued recall, memory was always better for words generated by the students relative to the identical words that were simply read aloud. Similar findings using the generation of related words and antonyms were found by Jacoby (1978). Although the original studies of Jacoby (1978) and Slamecka and Graf (1978) were based on paired stimulus conditions in which one member of the pair cued generation of the other member of the pair, Glisky & Rabinowitz (1985) demonstrated that single words generated from fragments of the single word were sufficient to improve memory in subsequent tests.

Since the original studies of Jacoby (1978), and Slamecka and Graf (1978), a generation effect has been found with participants of all ages (both with and without disabilities), across multiple testing conditions (forced recognition, free recall, cued recall, etc.), and for a multitude of self-generated items such as word fragments, sentences, nonsense words, numbers, pictures, and non-sense figures (Boyle & Weishaar, 1997; Foos, Mora, Tkacz, 1994; Gardiner & Rowley, 1984; Gardiner, 1988; Glisky & Rabinowitz, 1985; Graf, 1980; Johns & Swanson, 1988; Kinjo & Snodgrass, 2000; McFarland, Duncan, & Bruno, 1983; McFarland, Frey, & Rhodes, 1980; McNamara, 1995; Peyniriloglu, 1989; Pring, Freestone, & Katan, 1990). Overall, these studies demonstrate the robustness of the generation effect and suggest that it may be a viable method for teaching the relationship between symbols and their referents. Hence, the purpose of the following study was to develop and test the efficacy of automated software based on the generation effect to teach the relationship between symbols and referents. More specifically, automated software based on the generation effect was developed for presenting symbols and referents on the Pathfinder (a computerized AAC device manufactured by Prentke-Romich Company (PRC)) and this software was tested for its capacity to promote learning at retention intervals up to one week post acquisition training. As this procedure was automated, it named “self-generation.”

Method

Rationale for choosing lexigrams

The present study was funded by an STTR grant from the National Institute Health between Purdue University and PRC. The protocol in the original proposal specified that Blissymbols would be used, however, internal alpha testing with **adults without disabilities** using Blissymbols revealed a ceiling effect across all conditions. Subsequent query of the participants determined that the ceiling was due primarily to Blissymbol iconicity. That is, there was a substantial resemblance between the Blissymbols and their referents such that memory performance was at maximum levels. This ceiling occurred despite the selection of Blissymbols with the lowest iconicity ratings. Hence, it was impossible to reselect another group of Blissymbols and lexigrams were selected to replace Blissymbols.

In short, lexigrams were used during the 1970s at the Yerkes Regional Primate Center to study communication in chimpanzees (Rumbaugh, 1977). Nine basic elements served as the basis for construction of lexigrams. Because these elements could be randomly combined to produce lexigrams, they were ideally suited for the purpose of this study. They afforded the opportunity for easy generation in addition to experimenter controlled construction and symbol-referent pairing (a mechanism conducive to eliminating the possible impact of iconicity as a confounding factor).

Experimental Design

A repeated measures within subjects design was used. Memory for symbol-referent pairs was measured at three intervals (immediately, 24 hours, and 1 week) after the learning

phase. Symbol-referent pairs were taught via two variations of the self-generation procedure. The symbol was generated in one variation. In the other variation, the referent was generated. Two levels of complexity were used in the symbol generation condition. High complexity symbols consisted of lexigrams constructed from four elements. Low complexity symbols were lexigrams composed of two elements. Paired associate presentations that mimicked the commonly used “flash card” learning procedure served as controls.

Overview of self-generation conditions

Each participant self-generated both lexigrams and referents in the LCD display at the top of the Pathfinder (see Figure 1). Self-generation responses for both the symbol generation and referent generation conditions consisted of depressing any key on the Pathfinder when cued by a tone.

Symbol generation

There were two levels of symbol complexity with the symbol generation condition. Low complexity symbols consisted of lexigrams composed of two elements. High complexity symbols were lexigrams composed of four elements.

In the symbol generation condition, the first key depression caused the referent to be shown in the left side of the display. The referent remained displayed for the duration of the symbol generation procedure. The second key depression caused the first element to be displayed to the right of the referent. After 5 seconds, the first element disappeared and a tone to depress any key was produced by the Pathfinder. Depression of any key caused the symbol in its next stage of construction to appear and the second element was overlaid on the first element after 400 milliseconds. This process continued until the symbol was completely constructed.

The same process and parameters were employed for the construction of both low and high complexity lexigrams. The only difference was that construction was complete after the second element was overlaid in the low complexity condition, whereas, construction was complete after overlay of the fourth element in the high complexity condition. Shown below in Figure 2 is a representation of the construction process of a low complexity symbol for the referent, *Run*.

Referent Generation

In the referent generation condition, the first key depression caused the lexigram to be displayed at the right side of the display -It remained visible for the duration of the referent generation process. The second key depression caused the first letter of the referent to be shown at the far left side of the display. After 5 seconds, the first letter disappeared and a tone to depress any key was produced. Depression of any key caused the first letter to reappear and the second letter appeared directly to the right of the first letter after 400 milliseconds. This process continued until the referent was completely constructed. A representation of referent generation is shown in Figure 3 below.

Overview of paired-associative control conditions

A commonly used technique to teach the relationship between two items is the *flashcard* procedure. In our control conditions, we used a paired associate procedure for presenting symbolreferent pairs that approximated a *flashcard* learning paradigm. Our paired-associative control for the referent generation condition was as follows. The first key depression caused the symbol to be displayed and it remained visible throughout the trial. The second key depression caused the referent to be displayed in its entirety to left of the symbol. After 5 second, the referent disappeared. Next, a tone to depress any key was

produced by the Pathfinder. Depression of any key caused the referent to be re-displayed, which disappeared again after 5 seconds. This continued until the referent was presented four times.

The paired associate procedure for the symbol generation conditions were basically the same as the for the referent control, except that in the paired associate symbol generation conditions, the referents remained displayed for the duration of the trial and the symbol (shown in its entirety) disappeared and reappeared contingent on key depression. In the low complexity symbol generation condition, generation consisted of two construction phases and was twice as long as the construction phase for the high complexity symbol generation. Hence, in the paired associate control for the low complexity symbol generation condition, the symbol was shown two times. And in the paired associate control for the high complexity symbol generation, the symbol was shown four times.

Shown below in Figure 4 is a representation of how the symbol-referent pair from the above example would appear in the paired associate control for the referent generation condition. In the controls for the symbol generation conditions, the symbol would disappear and reappear rather than the referent and the referent would remain constantly displayed for the duration of a trial.

Timing parameters

The Pathfinder was programmed to present symbol and referents in the LCD screen based on the following specifications during the learning phase. All presentations were contingent upon depression of any key when cue by a tone generated by the Pathfinder. If the participant failed to depress any key within 4 seconds, the tone was produced again as a reminder. The reminder every 4 seconds was programmed to continue until a key was depressed.

The learning phase was initiated by the experimenter depressing the “run” button, which was the key located at the far right hand bottom of the device. There was a 2 second lag from the depression of the “run” button to the start of the learning phase.

For the symbol generation conditions and their paired associate controls, the first key depression caused the referent to be displayed at the left side of the display. The referent remained displayed for the duration of the symbol-referent presentation or trial. Subsequent key depressions resulted in the presentation to the right of the referent of the symbol (either in its entirety (the paired associate control) or in one of its construction forms). The symbol remained displayed for 5 seconds before disappearing. One half second after disappearing, the tone for depressing any key was produced (unless it was the end of trial for the symbol-referent pair). Key depression either brought back the symbol for the control or produced an image of the symbol in the next phase of construction for the generation conditions.

For the referent generation condition and its paired associate control, the first key depression resulted in the symbol being displayed in its entirety in the right side of the display. The symbol remained displayed for the duration of the symbol-referent trial. Subsequent key depressions resulted in the presentation to the left of the symbol of the referent (either in its entirety for the control or in one of its stages of construction for the referent generation condition). The referent (control) or partially constructed referent (generation condition) remained displayed for 5 seconds and then disappeared. One half second after disappearing, the tone for key depression was produced (unless it was the end of trial for the symbol-referent pair). In the control condition, key depression brought back the referent in its entirety. In the generation condition, key depression resulted in the referent being displayed with the next letter added.

After completion of generation (both symbol and referents) or the appropriate number of control presentations, a tone (different from the key depression tone) was produced and the contents of the display disappeared. This tone signaled the completion of the trial for the symbol-referent pair. After an inter-trial interval of 2 seconds, the tone for key depression was produced and a new trial for a different symbol referent pair was started.

Upon completion of the presentation of the last symbol-referent pair, a tone signaling the end of the testing session was produced. This end of session signal also included Xs being displayed in LCD screen and the diodes on all of the keys being lighted.

Materials

Lexigrams construction

Shown below in Figure 5 are the nine basic elements (Rumbaugh, 1977) used to construct high and low complexity lexigrams. High complexity lexigrams were constructed from four randomly determined elements. Low complexity lexigrams were constructed from two randomly determined elements. Please note that the lexigrams used in the study were reversed black/white contrast from those shown below. That is, the solid black circle and triangle would be shown as solid white on a black background, and the black line figures appeared as white line figures on a black background.

Referent Selection

Second grade spelling books from the Technology Resource Center at Purdue University were used as the source of referents. An initial search found that there were insufficient numbers of two letter words. Hence, three and four letter words were chosen. Of the three and four letter words found, there were insufficient numbers of adjectives and adverbs to adequately divide among the conditions and foils for the multiple choice test. A total of 246 four letter words were found (159 nouns and 87 verbs) and a total of 102 three letter words were found (64 nouns and 38 verbs). These three and four letter nouns and verbs served as the source of referents and foils.

In development of the protocol, it was hypothesized that complexity of the symbol could influence learning. Therefore, symbol complexity (defined as the number of elements used to construct a lexigram) was designated as a variable to manipulate and investigate. To maximize potential differences arising from complexity, it was decided that complexity should differ by at least two elements. For symbol generation to occur, a symbol must have at least two elements. This set a lower boundary on complexity at two elements. Based on observations of lexigrams composed of more than four elements, it was determined complexity levels of five or more elements resulted in symbols that were difficult to distinguish from each other. Hence, it was decided that symbols of low complexity would be composed of two elements and high complexity symbols would be composed of four elements. To compliment the symbol generation conditions, a referent generation condition was used. Because of the shortage of two letter words, it was not possible to have a low complexity referent generation condition of two letter words to parallel the low complexity symbol generation. Thus, only a four letter referent generation condition was used.

Assignment of Referents

A primary limitation in determining the breakdown of the two referent word lengths by condition was the referent generation condition. As mentioned above, it was determined that the referent generation condition was to be based on the generation of four letter referents. This meant that only four letter referents would be assigned to this condition and its control. The relevant symbol generation comparison for this referent generation condition was the

high complexity symbol condition. In addition, another relevant comparison for the high symbol generation condition was to the low complexity symbol generation. Based on these limitations, the assignment of words per condition as shown in Table 1 was used.

Within the above limitations, the specific assignment of referents to lexigrams and lexigrams to conditions was randomly determined. It should be noted that a software error concerning the lexigram bitmaps resulted in duplicate assignment of four lexigrams. Because each duplication affected two referents, eight symbol-referent pairs had to be disregarded from data analysis. Fortunately, the duplication was not clustered within any one condition and did not result in the disproportionate reduction in analyzable items in any one condition. Specifically, the duplications resulted in the following reduction of items per condition: Low complexity control, 1 three letter verb; low complexity symbol generation, 1 two letter noun; high complexity control, 1 four letter noun; high complexity symbol generation, 1 three letter noun; referent control, 2 verbs; referent generation, 2 nouns.

Test Booklets

Booklets for testing retention were constructed from heavy duty 8 ½ by 11 inch sheets of paper thick enough to prevent the material from the underlying page to be seen. To conserve paper, these sheets were cut in half along the 11 inch dimension. Centered on each half sheet was one lexigram. Below the lexigram were five word choices. One choice was the correct referent. The other choices were foils. The position on the page of the target and foils was randomly determined. There were insufficient numbers of words not assigned to symbols to have novel foils for each multiple choice question. Therefore, foils were randomly selected from the words not assigned to be symbols and also from the words used as targets (those assigned to other symbols). Each set of foils was required to have least one three letter word and one four letter word. Also, each set of four foils had at least one novel word and one incorrect word that had been assigned to another symbol.

Participants

Non-disability groups consisted of Purdue students and third graders. These groups were composed of 12 Purdue students (6 males; 6 females) and 12 third graders (7 males; 5 females). Originally, it was anticipated that these 2 non-disability groups would be matched by disability groups with little or no functional speech, however, despite rigorous recruitment efforts; it was not possible to obtain full complimentary disability groups. Recruitment did yield two participants with little or no functional speech. Both were male. One participant was a developmentally delayed 7th grader with cerebral palsy and attention deficit disorder (ADD). The other participant was a 6th grader who was being advanced to the 9th grade in the next academic year. This participant was held back in the 6th grade because of failure to meet academic requirements. Had he not been held back, he would have been in the 8th grade at the time of testing. His speech-language-pathologist (SLP) reported that he was going to be advanced to the 9th grade because of academic progress made through remedial special education services. This participant was learning disabled with speech apraxia, and ADD.

In addition, this participant could not initially recognize words by sight alone. According to the student's SLP, it was necessary for this participant to hear the word in addition to seeing it for the first time for recognition to occur. The SLP stated that subsequent visual presentations of the words would result in sight recognition. Based on these assertions, the following modifications recommended by the SLP were made to the protocol: 1) during initial presentations of symbol-referents pairs, the experimenter said the referent aloud; 2) word choices on the multiple-choice test were read aloud.

Procedure

Testing consisted of three sessions. During the first session, participants received the following in sequence of events: 1) capacity to depress key test; 2) pre-test to make sure that the participant understood the relationship between symbols and referents; 3) an explanation and demonstration of tones that would be heard; 4) a demonstration and practice trial for each condition; 5) acquisition training; 6) retention testing immediately following acquisition. The second and third sessions were given 24 hours and one week after the first session, respectively. Both of these sessions consisted only of retention testing. A script detailing what to do and say was followed by the experimenters. A brief description of each component is given below.

Capacity to depress keys

The purpose of this test was to determine whether the participant had the capacity to depress the keys. When in this test mode, depression of any key caused the diode on the depressed key to be lighted. The experimenter instructed the participant to depress any key and observed for the lighted diode during depression. This was repeated four times.

Pretest

The purpose of this test was to determine whether the participant understood the relationship between symbols and referents. This consisted of a paper test in which the participant was shown a lexigram with its referent directly below. The participant was told that the symbol had the meaning of the word below. Next, the participant was shown a page in which the symbol was shown with the correct meaning and four foils and was asked to point to the word that the symbol meant. This was repeated for four different symbol-referent pairs. The order in which the four symbol-referent pairs were presented to each participant was determined with a random number generator.

Explanation and demonstration of tones

During this component, the experimenter demonstrated the tone that would be heard during the test and what they meant. The experimenter also requested that the participant demonstrate the response required when the tone to depress any key was heard.

Demonstration and practice

During this phase, the experimenter demonstrated the key depression response contingent on the tone to depress any key and pointed out what was being displayed in the Pathfinder's screen for each generation and control condition. After each demonstration, the participant was given a practice trial during which the experimenter observed to make certain that the participant understood the procedure.

Acquisition training

This consisted of the learning phase of the experimenter in which the participant independently depressed any key to have the symbol-referent pairs presented in the various generation and control formats. Each participant saw 74 symbol-referent pairs.

A possible confound for memory research for items presented in lists (i.e., one after another) arises from primacy and recency effects (Mulligan, 2002; Rabinowitz & Craik, 1986). Primacy refers to superior memory for the first few items in a list and recency refers to superior memory for the last few items. One method for dealing with these confounds is the addition of buffer items to the beginning and end of memory lists (Mulligan, 2002; Rabinowitz & Craik, 1986). Buffer items are presented to participants but they are not tested for memory.

In the present study, the first three symbol-referent pairs served as primacy buffers and the last three served as recency buffers. These buffers were always the same six symbol-referent pairs. For each participant, the software randomly determined the order at the beginning and end of the list these buffers would occupy. Memory for the buffers was never tested. The presentation order of the remaining 68 non-buffer symbol-referent pairs was randomly determined by the Pathfinder. These 68 pairs were tested for retention.

Retention testing (immediately, 24 hrs, and 1 week post acquisition)

Memory for the symbol and its referent was tested with a paper and pencil procedure. This procedure consisted of a test booklet containing the symbol shown on a page with the referent and four foils shown below. The participant was instructed to circle the word the symbols meant.

Results

The statistical consulting service offered through Purdue University served as consultants for data analysis. Based on their advice, a mixed design ANOVA was performed with SAS software on the data obtained from the group of third graders without disabilities and the group of Purdue students. Between subject factors were sex and group. Within subject factors were test and presentation condition of symbol-referent pairs. For each participant, a mean percent correct was calculated for the multiple-choice questions for each condition. These scores served as the measurement for the analysis reported below.

Type II errors occur when the null hypothesis is false but accepted as true. In other words, there was a real difference but the experimenter(s) reported that there was no difference. As the present study was an initial exploratory study, statistical significance was assessed at a liberal $p=0.10$ level, rather than at the more conservative level of $p=0.05$. It is important during exploratory studies to reduce erroneously reporting that treatment and/or other differences were not found. Type II errors at exploratory stages of research can lead future experimenters to ignore potentially fruitful areas of development.

Main effects of tests ($F=8.52$, $p=0.0008$) and of generation condition ($F=1.93$; $p=0.096$) were found. To compensate for multiple comparisons, a Tukey least squared test of means procedure was used on all subsequent comparisons of means. Collapsed over conditions and groups, performance on the second and third tests were both significantly different from the first test (Tukey least squared test of means, $t=2.68$, $p=0.01$; $t=4.06$, $p=0.0002$, respectively). Performance on the second test did not differ from the third. The mean correct performance on the 3 tests is shown in Table 2.

Mean percent correct for each condition on each retention interval is shown in Figure 6. Based on a Tukey least squared test of means for these data, the paired associate control for the referent generation condition produced the best immediate memory performance. Performance in the referent generation condition was the most stable over the week retention intention interval, showing less than a 3 percent decrease in performance after a week. When tested immediately after acquisition training, performance in the paired associate referent control was significantly better than the lowest performing condition, high complexity symbol generation (Tukey least squared test of means, $t=2.04$, $p=0.042$). The memory advantage for the paired associate referent control, however, was only transitory and faded over the week retention interval. After the week long retention interval, the best memory performance was found in the referent generation condition and the worst in the high complexity symbol generation and paired associate controls. Referent generation performance was significantly better than the high complexity symbol generation (Tukey least squared test of means, $t=2.09$, $p=0.038$) and better than the paired associate control for

the high complexity symbol generation condition (Tukey least squared test of means, $t=1.87$, $p=0.062$) when tested 1 week after acquisition training. Whereas, performance in the paired associate control for the referent generation did not differ significantly in either the low or high complexity symbol generation conditions nor from the paired associate controls for either of these symbol generation conditions on the weekly test.

A pattern of long-term retention similar to that found with the Purdue students and third graders without disabilities was found for the two individuals with little or no functional speech. Averaged over these 2 participants, retention after one week was the highest in the referent generation (mean=31.5%) compared to a mean of 25.0% for the referent generation control. As with the Purdue students and third graders without disabilities, the lowest performance was again found with the high complexity symbol generation (mean=7.7%) and its control (mean=11.2%). Furthermore, consistent with performance of the participants without disabilities, the low complexity symbol generation (mean=22.2%) and its control (mean=16.2%) was better than the high complexity symbol generation and its control.

Conclusion

A major finding of this study is that long-term retention of graphic symbol-referent pairs is facilitated by referent generation. After a week-long retention interval, the best memory performance was found in the referent generation condition. Although performance in the referent generation condition was not as great as the referent control when tested immediately after acquisition, referent generation showed only a 3 point percentage drop over a week, whereas, the referent control showed a 12 point drop in performance over the week interval and did not differ significantly from performance in either of the two poorest performing conditions, the high symbol generation and its control, on the weekly test. Considering that each symbol-referent pair was presented in only one trial with a total duration of 20 seconds for the symbol-referent presentation, the amount of learning and retention after a week for referent generation is rather remarkable.

For the purpose of improving symbol communication, long-term rather than short-term retention is the critical factor. Communication would be rather ineffective if the meaning of a symbol rapidly faded and could not be retrieved from long-term storage as demanded by future circumstances. Our findings demonstrate that referent generation is optimum for enhancing long-term retention.

In the condition of referent generation, a possible processing scenario can be envisioned as the participant making mental guesses as to the actual word being constructed. Although the random procedures used to determine the elements composing each symbol and the assignment of symbols to referents minimized iconicity, the participants were unaware of this fact and may have tried to use the symbol as a cue to aid in identification during guessing of the referent being constructed. This corollary cueing process may have served to reinforce the association between symbol and referent. Consistent with this notion was the observation that some of the third graders said aloud the referent before it was completely generated, an indication that they were making guesses. However, consistent with the Glisky and Rabinowitz (1985) study, the guessing could have been due to the completion of the word fragment only. The fact that foils were assigned with a stipulation that at least one foil in each set of multiple choices was not novel (i.e., it had to be used with other in the multiple choice sets of other symbols) reduces the likelihood that participants were using only recognition of a word previously experienced as the basis for choosing that particular word. This adds weight to the scenario in which the symbol is involved in cueing the completion of the referent and the development of a cognitive link between the symbol and referent. However, without a comparison condition analogous to the single word fragment

used in Glisky and Rabinowitz (1985), it is not possible to determine the degree to which the processing involved cueing from the symbol or incomplete referent. Caution should be used when interpreting the underlying mechanism(s) of the performance difference. Additional research should be conducted to dissect potential mechanisms that may have contributed to difference in performance.

In contrast, in the paired associate control for the referent generation condition there was no opportunity for mental guessing and deeper processing because the referent was presented in its entirety. Also, only superficial processing would be expected in the symbol generation condition because the random basis for selecting elements for each symbol and for the overlay or generation sequence precluded educated guessing based on prior knowledge. Our findings in the symbol generation conditions are consistent with superficial processing.

In the present study, the predominant participants were those without AAC needs who presumably had some degree of vocabulary development. In the scenario above, the vocabulary of the participant is hypothesized to play a role in the development of the association between the referent being generated and the graphic symbol. Although it is likely that AAC graphic symbol users may have limited referent vocabulary, it is also a possibility that there is some degree of latent referent vocabulary potential that is undetectable with currently available instruments. In such cases, a referent generation paradigm such as used in this study could be used to develop latent potential, resulting in an increased vocabulary.

In addition to memory facilitation by referent generation, high complexity symbols were found to be more difficult to learn than low complexity symbols. A plausible explanation is that engrams formed from high complexity symbols contain more overlapping information than low complexity symbols, resulting in a high degree of confusion and errors during the retrieval process. It is worth noting that only high complexity symbols were used in the referent generation condition. Presumably, complexity should have the same underlying effect on memory formation in the referent generation condition as found in the symbol generation conditions. Therefore, it is likely that an even greater degree of memory enhancement would have been found with the use of low complexity symbols in the referent generation condition. However, alternative explanations are possible and should be entertained by the reader. For example, more referents were tested in the high complexity conditions than the other conditions. Although the high complexity conditions tended to exhibit low level performance, which is counter intuitive to expectations based on number of trials (i.e., one would expect that greater number of learning trials would equate to better not poorer performance), caution should be used in attributing of the poorer performance to increased complexity. Additional research focused on the effects of complexity with matched learning trials should be conducted to more thoroughly understand the influences of symbol complexity.

In short, the present study provides positive evidence concerning the potential of referent generation as a technique for enhancing symbol-referent based AAC strategies and contributes to the foundation of evidence from which educators and AAC professionals can use to improve communication. The software developed for the Pathfinder could easily be modified for use with devices and adapted to teach other graphic symbol systems. The capacity for automation provides the user with the capacity for independent learning and practice and requires minimal direct instructional time from the educator. Additional learning and practice could easily be implemented at home.

The results from the AAC users are difficult to interpret because of their small number. Their results, however, are consistent with those of without AAC needs. Regardless of the

consistency, the reader is cautioned concerning generalizations. The present study has identified potentially valuable areas for future research with AAC users. Until such research has been conducted, generalizations should be considered premature.

Finally, it should be noted that the only response required for the protocol was the depression of any key, therefore it should be usable by individuals with limited motor skills (a condition common among many AAC users). The viability of this is evident by the participation of an individual with cerebral palsy who had limited motor capacity and control. This individual did not experience difficulty performing the required response.

Furthermore, with the use of external switches, the procedure could easily be adapted for use with individuals with even more severe motor limitations.

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Figure 1.
The Pathfinder (color figure available online).

LCD Screen	Description
Run	Key depression tone heard, participant depresses key, and Run appears in LCD
Run	After 5 sec., key depression tone heard, key is depressed, and symbol in first stage of generation is shown
Run	After being displayed for 5 sec., the symbol under construction disappears
Run	0.5 sec. after the symbol under construction disappears; a tone to depress any key is heard. Upon depression of any key, the symbol is shown in its previous stage of generation
Run	After 400 milliseconds, the second element is overlaid.
	After 5 sec., the symbol and referent disappear and tone signaling and inter-trial interval is produced

Figure 2.
A representation of generation of a low complexity symbol.

Figure 3.
A representation of the generation process for the referent, Hook.

<u>LCD Screen</u>	<u>Description</u>
	Key depression tone heard, participant depresses key, and symbol appears in LCD
Hook	After 5 sec., key depression tone heard, key is depressed, and referent in first stage of generation is shown
	After being displayed for 5 sec., the referent disappears
Hook	After 5 sec., key depression tone heard, key is depressed, and referent reappears
	After being displayed for 5 sec., the referent disappears
Hook	After 5 sec., key depression tone heard, key is depressed, and referent reappears
	After being displayed for 5 sec., the referent disappears
Hook	After 5 sec., key depression tone heard, key is depressed, and referent reappears
	After 5 sec., the symbol and referent disappear and tone signaling and inter-trial interval is produced

Figure 4. A representation of the paired associate control for the referent generation condition

Figure 5.
The nine basic elements used to construct lexigrams.

Figure 6.

Mean percent correct measure immediately, 24 hours, and 1 week after training for the different conditions (RPAC=Referent Paired Associate Control; RG=Referent Generation; HCSC=High Complexity Symbol Generation; HPAC=High Complexity Paired Associate Control; LCSC=Low Complexity Symbol Generation; LPAC=Low Complexity Paired Associate Control).

Table 1

The assignment of words of different lengths and part of speech to the different conditions.

Condition	Word length & Parts of speech
Referent Generation	Ten 4 letter words (5 nouns; 5 verbs)
Referent Generation Control	Ten 4 letter words (5 nouns; 5 verbs)
High Complexity Symbol Generation	Nine 4 letter words (5 nouns; 4 verbs); and five 3 letter words (2 nouns; 3 verbs)
High Complexity Symbol Generation Control	Nine 4 letter words (5 nouns; 4 verbs); five 3 letter words (2 nouns; 3 verbs)
Low Complexity Symbol Generation	Five 4 letter words (3 nouns; 2 verbs); five 3 letter words (2 nouns; 3 verbs)
Low Complexity Symbol Generation Control	Five 4 letter words (3 nouns; 2 verbs); five 3 letter words (2 nouns; 3 verbs)

Table 2

Mean performance collapsed over groups and conditions on the three retention intervals (immediately, 24 hours, and 1 week after acquisition training).

Test 1 (Immediate)	Test 2 (24 hours)	Test 3 (1 week)
39.53	34.28	31.56