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Message-Encoding Techniques for Augmentative Communication Systems: The Recall Performances of Adults With Severe Speech Impairments

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This study investigated the cognitive and linguistic processing demands of message-encoding techniques used to retrieve prestored messages from computer-based augmentative communication systems. Twelve physically disabled adults with severe speech impairments participated in six counterbalanced experimental conditions, consisting of three encoding techniques (salient letter, letter category, and iconic codes), each in a personalized condition in which subjects selected their own codes and in a nonpersonalized condition in which codes were preselected by a clinician. In each of the experimental conditions, the subjects participated in five learning and testing sessions. During these sessions, the subjects learned the codes for lists of 80 messages, half of which involved concrete referents and half abstract concepts. Results indicated that the subjects were more accurate in recalling the codes to retrieve preprogrammed messages when using the two letter encoding techniques than when using the iconic technique. No reliable differences were found between recall performances with personalized codes and with nonpersonalized ones for any of the three encoding techniques. Code recall improved consistently across the series of learning sessions; there were no significant differences in the rates of learning across the encoding techniques. Subjects were found to be more accurate at recalling the codes to retrieve concrete messages than those to retrieve abstract messages.

KEY WORDS: augmentative communication systems, severe speech impairments, technology (assistive), message encoding

People who use augmentative communication systems typically have difficulty initiating interactions and participating fully in conversational exchanges (e.g., Calculator & Dollaghan, 1982; Harris, 1982; Light, Collier & Parnes, 1985a). One of the factors contributing to these communication difficulties is the severely reduced rate of communication via an augmentative communication system as compared to the rate of natural speech (Foulds, 1987; Yoder & Kraat, 1983). Whereas the latter rate falls somewhere between 125–175 words per min, communication rates via an aided augmentative communication system typically remain well below 15 words per min, less than 10% of the rate of natural speech (Foulds, 1980; Foulds, 1987).

One solution to the problem of reduced rate is the use of message-encoding techniques—techniques in which messages are preprogrammed into computer-based augmentative communication systems. Rather than composing messages letter by letter (or item by item), the communicator, using a message-encoding technique, is able to use a short sequence of keystrokes (i.e., a code) to retrieve a full, preprogrammed message that is then spoken or printed via the communication device.

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Current Approaches to Message Encoding

With the augmentative communication technology currently available, three approaches to coding prestored messages have been used frequently: letter codes based on the principal words in the message (salient letter codes); letter codes based on a categorical system for encoding the message (letter category codes); or codes based on pictographs and their associations (iconic codes).

Salient Letter Codes

The salient letter encoding technique involves the selection of the initial letters of the most salient content words in the prestored message for use as the code. For example, the message, "Please open the door for me" could be coded as "OD" since these are the initial letters of the most salient content words (open door). While this approach seems to involve a fairly straightforward recall strategy, it requires clients to have at least some skills in the use of traditional orthography. Furthermore, it has been argued that this technique would be effective only if the client recalls the message in its correct syntactic form (Musselwhite & St. Louis, 1988). For example, if a client wants to express the message "Please open the door for me," but recalls it in the form, "Could you please help me with the door?" he or she may have difficulty recalling the correct letter code since the "O" for "open" is no longer a salient letter in the transformed message.

Letter Category Codes

Several authors have proposed a letter category system for selecting letter codes to circumvent the problem of remembering the correct form of messages to derive salient letter codes (Fishman, 1985; Graff & Wotus, 1985). They suggested that preprogrammed messages be categorized according to their primary content or intent. The first letter of the code is then selected on the basis of this category. For example, the message, "Please open the door for me" might be considered as one of a set of messages concerned with directions and be coded under the letter "D" for "Directions." A second letter is selected as a discriminator or specifier within the category, based on the specific content of the message. In this example, the letter "D" might be selected to indicate the content of "Door," so that the message "Please open the door for me" would be retrieved by selecting the letters "DD" (Direction Door).

Iconic Codes

Baker (1982, 1986) has argued that the use of letter codes limits the number of messages that can be recalled easily by a user, since the codes are still somewhat arbitrary and abstract in nature and since they often result in "collisions," when the same two-letter sequence is selected to code two different messages. Baker has proposed the use of an alternative encoding technique, entitled Minspeak, as a more effective approach to message encoding. Minspeak (referred to in this paper as the iconic technique) involves the use of "icons," pictures that are considered rich in semantic associations. For example, the icon of one elephant following another might represent concepts of gray, trunk, heads or tails (sports), following, heavy, double, smell, peanuts, we, parade, and so on (Baker, 1983). The meaning of each prestored message is summarized by a series of concepts and an appropriate sequence of icons is selected to represent the concepts. For example, the message "Please open the door for me" might be stored under the icons of an open treasure chest representing the concept of "Open" and the icon of a house indicating the "Door."

Research Evaluating Message-Encoding Techniques

While the merits of the three encoding techniques have been debated clinically, to date there are few empirically based guidelines to support clinicians in selecting the most appropriate message-encoding technique for a client. Most of the studies (e.g., Angelo, 1987; Beukelman & Yorkston, 1984; Gardner-Bonneau & Schwartz, 1989) have evaluated the effect of encoding techniques with nondisabled college students. The choice of this subject group poses threats to the external validity of these studies. Results from nondisabled college students may not be generalizable to the population of augmentative communicators, many of whom have concomitant cognitive disabilities and limited educational experiences. Only one study has considered the impact of message-encoding techniques on the accuracy of code recall by a group of physically disabled clients who actually used AAC systems. Results of this study by Light, Lindsay, Siegel, and Parnes (1990) indicated that the functionally literate subjects recalled salient letter codes more accurately than either letter category codes or iconic codes. Furthermore, the subjects recalled the codes for concrete messages (i.e., messages involving objects and activities) more accurately than the codes for abstract messages (i.e., messages that involved abstract concepts).

Although the results of the study by Light et al. offer some preliminary evidence regarding the effectiveness of message-encoding techniques with physically disabled individuals with severe speech impairments, there are a number of limitations to the generalizability of the results. First, the study by Light et al. employed a short list of messages and codes (30) and a short learning time (15 min) prior to testing code recall. Results of the study may not be generalizable to larger message lists and longer periods of code learning, such as those occurring in most clinical applications of message-encoding techniques. Secondly, the codes used in the study were all nonpersonalized ones, that is, they were preselected by an experienced clinician and not by the clients themselves. In contrast, in current clinical practice, many message-encoding techniques developed for clients use personalized codes, that is, codes selected by the clients themselves.

In light of the limitations in the research to date, the present study was designed to investigate the accuracy of recall of message codes by physically disabled adolescents and young adults who use augmentative communication systems and have varying levels of literacy skills. The study evaluated the effect of the following factors: the encoding technique used (salient letter, letter category, iconic codes); the degree of personalization of the codes (personalized codes selected by the subjects or nonpersonalized codes preselected by a clinician); the number of learning sessions (one to five learning sessions); and the nature of the messages (concrete or abstract).

Methodology

Design

The study used a within-subjects design with repeated measures to control for the heterogeneity across subjects that is typical within the population of physically disabled individuals who use augmentative communication systems. Independent variables in the study were as follows: encoding technique (salient letter, letter category, and iconic codes); personalization of the codes (personalized codes selected by the subjects themselves, or nonpersonalized codes preselected by an experienced clinician); session (one to five learning and testing sessions); message type (concrete vs. abstract messages); and context type (explicit vs. oblique contexts used to test recall of the messages and codes). The factors of personalization and encoding technique were counterbalanced across subjects in a Latin Square design. Half of the subjects participated in the personalized conditions first, followed by the nonpersonalized conditions; the remaining subjects participated in the nonpersonalized conditions first, followed by the personalized ones. Within the personalized and the nonpersonalized conditions, each of the subjects participated in each of the three encoding conditions. The sequence of the encoding techniques was counterbalanced across subjects.

Subjects

Twelve subjects participated in the study. Subjects were selected based on the following criteria: (a) 18 years of age or older; (b) congenitally physically disabled; (c) severely speech impaired (i.e., speech inadequate to meet daily communication needs); (d) using augmentative communication systems that did not involve any of the encoding techniques under study; (e) able to use direct selection techniques (e.g., pointing with a finger, thumb, headstick, or chinpointer) to operate a communication device; and (f) reading skills at least at a grade one level, according to the report of primary caregivers. All subjects (and their legal guardians, as appropriate) were informed of the goals, procedures, and time commitment of the study and consent to participate was obtained.

Table 1 provides detailed profiles of each of the subjects in the study. Of the 12 subjects, 7 were male and 5 were female. The subjects ranged in age from 18 to 35 years, with a mean age of 26. All were physically disabled: 11 had cerebral palsy and the remaining subject (Subject 7) had dystonia musculorum deformans, a progressive condition marked by severe muscular contractions. Only one of the subjects (Subject 1) was ambulatory. The remaining subjects used powered wheelchairs (7 subjects) or manual wheelchairs (4 subjects) as mobility aids.

The subjects used a wide range of augmentative communication systems in face-to-face conversations (see Table 1). All had been using their systems for at least 1 year prior to the commencement of the study. None of the subjects used any of the encoding techniques under study within their augmentative communication systems. Eight of the subjects used augmentative communication systems incorporating some form of traditional orthography (Subjects 1, 2, 3, 7, 8, 9, 11, and 12); 4 subjects used augmentative communication systems that did not incorporate orthography (Subjects 4, 5, 6, and 10).

Educational history and residential settings varied across the 12 subjects (see Table 1). Table 2 provides background information on the subjects in the following areas: nonverbal reasoning skills as measured by the Raven's Standard Progressive Matrices (Raven, 1960), receptive vocabulary as measured by the Peabody Picture Vocabulary Test-Revised (Dunn & Dunn, 1981), reading comprehension as measured by the Reading Comprehension Subtest of the Stanford Achievement Test (Gardner, Rudman, Karlsen & Merwin, 1982), and spelling as measured by the Spelling Subtest of the Wide Range Achievement Test (Jastak & Jastak, 1978). Of note is the observation that only 3 subjects demonstrated reading skills at a fifth grade level or higher and spelling skills above the 25th percentile (Subjects 2, 3, and 9); the remaining 9 subjects demonstrated reading skills at an early third grade level or lower and spelling skills below the 1st percentile.

Materials

Six lists of 80 messages were prepared for use in the six experimental conditions in the study. Message lists were counterbalanced across the experimental conditions to control for potential list effects. The message lists were randomly selected without replacement from a pool of 590 different messages, formed from vocabularies actually used in augmentative communication systems for conversational purposes by physically disabled adolescents and adults with severe speech impairments. The selection of messages for each of the lists was random within the constraint that 40 messages in each list were rated as concrete and 40 were rated as abstract. Concrete messages were defined as those messages that involved a concrete object or activity (e.g., "I'd like a cup of coffee, please"; "I want to work on my computer"). Abstract messages were defined as those messages that did not involve concrete objects or activities and that involved abstract concepts (e.g., "That's not what I meant"; "I don't understand"). Interrater agreement (number of agreements divided by total number of agreements and disagreements) was calculated for the designation of concrete and abstract messages by the first author and a clinician with experience in augmentative communication for a randomly selected sample of 50 messages. Interrater agreement was found to be 92%.

For each of the messages in the six lists, a conversational context was developed to be used in the learning and testing sessions to cue recall of the targeted messages. Recall of the messages and their codes based on the cue of a conversa-

TABLE 1. Characteristics of the subjects.

Subject	Gender	Age	Diagnosis	AAC Systems	Access	Education/Vocation	Residence
1	M	23	Cerebral palsy spastic	Manual signs/gestures; Sharp Memowriter[1]	Direct selection with right index finger	Completed life skills program in special education class; Adult literacy program	Home with parent
2	F	30	Cerebral palsy athetoid	Alphabet Board	Direct selection with right index finger	Completed Grade 12 (some subjects in Grade 13); attended creative writing program at community college	Home with parents
3	M	28	Cerebral palsy mixed spastic athetoid	Alphabet Board	Direct selection with headstick	Completed Grade 9; vocational program in computer applications; currently employed	Apartment—independent living
4	M	28	Cerebral palsy, mixed athetoid and spastic	Blissymbol[2] Board	Direct selection with left index finger	Completed schooling in orthopaedic programs; currently attending an adult life skills program	Group home
5	M	35	Cerebral palsy spastic; mild hearing loss—left ear	Speech; Blissymbol[2] Board	Direct selection with right index finger	Completed schooling in orthopaedic programs; currently attending an adult life skills program	Group home (previously lived in an institution)
6	F	18	Cerebral palsy spastic; moderate high-frequency hearing loss—right ear	Speech; Signs/gestures; Blissymbol[2] Board	Direct selection with right or left index finger	Currently attends a special education life skills program in high school	Home with parents
7	F	32	Dystonia musculorum deformans	Alphabet/Word Board	Direct selection with supinated index finger or baby finger	No longer attending an educational program; completed some high school-level studies	Institution
8	F	22	Cerebral palsy mixed spastic and athetoid	Word Board	Direct selection with right index finger	Completed schooling in special education programs; currently attending an adult literacy program	Group home
9	M	27	Cerebral palsy	Speech; Oral spelling; Epson Speechpac[3]	Direct selection with right middle finger	Completed vocational program in computer applications; currently attending an adult literacy program	Group home
10	M	25	Cerebral palsy spastic	Speech; Oral spelling; Gestures	n/a	Completed schooling in orthopaedic programs; currently employed (part time)	Apartment—independent living
11	F	22	Cerebral palsy athetoid	Speech; Alltalk[4]; Word Board	Direct selection with headstick; listener-assisted scanning	Completed schooling in orthopaedic programs; currently involved in a vocational workshop program	Home with parents
12	M	26	Cerebral palsy athetoid	Speech; Oral spelling; Epson Speechpac	Direct selection with right index finger	Completed schooling in orthopaedic programs; completed vocational program in computer applications; not currently employed	Group home

Note. [1]Sharp Memowriter, no longer commercially available; [2]Blissymbols, available from Blissymbolics Communication International, 250 Ferrand Drive, Don Mills, ON, Canada M3C 3P2; [3]Speechpac/Epson, available from Adaptive Communication Systems Inc., Box 12440, Pittsburgh, PA 15231, U.S.A. [4]Alltalk, available from Adaptive Communication Systems Inc., Box 12440, Pittsburgh, PA 15231, U.S.A.

tional context was used in an attempt to replicate some of the demands of using message-encoding techniques within daily interactions. Two types of contextual cues were used: explicit contexts and oblique ones. Explicit contexts closely mirrored the form and content of the targeted message, while oblique contexts provided general semantic cues to prompt recall, but did not mirror the specific form or lexicon of the targeted message. For example, if the target message was "I want a cup of coffee," the explicit conversational context would be "You want a cup of coffee, so you say . . .," whereas the oblique context might be "It's coffee break and you are thirsty so you say . . ." Half of the messages had explicit contexts

TABLE 2. Nonverbal reasoning, receptive language, reading comprehension, and spelling scores for the subjects.

	Ravens		PPVT		SAT Reading		WRAT Spelling	
Subject	Raw	Percentile	Standard	Percentile	Scaled	Grade	Standard	Percentile
1	11	<5	70	2	576	Gr.2.8	60	0.8
2	36	25–50	108	66	674	Gr.8.3	114	82.0
3	32	10–25	78	7	665	Gr.7.5	91	27.0
4	25	<10	72	3	519	Gr.1.9	56	0.4
5	33	~25	<40	<1	528	Gr.2.0	53	0.1
6	25	<10	<40	<1	500	Gr.1.7	57	0.5
7	26	10–25	59	<1	590	Gr.3.1	61	0.9
8	24	<10	65	1	482	Gr.1.5	55	0.3
9	31	10–25	68	2	640	Gr.5.5	90	25.0
10	34	10–25	86	18	561	Gr.2.5	56	0.4
11	15	<5	75	5	528	Gr.2.0	55	0.3
12	40	25–50	99	48	584	Gr.3.0	57	0.5

(20 concrete messages and 20 abstract messages); the remaining half had oblique contexts. Interrater agreement was calculated for coding the contexts by the first author and a clinician experienced in augmentative communication for a randomly selected list of 80 messages and contexts. Interrater agreement was determined to be 95%.

For each message in the six lists, a two-element code was selected by an experienced clinician in the AAC field, according to the rules of each of the three message encoding techniques: Salient letter codes were based on the first letters of the salient words in the messages; letter category codes were based on the first letters of a category and a specifier as described by Fishman (1985) and Graff and Wotus (1985); and iconic codes were derived from the icons (see Figure 1) and the semantic associations for these icons described by Baker (1982, 1985, 1986). These predetermined codes were used within the nonpersonalized conditions in the study.

Procedures

Within each of the six experimental conditions, subjects participated in a series of six sessions: an introductory

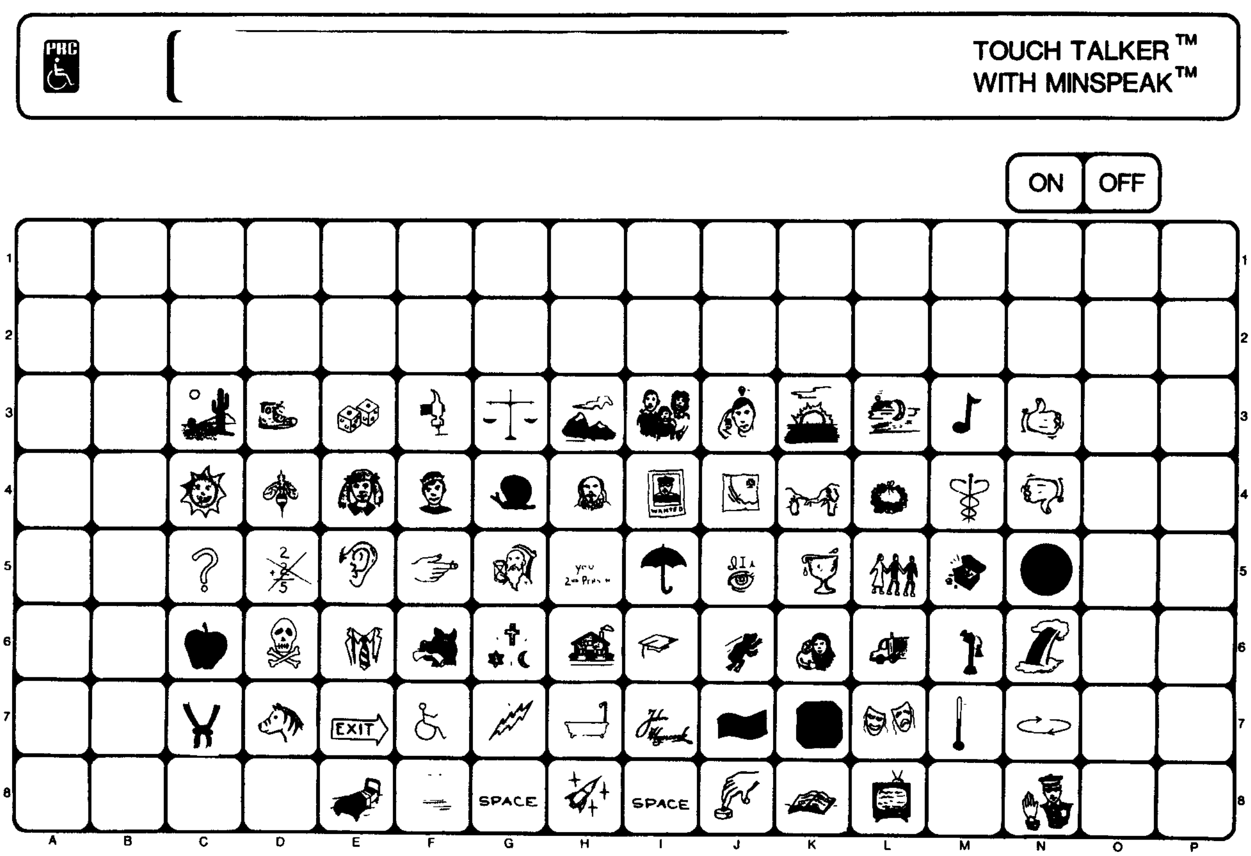

FIGURE 1. The overlay of icons used for the iconic encoding conditions.

session, four learning and testing sessions scheduled at 2–3 day intervals, and a final probe test conducted 1 week after the fourth learning session.

During the introductory sessions for each experimental condition, the encoding technique was explained to the subjects and the list of 80 messages was introduced. Within the nonpersonalized conditions, the subjects were also introduced to the two element codes (preselected by a clinician) required to retrieve the prestored messages from the voice output communication device. Within the personalized conditions, the subjects were asked to select appropriate codes for the 80 messages in the list based on the rules of the encoding technique under study.

During each of the four learning sessions in each experimental condition, the 80 conversational contexts (40 explicit and 40 oblique) were presented to the subjects orally, one at a time, in random order. The subjects were asked to enter the correct code into a preprogrammed computer-based communication device to retrieve the targeted message, which was then spoken out by the speech synthesizer. If the subjects correctly selected the targeted code and retrieved the intended message, the next conversational context was presented. If the selections made by the subjects were incorrect or if the subjects did not begin to respond within 30 sec, the targeted message and its code were presented orally to the subjects, the association between the message and code was reviewed, and the subjects were asked to select the correct code on the computer-based device.

One week after the fourth and final learning session in each of the conditions, a follow-up probe test (Session #5) was conducted to investigate the subjects' retention of the codes over a longer time period.

Measures and Data Analyses

The dependent measure in the study was the accuracy of code recall within the four learning sessions and the final probe test. Responses were considered to be correct if the subjects accurately selected the two-element code and retrieved the targeted message. Self-corrections that resulted in the final selection of the correct code sequence were also coded as correct, provided the correction occurred prior to the onset of the message spoken via the speech synthesizer. Responses were coded as incorrect under the following conditions: failure to begin to make a selection within 30 sec of the contextual cue, omission of one element in the two-element code, reversal of the elements in the code sequence, and/or selection of one or more elements that were incorrect.

Frequencies and proportions of correct responses for each of the subjects within the learning sessions and the final follow-up tests in each of the conditions were calculated. A within-subjects univariate analysis of variance[1] was conducted to test for the main effects and the interaction effects of the following within-subjects factors: (a) encoding technique (salient letter, letter category, iconic); (b) personalization of the codes (personalized or nonpersonalized); (c) message (concrete vs. abstract); (d) context (explicit vs. oblique); and (e) session (one to five learning sessions). The Greenhouse-Geisser correction was used in the univariate analysis to protect against the possibility of a positively-biased *F* test in the presence of any violations to the homogeneity of variances. Analytic comparisons of differences between the three encoding techniques were planned.

TABLE 3. Frequencies and proportions (in parentheses) of correct responses for the three encoding techniques.

	Encoding technique		
Subject	Salient letter	Letter category	Iconic
1	584.64 (.73)	276.14 (.35)	181.22 (.23)
2	644.22 (.81)	627.64 (.78)	525.14 (.66)
3	709.14 (.89)	566.22 (.71)	460.64 (.58)
4	392.64 (.49)	357.14 (.45)	414.22 (.52)
5	457.22 (.57)	422.64 (.53)	399.14 (.50)
6	259.14 (.32)	248.22 (.31)	204.64 (.26)
7	474.64 (.59)	419.14 (.52)	304.22 (.38)
8	315.22 (.39)	257.64 (.32)	219.14 (.27)
9	434.14 (.54)	387.22 (.48)	181.64 (.23)
10	423.64 (.53)	385.14 (.48)	338.22 (.42)
11	556.22 (.70)	459.64 (.57)	452.14 (.57)
12	526.14 (.65)	539.22 (.67)	461.64 (.58)
Mean	480.58 (.60)	412.17 (.52)	345.17 (.43)
SD	130.36	121.49	124.09

Note. Practice effects have been removed from this data matrix based on the Latin Square design as recommended by Keppel (1982). There were 800 potential responses in each of the encoding conditions.

Results

The main effect for encoding technique was statistically significant [$F(2,20) = 12.01$; $p<.01$]. As illustrated in Table 3, the mean accuracy of code recall for the group across the five learning and testing sessions was greatest for the salient letter technique (60% accuracy) and poorest for the iconic technique (43% accuracy). The main effect for context was also statistically significant [$F(1,10) = 218.86$; $p<.001$]. The subjects were more accurate recalling codes in response to the explicit contextual cues (59% accuracy) than in response to the oblique cues (44% accuracy).

[1]The validity of the within-subjects univariate analysis of variance rests on the assumption of equal variances of differences between each pair of treatments at all levels of the independent factors in the study. Violations to the assumption of the homogeneity of variances tend to produce positively biased *F* tests (Collier, Baker, Mandeville, & Hayes, 1967). There are two potential approaches to statistical analysis that address this problem: use of a univariate analysis of variance with a correction factor (Greenhouse Geisser correction) and use of a within-subjects multivariate analysis of variance. Finn and Mattsson (1978) and McCall and Applebaum (1973) have suggested that a univariate approach to the analysis of variance may be preferred because it offers greater power. O'Brien and Kaiser (1985) have argued, however, that given the difficulty of evaluating the assumption of homogeneity of variances and of calculating the appropriate correction factor, it is preferable to use a within-subjects multivariate analysis of variance that does not depend on this assumption. The data from this study were analyzed using both univariate (employing the Greenhouse-Geisser correction) and multivariate procedures. The pattern of results was similar across the two statistical approaches. Therefore, the univariate results are reported in the body of the text for ease of presentation. Where discrepancies exist between the multivariate and univariate findings, they are indicated.

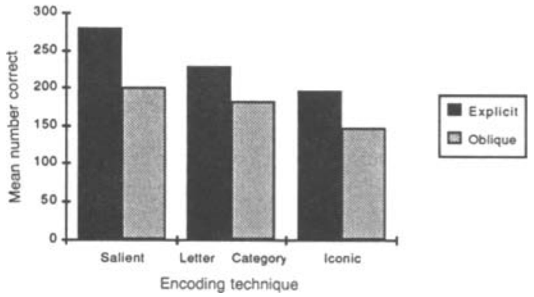

FIGURE 2. Mean frequencies of correct responses for the three encoding techniques in the explicit and oblique recall contexts.

It should be noted, however, that the main effects of encoding technique and Context were qualified by a statistically significant Encoding × Context interaction [$F(2,20) = 8.40$; $p<.01$]. As is apparent in Figure 2, performances with the three encoding techniques differed in degree, but not direction, depending on the type of contextual cue used to test recall. In the explicit contexts, analytic comparisons found that there were statistically significant differences between the salient letter technique and the iconic technique [$F(1,10) = 23.12$; $p<.01$], between the letter category technique and the iconic technique [$F(1,10) = 6.51$; $p<.05$], and between the salient letter technique and the letter category technique [$F(1,10) = 18.23$; $p<.01$]. In the oblique contexts, there were also statistically significant differences between the salient letter technique and the iconic technique [$F(1,10) = 7.32$; $p<.05$] and between the letter category and the iconic technique [$F(1,10) = 15.84$; $p<.01$]. There was no reliable difference, however, between the two-letter encoding techniques. Thus, regardless of the type of contextual cue used to test recall, the group results indicated that performance with the letter-encoding techniques was superior to the iconic technique.

The main effect for personalization was not statistically significant. The mean accuracy of code recall by the group was similar for the nonpersonalized codes (53%) and for the personalized codes (50%). (See Table 4.) The interaction between the factors of personalization and encoding technique was not statistically significant. There was no reliable difference in recall performance between the personalized and nonpersonalized conditions across the encoding techniques.

The main effect for message was statistically significant [$F(1,10) = 42.19$; $p<.001$]. The subjects were more accurate recalling the concrete messages (50% accuracy) than the abstract ones (43% accuracy). (See Table 5.)

As expected, the main effect for session was statistically significant [$F(4,40) = 166.44$, $p<.001$]. (See Table 6). Although there was variation across the subjects in their rate of learning, all of the subjects' performances improved across the first four learning sessions, with their performances leveling off in the final probe test that was conducted 1 week after the fourth learning session. The interaction between encoding technique and session was not statistically significant. Learning curves were parallel across the three encoding techniques (see Figure 3).

TABLE 4. Frequencies and proportions (in parentheses) of correct responses for the nonpersonalized and personalized codes.

Subject	Nonpersonalized	Personalized
1	484.96 (.40)	557.04 (.46)
2	901.96 (.75)	895.04 (.75)
3	859.96 (.72)	876.04 (.73)
4	643.04 (.54)	520.96 (.43)
5	659.04 (.55)	619.96 (.52)
6	414.04 (.35)	297.96 (.25)
7	683.96 (.57)	514.04 (.43)
8	405.96 (.34)	386.04 (.32)
9	557.96 (.46)	445.04 (.37)
10	552.04 (.46)	594.96 (.50)
11	729.04 (.61)	738.96 (.62)
12	757.04 (.63)	759.96 (.63)
Mean	637.42 (.53)	600.50 (.50)
SD	161.02	187.10

Note. Practice effects have been removed from this data matrix based on the Latin square design as recommended by Keppel (1982). There were 1,200 potential responses in the nonpersonalized and personalized conditions.

None of the remaining results were found to be statistically significant in both the univariate and multivariate analyses.[2]

Discussion

The Effect of Message Encoding Technique

The group results indicate that the codes in the letter-encoding techniques were recalled more accurately than the codes in the iconic technique, thus replicating the earlier results by Light et al. (1990). It is interesting to note that the letter codes were recalled more accurately than the iconic

[2]Three interactions were found to be statistically significant at the .05 level in the univariate analysis: Message × Session [$F(4,40) = 4.58$; $p<.05$]; Context × Session [$F(4,40) = 5.66$; $p<.05$]; and Encoding technique × Context × Session [$F(8,80) = 3.10$; $p<.05$]. It should be noted, however, that *none* of these interactions were found to be statistically significant in the multivariate analysis. Therefore, these results should be considered equivocal.

TABLE 5. Frequencies and proportions (in parentheses) of correct responses for the concrete and abstract messages.

Subject	Concrete	Abstract
1	530 (.44)	512 (.43)
2	952 (.79)	845 (.70)
3	889 (.74)	847 (.71)
4	726 (.60)	438 (.36)
5	816 (.68)	463 (.39)
6	467 (.39)	245 (.20)
7	729 (.61)	469 (.39)
8	496 (.41)	296 (.25)
9	586 (.49)	417 (.35)
10	710 (.59)	437 (.36)
11	832 (.69)	636 (.53)
12	881 (.73)	636 (.53)
Mean	717.8 (.50)	520.1 (.43)
SD	164.7	189.6

Note. There were 1,200 potential responses in the concrete and abstract conditions.

TABLE 6. Frequencies and proportions (in parentheses) of correct responses for the four learning sessions and the final probe test (Session 5).

Subject	Session 1	Session 2	Session 3	Session 4	Session 5
1	90 (.19)	153 (.32)	204 (.42)	282 (.59)	313 (.65)
2	254 (.53)	309 (.64)	384 (.80)	424 (.88)	426 (.89)
3	223 (.46)	313 (.65)	368 (.77)	410 (.85)	422 (.88)
4	132 (.28)	188 (.39)	237 (.49)	299 (.62)	308 (.64)
5	138 (.29)	192 (.40)	266 (.55)	332 (.69)	351 (.73)
6	71 (.15)	111 (.23)	138 (.29)	191 (.40)	201 (.42)
7	138 (.29)	204 (.42)	251 (.52)	292 (.61)	313 (.65)
8	106 (.22)	129 (.27)	157 (.33)	189 (.39)	211 (.44)
9	115 (.24)	177 (.37)	205 (.43)	250 (.52)	256 (.53)
10	117 (.24)	179 (.37)	240 (.50)	314 (.65)	297 (.62)
11	149 (.31)	237 (.49)	319 (.66)	375 (.78)	388 (.81)
12	186 (.39)	272 (.57)	328 (.68)	356 (.74)	375 (.78)
Mean	143.2 (.30)	205.3 (.43)	258.1 (.54)	309.5 (.64)	321.8 (.67)
SD	53.6	65.5	78.5	76.0	74.5

Note. There were 480 possible responses for each of the sessions (80 messages and codes for each of the six experimental conditions.) Learning sessions (1–4) were scheduled at 2–3 day intervals; the final probe test (Session 5) was scheduled 1 week after Learning Session 4.

codes by the group despite the fact that the majority of the subjects had severe impairments in their reading and spelling skills. Each of the encoding techniques is discussed below in light of the different code characteristics and linguistic processing demands in an effort to understand better the pattern of results observed.

Salient letter technique. As noted earlier, it has been argued that using the salient-letter encoding technique would necessitate recall of the exact content and syntactic form of the message (Musselwhite & St. Louis, 1988). If this were so, the technique would be expected to impose considerable memory demands because research indicates that recollections from long-term memory typically omit the details of form and condense the meaning of sentences (Sachs, 1967). In fact, subjects from this study did not seem to attempt to recall the full syntactic form of the messages. Rather, the subjects seemed to condense the messages into an abbreviated form that captured the semantic essence but omitted the irrelevant details. For example, the message "Let's go to the store" was condensed and remembered as the abbreviated message "Go store." The necessary codes to retrieve the messages from the computer-based communication system were then reconstructed by the subject by recalling the abbreviated message ("Go store") and selecting the first letters of the words in the abbreviated message (GS).

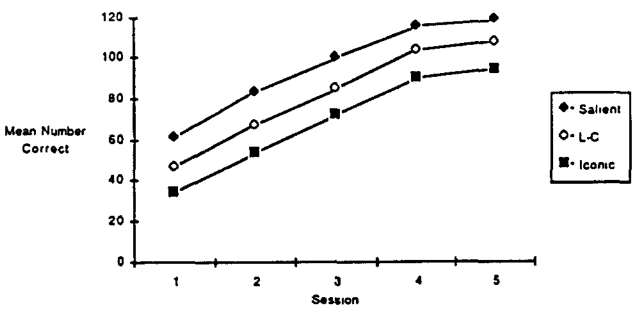

FIGURE 3. Mean frequencies of correct responses for the three encoding techniques across the four learning sessions and the final probe test (Session 5).

Recall performance was facilitated because the two-letter code was actually embedded in the abbreviated message and did not need to be recalled independently. The abbreviated message thus served as a more meaningful and functional memory unit than the letter code. Tulving and Thompson (1973) have argued that recall is greatly facilitated if relatively meaningless items to be remembered (in this case, the letter bigram "GS") are integrated into larger, more meaningful units (in this case, the abbreviated message "Go store"). The process of abbreviating messages may have been largely automatic for most of the subjects in the study, as persons using augmentative communication systems frequently use telegraphic messages in their daily communication (e.g., Calculator & Dollaghan, 1982; Harris, 1982; Light, Collier & Parnes, 1985b). Reconstructing the codes from the abbreviated messages did require *initial letter* spelling skills from the subjects and there was some evidence that spelling ability (as measured by the WRAT) was correlated with performance using the salient letter technique ($r = .57$; $p < .05$).[3]

Letter category technique. In the present study, the letter category technique was found to be superior to the iconic technique, but it did not achieve results superior to the salient letter technique. Theoretically, it would seem that the categorization of messages and codes, as in the letter category technique, should facilitate code learning and recall. In learning a categorical framework, the learner is encouraged to process and elaborate the messages and codes semantically. Craik and Lockhart (1972) and Craik and Tulving (1975) have noted that memory performance is greatly enhanced by such deep processing of the stimuli.

Based on this theory, it is surprising that the letter category technique did not outperform the salient letter technique. A number of factors may have limited full realization of the facilitative effects of categorization. The format of the learn-

[3]The correlation reported should be interpreted cautiously given the small group of subjects and the limitations to the range of achievement scores (i.e., the paucity of scores in the upper ranges).

ing and testing sessions may not have encouraged the subjects to attend to the categorical framework used. Target messages and codes were presented in random order. Subjects may have found it difficult to define category groupings clearly within the random presentations. It is possible as well that the categorical organization used in this study was not optimal. Recall performance might have been improved with a schematic organization as compared to the taxonomic one used. For example, Rabinowitz and Mandler (1983) found that subjects without disabilities recalled nouns and phrases more accurately when the lists were blocked schematically (e.g., groupings such as going to a party, going to a baseball game) than when the vocabulary was blocked taxonomically (e.g., groupings such as food, clothing, places). Future research is required to explore the efficacy of various organizations within "categorical" coding systems.

Finally, the higher-order rule system used to derive codes in the letter category encoding technique as compared to the salient letter technique may have been too complex for many of the subjects to master easily, thereby impeding recall efforts. Research with subjects without disabilities has suggested that the simpler the rule system governing the coding technique, the better the recall performance (Ehrenreich & Porcu, 1982; Hirsch-Pasek, Nudelman & Schneider, 1982; Streeter, Ackroff, & Taylor, 1983).

The categorical rule system did seem to offer the subjects two advantages in recall demands compared to the salient letter technique. The spelling demands of the former technique were slightly reduced because the range of key words in the codes was limited by the categorical framework. Secondly, the letter category technique allowed the subjects to attempt to reconstruct codes if they could not be recalled. These reconstructions depended on identifying the general content of the message; unlike the salient letter technique, they did not require recall of the form of the message, not even an abbreviated form.

Iconic technique. Recall performance with the iconic technique was worse than with the letter encoding techniques for the group of subjects. A number of factors inherent to the iconic technique may have hampered recall performance. Subjects may have had difficulty understanding the complex associations of the icon set used; representing specific concepts with icons (especially abstract concepts); transforming messages into iconic codes through verbal associations; chunking the two picture codes into a single, meaningful unit; and/or defining and recalling the icon associations consistently.

The group results clearly demonstrate that the letter encoding techniques were superior to the iconic technique. Further research is necessary to test the validity of the hypotheses proposed to account for the results.

The Effect of Personalization of Codes

Within the present study, there was no benefit found for personalized codes over nonpersonalized ones in the accuracy of code recall. Two theoretical constructs should be considered in attempting to explain this result: the generation effect and the effect of internal consistency. The "generation effect" is the term used to describe the superior performance found in the recall of items that are self-generated, as compared to items that are simply presented to subjects for learning (e.g., Gardiner & Hampton, 1985; Slamecka & Graf, 1978). These findings have been reported for a variety of stimuli including words and sentences. The recall advantage arising from the generation effect has been explained in various terms: the result of deeper linguistic and cognitive processing due to the task of generating the to-be-remembered items or the result of the initial retrieval of items from semantic memory during the generation of the to-be-remembered items (Slamecka & Graf, 1978). According to either of these hypotheses, one might have predicted a generation effect in the present study, leading to a recall advantage for the personalized codes that were self-generated. In fact, no evidence was found for superior recall for the self-generated codes as compared to the nonpersonalized codes.

These findings are probably best explained by the lack of internal consistency in the code selections made by the subjects. Although subjects were given a set of rules to follow in selecting their codes, these rules did not dictate a specific application; rather, they were open to the interpretation of the subjects. For example, in the letter category technique, the subjects were instructed to categorize the messages. How they applied this rule and defined category membership was left entirely to the subjects to determine by themselves. Research with persons without disabilities has found that subjects tend to select codes or abbreviations without recourse to consistent rules (Grudin & Barnard, 1985; Hodge & Pennington, 1973; Streeter et al., 1983). In fact, Streeter et al. (1983) concluded that personalized coding systems tended to be idiosyncratic, variable, and not particularly amenable to consistent rule-based definition. Setting up a coding system that is internally consistent requires considerable metalinguistic and metacognitive skill. The coder must be able to identify which features of the codes are most critical to control, develop specific rules to control these features within the broader rules of the coding system, apply the rules consistently in selecting the codes, and deal with any conflicts in coding as effectively as possible. The task may have been a formidable one for the subjects in the current study, most of whom had significant linguistic and cognitive impairments.

Thus, it seems that the recall advantage for the personalized codes that would have been predicted theoretically due to the generation effect may have been negated by the inconsistencies in the coding systems developed by the subjects. If this hypothesis is correct, then a "semi-personalized" coding technique should maximize recall performance. Such a semi-personalized technique would capitalize on client-generated associations, thus maximizing the generation effect, but at the same time coding would be structured by the clinician to ensure the internal consistency and logic of the system. Future research should be directed toward assessing the effectiveness of semi-personalized coding systems.

The Effect of Learning Trials

The accuracy of code recall improved on a consistent basis over the four learning and testing sessions in the present study.

A number of factors may have contributed to the improved recall performances over trials: the repeated exposure to the codes (cf. Rumelhart, Hinton & McClelland, 1986), the opportunities for additional processing and elaboration of the codes (cf. Craik & Lockhart, 1972), and the retrieval attempts on each learning trial (cf. McDaniel & Masson, 1985). Despite the evidence that learning did occur over the successive sessions in this study, there is no evidence that the learning that occurred was maximal. The instructional strategies used promoted improvements in recall performance, but it is possible that other instructional strategies would have led to even greater improvements in recall.

The results of the investigation of maintenance of code learning postintervention were generally positive. Although subjects made few gains from the fourth learning session to the final probe test 1 week later, they did maintain their levels of performance. There was no evidence in the study of significant "forgetting" of codes during the 1-week interval. Further research is necessary to consider the issue of long-term maintenance.

There was no interaction between the length of learning and the message-encoding technique used; rather, the gains made by the subjects over the five sessions were equivalent for the three encoding techniques. From the results of the present study, there is no reason to believe that the advantage of the letter encoding techniques over the iconic technique would not be maintained with ongoing instruction over continued learning sessions.

Although there was no variation in the slopes of the learning curves across the three message-encoding techniques, there was considerable variation in the rate of learning observed across the 12 subjects. The mean gain score for the group across the three techniques, from the first learning session to the fifth and final test, was an increase of 30 codes. Performances ranged from a mean gain of 18 codes for Subject 8 to a mean gain of 40 codes for Subject 11. Campione, Brown, and Bryant (1985) have argued that learning is dependent, at least in part, on the cognitive and linguistic abilities individuals bring to the learning task, especially their mnemonic strategies: ". . . an extremely important source of individual or comparative differences in associative memory tasks is the tendency and ability to bring to bear the kinds of simple mnemonic strategies necessary for adequate performance" (p. 114).

The Effect of Message Concreteness

The results of this study indicated that there was a statistically significant main effect for message concreteness. These results were in keeping with the earlier results reported by Light et al. (1990). The recall advantage for concrete items over abstract items found in these two studies is not surprising; in reviewing research from a variety of fields, Marschark, Richman, Yuille, and Hunt (1987) concluded that the "concreteness" effect is the most robust finding in the literature on memory. The recall advantage for concrete items over abstract ones is probably best explained by the effects of differential linguistic and cognitive processing of the concrete and abstract materials during learning. The specific mechanisms of this differential processing are not entirely clear. Johnson, Bransford, Nyberg, and Cleary (1972) suggested that concrete items are easier to comprehend than abstract ones, thus facilitating memory performance. Brown and Watson (1987) argued that concrete items tend to be acquired at an earlier age than abstract ones; since concrete items have been in the lexicon longer, they are easier to recall. Gernsbacher (1984) and Kroll and Merves (1986) explained that concrete items tend to be more familiar than abstract ones, thus learners have more experiential information related to concrete items to support the memory process. Schwanenflugel and Shoben (1983), Schwanenflugel, Harnishfeger, and Stowe (1988), and Wattenmaker and Shoben (1987) have all proposed that there is more contextual information available to support the memorization of concrete materials than abstract ones, thus accounting for the recall advantage observed. Within the present study, factors of message comprehensibility, age of acquisition, familiarity, and context availability were not controlled. Identifying the effects, if any, of these variables and further specifying the mechanisms accounting for the differential processing of concrete and abstract messages remains a question for future research.

It is apparent from the results of the present study, however, that the development of an effective encoding technique for a client extends well beyond the specific codes selected, and must also consider seriously the features of the vocabulary items to be selected and prestored. The results of the study indicate that recall performance depends not only on the codes selected, but also on the prestored messages. The clinical literature in the field of augmentative communication proposes the use of nonspecific phrases in communication devices, because these phrases permit a greater range of applications. However, from the present study and the earlier study by Light et al. (1990), it is apparent that the codes for nonspecific messages were more difficult to recall than those for concrete, specific messages. For some individuals, an overabundance of prestored messages that are abstract or nonspecific in nature may overtax their cognitive and linguistic processing and impair their communicative functioning. In order to maximize the client's recall of codes, careful consideration should be given to the concreteness of the messages selected as well as to a number of message factors such as the comprehensibility of the messages, the typical age of acquisition of the lexical item, and the context availability.

Conclusions and Future Directions

The problem of optimizing the rate of communication for physically disabled persons who use augmentative communication systems has confronted the field for many years. However, to date, there has been little empirically based information to guide in the understanding and application of message-encoding techniques as one potential solution to the problem of communication rate. The present study replicates the main findings of the earlier study by Light et al. (1990), and extends these findings by investigating the efficacy of encoding techniques with physically disabled adults with a range of language and literacy skills, by considering the impact of nonpersonalized and personalized codes and by assessing learning over a number of sessions with a fairly large corpus of prestored messages and codes.

The study raises a number of issues for future research: the use of encoding techniques with nonliterate people and with people with acquired communication disorders; the use of encoding techniques to retrieve words as well as full messages; the maintenance of code learning and generalization to communicative use in the natural environment; the efficacy of various instructional techniques to teach message codes; and the effect of semi-personalized coding techniques. Future research is required to address these questions so that we can extend our understanding of augmentative communication techniques and ensure that these techniques truly enhance the communication functioning of persons with severe communication disorders.

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