Development and Evaluation of the Expertise Module of a System for Training Teachers in Adapting Alternative Communication to Disabled Children

David Mioduser

Tel-Aviv University, School of Education
Ramat-Aviv, 69978, Israel
e-mail: miodu@post.tau.ac.il

Shoshi Waldman

Levinsky Teachers College, Meimad Center, Computers Division
15 Persitch st., Tel-Aviv, Israel.
e-mail: shoshi@levinsky.macam98.ac.il

Yeshayahu Neventzal

The Hebrew University of Jerusalem
Giv'at Ram, Jerusalem 91904
Israel

Final and edited version to be published in:
Innovations in Education and Training International

SUMMARY

The adaptation process of Alternative Augmentative Communication (AAC) systems to disabled children is an interdisciplinary and highly knowledgeable decision-making endeavor. The work reported here is part of a project aimed at creating tools for training teachers in the complex and delicate diagnostic and adaptation process of AAC systems. The first version of a computer system was developed comprising: (a) a declarative knowledge-base focusing on knowledge about cases (66 case-variables divided into seven data categories, e.g., type of impairment, cognitive performance, motor skills) and knowledge about AAC systems; (b) a communication module (built upon the case-variables) allowing the trainee to enter data about actual cases; and (c) procedural knowledge for generating communication-system-adaptation recommendations based on the actual data. The system was evaluated for fifteen real cases, by comparing its recommendations with human experts' recommendations. The computer system produced, for all cases but two, the same recommendations as the human experts did. In the two remaining cases the AAC system recommended as second priority by the computer system matched the recommendation of the human experts. An analysis of the cases showed that these two were transitional (different AAC systems fit for different reasons) and complex, and even then the system's reliable recommendations reflected the flexibility and sensibility of its knowledge-base and adaptation procedures. Based on these results our next goal is to add tutorial and coaching features to the system to be used in special education training programs.

DEVELOPMENT AND EVALUATION OF THE EXPERTISE MODULE OF A SYSTEM FOR TRAINING TEACHERS IN ADAPTING ALTERNATIVE COMMUNICATION TO DISABLED CHILDREN

"Y's voice": On August 13, 1987 Y's voice was heard for the first time. He was then thirteen years old. He delivered his Bar Mitzva address and oration, spreading through the Temple's space his computer generated speech. It was the third turning point in Y's long term battle to overcome his communication impairment: from conventional communication boards, to computer word processing, to speech synthesis.

"Y's story": Until he was 11 years old, no alternative communication system was adapted to Y. He is a severe physically impaired child unable to control both upper and lower extremities and to emit more than a few involuntary guttural sounds. But Y is also a highly motivated and bright child, and once was given the appropriate support and tools, his communication activities began to grow at an unexpected rate. Why did he have to wait until age 11 for that support? A crucial reason (even if not the only one) was that the persons surrounding the child lacked appropriate knowledge about alternative communication systems, and about the process of adapting these systems to the child. Even the transition towards an orthographic system was encouraged only by the communication clinician against the other specialists' opinion who insisted in the more traditional and widely used Bliss symbols system. The child's motivation, high cognitive abilities, and needs did not find an appropriate communication channel for a long time, due to decisions made without appropriate knowledge and without a systemic approach to the problem solution.

This case is one of many of children suffering from Cerebral Palsy, and who are unable to communicate verbally. The selection of alternative and augmentative communication systems is usually made by the interdisciplinary team in charge of the child, her family and, if possible, by the child herself. An inappropriate recommendation of a communication system might harm the child's motivation and willingness to use it, and to try alternative systems in the future. In contrast, a satisfactory selection propitiates the prospect of unveiling the child's cognitive abilities and communicative potential.

The adaptation process of alternative communication is a complex process (Owens and House, 1984; Shane, 1986). Many information items from varied areas should be considered, e.g., the nature of the impairment; motor, cognitive, and motivational parameters; relevant developmental data; the nature of alternative communication systems; and the child's past experience with AAC systems. The adaptation process is a multi-variables, interdisciplinary, systemic, and highly knowledgeable decision-making endeavor (Ratcliff and Beukelman, 1995).

In Israel only a few people possess such expertise, and a few specialized centers are able to support treatment teams with appropriate knowledge. Moreover, this expertise is the result of invaluable personal experience, existing more as an intuitive body of implicit knowledge rather than as a formally organized knowledge-base (Napper, Robey, and McAfee, 1989). A recently published report addresses similar trends in the United States (Ratcliff and Beukelman, 1995). The authors report on the gap between available expert resources and growing needs, the lack of appropriate training (e.g. clinical clock hours, acquaintance with devices and technologies) in preprofessional programs, and lack of interdisciplinary components in these programs. The immediate consequences of this state of things are twofold. At the training level, there are serious difficulties in transmitting to novices the partially intuitive and non formally defined body of knowledge, as well as a multidisciplinary approach to AAC. At the practice level treatment teams depend highly on a few experts, who in return are unable to attend to all their requests.

The work reported here is part of an ongoing project aimed at creating effective tools for training teachers and clinicians in the complex and delicate diagnostic and adaptation process. This first stage of the project represented an attempt to deal with the definition, formalization and supply of knowledge related to the adaptation of alternative communication systems, by means of a computer decision support system. Our two main objectives were:

(a) To develop the expertise module of a training system which generates recommendations of communication systems for specific cases.

(b) To test the reliability of the recommendations generated by the computer system, by comparing them to decisions made by human experts about the same cases.

Based on the results of this first stage, our long term objective is to complete the system adding tutorial and coaching features, to be used as teaching tool in special education training programs.

DEVELOPMENT OF THE EXPERTISE MODULE OF THE "AACom" SYSTEM

The "AACom" system development follows the configuration and methodology that characterizes the construction of knowledge-based learning environments (Wenger, 1987). The accepted architecture of such systems comprises four main modules of expertise. The first is domain expertise, allowing the system to perform as an expert in a particular domain. The second is diagnostic expertise to asses the trainee's performance and knowledge-state at any given point in the tutorial interaction. The third is teaching expertise, focusing on instructional strategies and methods consistent with the instructional goals. The fourth are communication features of the system, enabling appropriate user/system interactions and knowledge conveyance.

The "AACom" system's first stage of development was aimed at creating reliable expertise about the diagnostic and adaptation process of AAC systems, as an essential pre-requisite for the further development of training and tutorial features.

At this stage the system comprises two main modules: The knowledge-base and the communication module. In the following sections these two components will be described.

The knowledge-base

The knowledge-base contains all the declarative and procedural knowledge required to process a case and generate appropriate recommendations (Clancey, 1987). The declarative knowledge focuses on two main topics: knowledge about a case and knowledge about alternative communication systems.

The knowledge about a case was defined as a set of 66 case-variables, as shown in Figure 1. The variables set was divided into seven data categories. The first two categories refer to general information about a case, her/his impairment, and past experience with Alternative Augmentative Communication (AAC) systems. The remaining five categories focus in detail on the case's behavior, motor skills, cognitive and psychomotoric performance.

Insert Figure 1 about here

For each variable a set of possible values was defined. Figure 2 shows the set of values for the variables "Location of handicap" (six values) and "Language disorders" (five values) . For the 66 case-variables a total of 268 values were defined. The complete set of variables form the generic shell for the description of any given case. A specific case description results from assigning to each variable one of its possible values (the procedure by which the user defines a specific case will be described in a later section).

Insert Figure 2 about here

The next component of the knowledge base focuses on AAC systems. Many different systems are in use all over the world. Some systems are based on the use of body, face and hand gestures. Other use different representational means such as models, pictures, or the regular alphabet. Nowadays computers contribute to the enrichment of the repertoire of AAC tools .

Computer technology affects the development of AAC tools in two ways. The first by creating computer versions of methods already in use upgrading them by means of the features and unique qualities of the new technologies. The second way is the creation of new tools and aids, such as text-to-speech, digital speech and synthesized speech software and devices. Good quality synthesized speech may contribute in significant ways to improve the communication performance of disabled persons, bringing the communication situation closer to normal. Several studies were conducted to evaluate the contribution of different properties of synthesized voices to communication intelligibility (e.g., Venkatagiri, 1991; Rupprecht, Beukelman, and Vrtiska, 1995;

Scherz, and Beer, 1995; Reynolds, Bond, and Fucli, 1996). Synthesized speech for the Hebrew language is currently only under development, and other alternatives are being considered such as the use of data-bases of digitized speech. The shortcoming of this method however is that being based on a repertoire of given items, it does not allow enough flexibility to accommodate to the varied expressive and communication needs of the users (Todman, Elder, and Alm, 1995).

In developing our system we have considered seven AAC systems commonly in use in Israel, namely, Objects, Photos, Picture Communication Symbols (PCS), Bliss, Orthography, Gestures, Sign Language. Let us describe briefly these communication methods.

Real objects as well as sets of models of objects may serve as communication means. Communication proceeds by pointing at an object or its model either to refer to its direct meaning (e.g., a door or a bed) or to convey an additional meaning (e.g., to go out, to sleep).

Another method is based in the use of photos (or pictures) to represent objects or concepts. These can range from hand-made pictures generated ad-hoc during the communication act, (thus allowing highly individualization) to conventional sets of printed cards or boards (Clark, 1981).

Picture Communication Symbols (PCS) is a communication set containing pictographic items (representations of object forms) and ideographic items (representations of concepts or ideas). All items are created using simple and clean line drawings.

The Bliss symbols system comprises pictographic, ideographic and arbitrary (but conventional) representational items. Items are built from a reduced set of basic forms.

Size and location relative to other symbols are of significance. New configurations can be created by the user to convey new meanings. By these features the Bliss set can be seen as midway method between the limited nature of a closed pictographic system and the complete flexibility of an alphabetic system (McNaughton, 1980).

Orthography is the basic method used in our culture to generate written communication. It is generic, highly abstract, modular and widely accepted as one of our cultural foundations. It takes different forms to adapt to the needs of different users (e.g., Braille or Morse). But it is also very demanding for people with cognitive or functional impairments (e.g., less able to deal with abstractions or not able to hear the phonetic representation of the written word).

Gestures are conventional body expressions. They fulfill communication functions on the basis of the common cultural background of the dialog partners. Gestures range from using head movements to signal yes or no responses to questions, to whole body mimicry (Vanderheiden and Lloyd, 1986).

Sign Languages are a combination of conventional hand movements, face and body gestures, and features such as pace and extension of the sign. In most cases there is a referential association between the sign and the represented concept or object. Sign languages are not mimicry translations of the spoken language: they have their own vocabulary and syntax. Natural sign languages were developed in different countries, and very often similar signs have different meanings in different locations.

For each communication system, a relevance-index was defined for every value of the case variables. The question asked was: "How relevant is the use of system x by a child showing condition y for variable z?" (e.g., How relevant is the use of Bliss symbols by a case for whom the value ataxia was defined for the variable Neuromuscular classification?). For a total of 268 values (of 66 variables), the relevance-index table for the seven AAC systems was generated. The relevance-index was set in a scale from '0' to 8, indicating total rejection or total acceptance of a given system for a given variable value. The seven indexes in between indicate different levels of appropriateness or applicability of the system, namely, "not recommendable", "hardly appropriate", "almost inapplicable", "applicable with difficulties", "consider for application", "applicable", "appropriate". A section of the relevance-index table for the values of the variable "Grammar structures" (category "Communication functioning") is shown in Figure 3.

Insert Figure 3 about here

The whole declarative knowledge-base is organized as a semantic network (e.g., Brachman, 1979). A schematic representation of the network is shown in Figure 4. The case-variables are linked to their category node, and to their values. Each value is linked by a relevance-index link to each of the seven communication systems.

Insert Figure 4 about here

The knowledge base is completed by procedural knowledge for testing the adaptation of AAC systems to a given case, and for generating the recommendation list of the three systems (in order of appropriateness) which appear to be the reasonable choices for the case.

An example of the adaptation process is shown in Figure 5. The adaptation mechanisms retrieve the pertinent relevance-index of each AAC system for each variable value defining the case (Figure 5 shows the retrieved relevance-indexes for the variables in the category “Communication functioning”). Next the total weight of each system for each of the seven categories of variables is computed. Finally the overall value of each communication system for the case is computed. Figure 5 shows the two systems (in order of appropriateness) recommended for the case considered. As a result of varied considerations and judgments (embedded in the computation procedures), some communication systems are discarded along the adaptation process. For that reason a “zero” appear as the value for some of the AAC systems, provoking their final rejection.

Insert Figure 5 about here

The Communication Module

The communication module takes the form of a diagnostic questionnaire. The diagnostic questionnaire is the tool used by the clinician or trainee to feed the case data into the system. Filling in the questionnaire means to define a specific value for each of the 66 case-variables. The user interface follows the filling card metaphor. This interface has the advantage of being a format with which the user is already used to (from commonly used paperwork), and at the same time fits perfectly the frame-like representation of the knowledge in the system.

The clinician is asked to fill in seven cards (or frames), one for each category of variables. Clicking on each variable opens a pop-up menu showing the possible values for that variable (Figure 6). The selected value will become part of the frame, as part of the instantiation process of the specific case information.

Insert Figure 6 about here

The case instantiation process in our system differs from the way it is performed in commonly used rule-based-systems interfaces. In those systems the user is asked to enter information for one question at a time, while the inference mechanism runs (e.g., see Napper et al., 1989). Each interaction is local, focused on a given question or issue, being difficult for the user to go back and review previous answers, or to get an overall picture of the ongoing process. In “AACom” we have separated the case instantiation stage from the adaptation stage, offering to the user the possibility to work back and forth on the case definition, and review the entries over the seven case cards.

Method for developing the system

The development of the system followed the methodology in use to build diagnostic expert and decision support systems (Waterman, 1986; Rolston, 1988; Luger, 1989). We also rely on the experience accumulated in the development of expertise-based training systems (e.g., Clancey, 1987; Hile et al., 1994; Mioduser and Margalit, in press). The first step was the definition of the knowledge base. First we developed a preliminary version of the set of case-variables and the relevance-indexes of the seven AAC systems for each variable. The resources for the definition of the variables were diagnostic models developed at research or treatment centers (e.g., Shane, 1980; Haney and Cangas, 1987) and accumulated knowledge at Israeli treatment centers. This first version of the variables set was submitted to six experts and leading researchers in the field in Israel and abroad for review and evaluation. The experts’ comments, suggestions and modifications were included in the final version of the 66 case-variables and the relevance-index table.

It should be noted that the current version of the computer system includes data about the seven AAC systems frequently in use in Israel. But given that the basic computational and data storage modules are generic, the knowledge-base can be easily expanded to include additional AAC systems. The key part of the process is the indexation of the features of each additional system for the 66 case-variables (following the procedure mentioned above in the section describing the knowledge-about-AAC-systems module). The new data is then added to the relevance-index table to be used by the existing adaptation-computing procedures to generate recommendations.

For the development of the computer system we used a modified version of the "Knowland" shell (Mioduser, 1990), an educational tool allowing the creation of frame-based knowledge representations. The system was supplemented with the routines needed to perform the adaptation process, and generate the recommendations list.

EVALUATION OF THE "AACOM" SYSTEM

Our second goal for this stage of the project was to test the reliability of the recommendations generated by the computer system, by comparing them to decisions made by human experts about the same cases.

We fed the computer system with data about fifteen cases, 2 to 16 years old children suffering from Cerebral Palsy who are unable to communicate verbally. All children are treated by expert teams in specialized institutions in Israel. All but one learn in special education schools. Each child presents a specific and different kind of communication impairment.

The data for each case was extracted from the children's file, and fed into the computer system following the format of the diagnostic questionnaire. In addition, the expert teams' recommendations of AAC systems adaptation for each case was summarized.

RESULTS

The recommendations generated by the computer system appear in Table 1. For 13 cases about three to four systems were recommended, with different recommendation values. For case #14 only one system was recommended. For case #3 only two systems were recommended, receiving very close recommendation values. For case #13 two systems were recommended as first priority, receiving the same recommendation value. For most cases about three to four systems were totally rejected.

Insert Table 1 about here

The differences in recommendation value between the first and secondly recommended system appear in the last column of Table 1. The differences range between 1 and 45 (for case #14 only one system was recommended).

Table 2 shows the comparison between the computer generated recommendations and the human experts' recommendations. For thirteen cases the system's recommendations were identical to the human experts' recommendations. For the two remaining cases the secondly recommended system was the same as the one recommended by the human experts. The only system recommended for case #14 by the system was also the system adapted for him by the expert team. Similarly, for case #13 a conjunction of two systems was recommended both by the computer system and the human experts.

Insert Table 2 about here

DISCUSSION

The results show that the computer system produced for all cases but two the same recommendations for adapting an AAC system to a child as the human experts did. But even in the two remaining cases the secondly recommended system matched that of the human experts. As for the set of fifteen cases included in this study, the systems performance can be considered highly reliable.

Moreover, the results highlight some additional issues. One is related to the difference in recommendation value between the first and the secondly recommended system. For five cases the difference was less than five points. This may be seen as a quantitative expression of the child's state regarding her current communication performance and needs. Minor differences indicate transitional stages, where changes in the child's (cognitive, emotional, motivational, motoric, etc.) state will justify the consideration of a different AAC system. It is highly conceivable that repeating the diagnostic and adaptation process a few months later could result into different recommendations for the case.

Another issue to be discussed relates to the two cases for whom the secondly recommended system matched the human experts'. We interviewed the experts treating these cases about the results, and they offered two comments. The first was that they considered very reasonable the computer generated system recommendation, fitting the overall conditions and needs of the children. Second, they mentioned that these are very problematic cases. The actually chosen AAC system has not proven yet to function according to the expectations, and the evaluation of its appropriateness for the child is still in process. In relation to the previous issue, it should be noted that the difference in recommendation value between the first and second system was minor (2 or 3 points), indicating again that the computer knowledge-base holds a reasonable degree of flexibility and sensibility even about cases whose profile could not be strongly defined.

A third issue relates to the definitely rejected systems (the "zero" systems in the recommendation table). Also about this issue the human experts' consented that the elimination of these systems fitted the cases' diagnostic data.

Completing the discussion we will present a fine-grained analysis of some of the more problematic cases already mentioned.

<u>Case #13: Two AAC systems were equally recommended as first priority</u>.

Two systems were equally recommended for this case: "Photos" and "PCS". As mentioned, the clinician told us that the child is currently in a transitional stage, using in fact both systems. The clinician sustains that there is evident gap between the child's poor performance and his cognitive potential, pointing at serious emotional and family problems as factors for this gap. A close examination of the diagnostic data however unveils some aspects that contradict the clinician's appreciation. Data regarding cognitive variables show, for example, that for the aspect "Expressive language for basic concepts" the child performs below his chronological age; for the aspect "Visual recognition of symbols" the child performs poorly; as well as for the aspect "Auditory discrimination of phrases". Considering only these and other data related to the <u>cognitive</u> and <u>general behavior</u> categories, the computer system's output indicated the lower level system (photos) as first priority (Table 3).

But the data for the case's general information variables (e.g., chronological age, type of impairment, institution at which he studies and is being treated) counterbalanced the previous picture indicating that PCS, an higher level system, can be considered as suitable alternative (as the clinician suggests).

This case exemplifies how different standpoints in the analysis of the case's data may lead to contradictory recommendations (and decisions): on the basis of factual general information (e.g., chronological age) the PCS system appears to be appropriate; in contrast cognitive and functional data indicated that the lower level system (photos) is the best alternative. The reasons for these recommendations, or in other words the factors affecting the differential ranking of AAC systems by the computer system, can be easily traced in the computer representation of the case. Thus as consequence of her participation in this study the clinician, who made her previous decisions based on a combination of objectively observed and intuitive data, had the opportunity to reflect on the case once again, this time against the background of the whole set of variables as stored in the knowledge-base and the recommendation-values table in the system's output. The system's knowledge base and output supported a better grounded discussion of the diverse factors and child's needs affecting the transitional stage under consideration.

Insert Table 3 about here

Case #8: The secondly recommended AAC system matched the clinician’s.

The system’s first recommendation for this case was “Photos”, while the child actually uses “PCS”. That means that according to the computer output the child should use a lower level system. Discussing the case with the child’s clinician she reported that the child’s use of the communication board (for the higher level system) is not too sophisticated, limiting herself to the automatic use of a reduced set of symbols. The child recognizes concrete symbols, but shows problems with verbs. She has also problems in coping with a number of stimulus items at a time in her communication board. And despite the length of the treatment (several years so far) and the child's family intensive support, her vocabulary (and hence its representation in the communication board) grows at a very slow pace. The team is considering now the inclusion of concrete pictures in her board (components of the lower level system), and to concentrate their effort in supporting the development of grammatical constructs. .

A review of the diagnostic data shows which variables-sets contributed most to the recommendation of the photos system: these were behavioral variables (e.g., frequent need for reinforcements, tendency to passiveness); cognitive variables (e.g., difficulties in linking words to express an idea, in creating sequences); and communication variables (e.g., receptive language lower than chronological age). Following the computer system results, the issue of giving a lower level communication system to the child was discussed with the treatment team. The idea considered was that lowering the cognitive demands implied in working only with symbols (as in PCS) could enrich the repertoire of words used, enable the formation of grammatical constructs, and improve the child's motivation. Even though the clinician is currently working on grammatical constructs using the PCS system, the extension of the vocabulary available to the child in it is far less rich than that available by the use of photos. An increase in the amount and content-variety of words could positively affect the child's expressive work, involvement and motivation.

From both cases becomes evident the potential of the computer system as a reflection and analysis tool for the clinicians, and eventually for teacher students and trainees. This due to the “transparency” of the data for all variables at the seven categories, and to the possibility to analyze not only the final recommendations but the quantitative adaptation results for each category by each AAC system.

CONCLUDING REMARKS

The work reported here had as its first objective to develop the expertise module of a computer system aimed at training teachers and clinicians in making decisions about adapting Augmentative and Alternative Communication systems to disabled children. The main problem we attempted to deal with is that (a) a great deal of interdisciplinary knowledge is required to accomplish such a delicate process, while (b) that knowledge resides almost exclusively in specialized institutions, mostly in the form of intuitive knowledge and non formalized accumulated experience. The implications are lack of appropriate knowledge at the school level or by remotely located clinicians, and difficulties in transmitting this knowledge to novices or teacher students.

The development of such an expertise module should meet at least two important conditions: to be comprehensive regarding its diagnostic and adaptation knowledge-base, and reliable in its recommendations. About the comprehensiveness of the knowledge base, a huge effort was invested in gathering, summarizing, devising and evaluating the set of case variables and AAC systems knowledge included in our system. The result is the 66 variables (and their 288 possible values) comprising the case description, and the detailed relevance-index table linking each of the seven systems to all the variable values.

As for reliability, the computer generated recommendations regarding fifteen real cases were compared with human experts recommendations, and the results were highly encouraging. A more detailed analysis of the results for the different variable categories in dialog with the expert clinicians, gave us important indications about the sensibility and flexibility of the “AACom” system.

As already stated in the introduction, the work reported here was the first stage of our project. The continuation will take place in two tracks. The first is the refining and completion of the actual system. For example, given aspects of the adaptation mechanisms should be further refined to allow a “fine-grain” analysis of doubtful results (e.g., too close recommendation values for a number of recommended systems). As part of the refinement process the running of more and diverse cases is needed, to test the system’s results in the widest possible range of situations.

The second track for continuing the development focuses on training features. A long term objective is for the system to be used in teacher colleges, or special education institutions as an aid to train teachers and clinicians. This means to add to the system appropriate tutoring features. In one aspect the tool as it is could serve the objective. As it happened during this stage of the work the system served as reflection and analysis aid for our discussions with the clinicians. In the same way it could be used already in its present form with novices and students. We have already started however with pilot tutoring sessions at which novices work with the computer system, on our way to define the required tutoring components to be developed (e.g., coaching on the diagnostic process; promoting the acquaintance with the comprehensive set of variables; generating explanations about adaptation considerations, “help” and glossary features; definition of an appropriate and representative cases bank; definition of instructional sequences).

Finally, we hope that this work contributes to elucidate some issues regarding the use of information technologies for dealing with complex areas of knowledge and decision making for educational purposes. Diagnostic and adaptation of Alternative Communication systems is a complex and knowledgeable process, based on gradual accumulation of knowledge and experience by clinicians and experts. Our project is aimed at providing support to experts, trainers and trainees in their delicate task to improve the prospects of better communication performance of disabled children.

REFERENCES

Brachman, R. J. (1979) On the epistemological status of semantic networks. In Findler, N. (ed.) Associative networks: Representation and use of knowledge by computers. Academic Press, New York.

Clancey, W. (1987) Knowledge-based tutoring. MIT Press, Cambridge, MA.

Clark, R. (1981) Learning words using traditional orthography and the symbols of Rebus, Bliss and Carrier. Journal of Speech and Hearing Disorders, 46(2), 191-196.

Haney, C. A., and Kangas, K. M. (1987) The assessment and evaluation of clients for Augmentative Communication systems: The Pennsylvania model. Pennsylvania Special Education Assistive Device Center.

Hile, M.; Campbell, D.; Ghobary, B., and Desrochers, M. (1994) Reliability of an automated Decision Support System for behavioral treatment planning: Preliminary results from the Mental Retardation-expert. Computers in Human Services, 10(4), 19-29.

Luger, G. F., and Stubblefield, W. A. (1989) Artificial Intelligence and the design of expert systems. Benjamin/Cummings Publishing Company, Redwood City, CA.

McNaughton, S. (1980) The application of Blissymbolics. In Schiefelbush, R. (ed.) Nonspeech language and communication: Analysis and intervention, University Park Press, Baltimore.

Mioduser, D. and Margalit, M. (In press). TTIPSS - a Computer-Based system for Training Teachers' Problem Solving and Educational Planning with Behavior Disordered Children.

Mioduser, D. (1990) Student representations of declarative and procedural knowledge. Unpublished doctoral dissertation, Tel-Aviv University.

Napper, S. A., Robey, B. L., and McAfee, P. H. (1989) An expert system for use in the prescription of electronic Augmentative and Alternative Communication devices. Augmentative and Alternative Communication, 5(2), 128-136.

Owens, R. E., and House, L. I. (1984) Decision-making processes in augmentative communication. Journal of Speech and Hearing Disorders, 49, 18-25.

Ratcliff, A. and Beukelaman, D. (1995). Preprofessional preparation in Augmentative and Alternative Communication: State-of-the-art report. Augmentative and Alternative Communication, 11(2), 61-73.

Rolston, D. W. (1988) Principles of Artificial Intelligence and expert systems development. McGraw-Hill, New York.

Shane, H. C. (1980) Approaches to assessing the communication of non-oral persons. In Schiefelbush, R. L. (ed.) Nonspeech language and communication: Analysis and intervention. University Park Press, Baltimore.

Shane, H. C. (1986). Goals and uses. In Blackstone, S. (ed.) Augmentative communication: An introduction. American Speech-Language-Hearing Association, Rockville, MD.

Vanderheiden, G., and Lloyd, L. (1986) Communication systems and their components. In Blackstone, S. (ed.) Augmentative communication: An introduction. American Speech-Language-Hearing Association, Rockville, MD.

Waterman, D. A. (1986) A guide to expert systems. Addison-Wesley, Reading, MA.

Wenger, E. (1987). Artificial intelligence and tutoring systems: Computational approaches to the communication of knowledge. Morgan Kauffman, Los Altos, CA.

Scherz,J. and Beer, M. (1995) Factors affecting the intelligibility of synthesized speech, Augmentative and Alternative Communication, 11(2),74-78.

Todman, J., Elder. L., and Alm, N. (1995) Evaluation of the content of computer-aided conversations, Augmentative and Alternative Communication, 11, 229-234.

Rupprecht, S., Beukelman, D., and Vrtiska, H. (1995) Comparative intelligibility of five synthesized voices, Augmentative and Alternative Communication, 11, 244-247.

Venkatagiri,H. (1991) Effects of rate and pitch variations on the intelligibility of synthesized speech, Augmentative and Alternative Communication, 7, 284-289.

Reynolds,M.E., Bond,Z.S., and Fucli, D.(1996) Synthetic speech intelligibility: comparison of native and non-native speakers of English. Augmentative and alternative communication, 12 ,32-36.

FIGURE CAPTIONS

Figure 1 The diagnostic variables

1. **<u>Case</u>** Age Neuromuscular classification Handicap location Muscle's tone Vision Language disorders Mental retardation Motivation Educational institution 2. **<u>AAC use in the past</u>** AAC system Period of usage Reason for interruption	3. **<u>Gross motor</u>** Body performance Range of hand motion Crossing of middle line Sitting Mobility and environment 4. **<u>Fine motor</u>** Hands' activation Hand's tone Fingers' separation Pencil holding Coordination 5. **<u>Communication behavior</u>** Motivation Initiates interaction Responds to interaction Means for yes/no responses Communication mean Current communication system Level of receptive language Level of expressive language Length of message Grammar structures Interaction with peers Asks questions Requests clarifications	6. **<u>Cognitive and psychomotoric functions</u>** Psychomotoric ability Receptive language for concepts Expressive language for concepts Expressive language for spatial concepts Visual memory Visual recognition of people Visual recognition of objects Visual recognition of photographs Visual recognition of pictures Visual recognition of symbols Auditory discrimination: sounds Auditory discrimination: words Auditory discrimination: phrases Auditory memory: words Auditory memory: sentences Follow simple directions Word recognition Symbol chunking Sequencing World recognition 7. **<u>Behavior</u>** Independence Exploration Need of reassurance Acceptance of new tasks Resistance to new tasks Fears changes Ease to frustrate Aggressiveness Passiveness Eager to interaction with adults

Figure 2: Values for the variables “Location of handicap” and “Language disorders”

<u>Location of Handicap</u>	**<u>Language Disorders</u>**
- Hemiplegia	- Anartria
- Paraplegia	- Aphasia
- Monoplegia	- Apraxia
- Diplegia	- Disartria
- Triplegia	- Dispraxia
- Quadroplegia	

Figure 3 Relevance-index table for the values of the variable “Grammar structures” from category “Communication functioning”

Category:
Communication functioning
Variable:
Grammar structures

Values for the variable	Relevance-index for each method						
	Objects	Photos	PCS	Bliss	Orthography	Gestures	Sign language
None	8	8	8	6	4	8	4
Two subjects	8	8	8	8	4	8	8
Verbs	8	8	8	8	4	8	8
Subjects and Verbs	6	8	8	8	8	8	8
Complex structure	0	2	8	8	8	2	8

Figure 4 Schematic representation of a section of the frames network

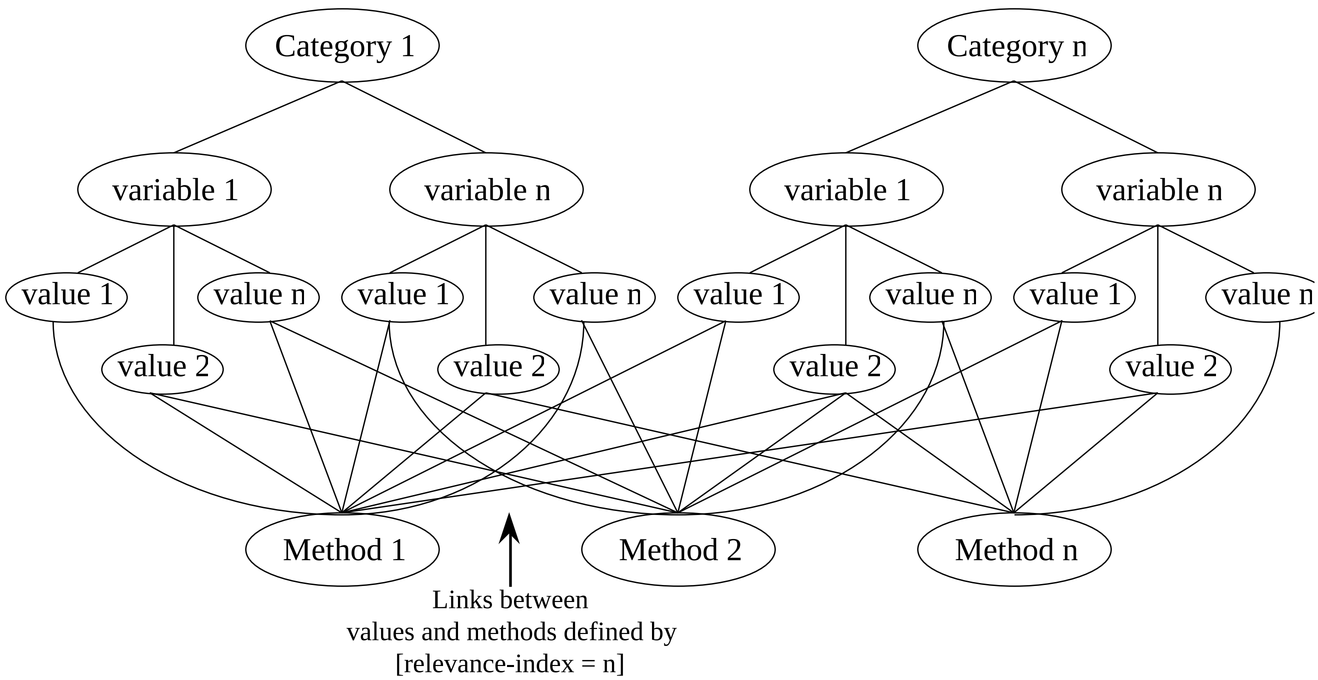

Figure 5 Output of the adaptation procedure for the category “Communication functioning” for case # 1

Case # 1

Category:
Communication functioning

Variables	Values for case #1	Objects	Photos	PCS	Bliss	Orthography	Gestures	Sign language
		Relevance-index for each method						
Motivation	Yes	8	8	8	8	8	8	8
Initiates interaction	Ocassionally	8	8	8	8	8	8	8
Responds to interaction	Allways	8	8	8	8	8	8	8
Means for yes/no responses	Shakes head	8	8	8	8	8	8	8
Communication mean	Communication board	0	8	8	8	8	6	6
Current communication method	Orthography	8	8	8	8	8	8	8
Level of receptive language	Fitting chronologic age	8	8	8	8	8	8	8
Level of expressive language	Lower than chronologic age	8	8	8	6	5	8	7
Length of message	Sentences	0	6	8	8	8	8	8
Grammar structures	Complex	0	2	8	8	8	2	8
Interaction with peers	Occasionaly	8	8	8	8	8	8	8
Asks questions	Occasionaly	8	8	8	8	8	8	8
Requests clarifications	Frequently	8	8	8	8	8	8	8
Recommendations for this category		0	96	104	102	101	96	101

Figure 6 “AACom” case-definition interface - example of value specification for a variable

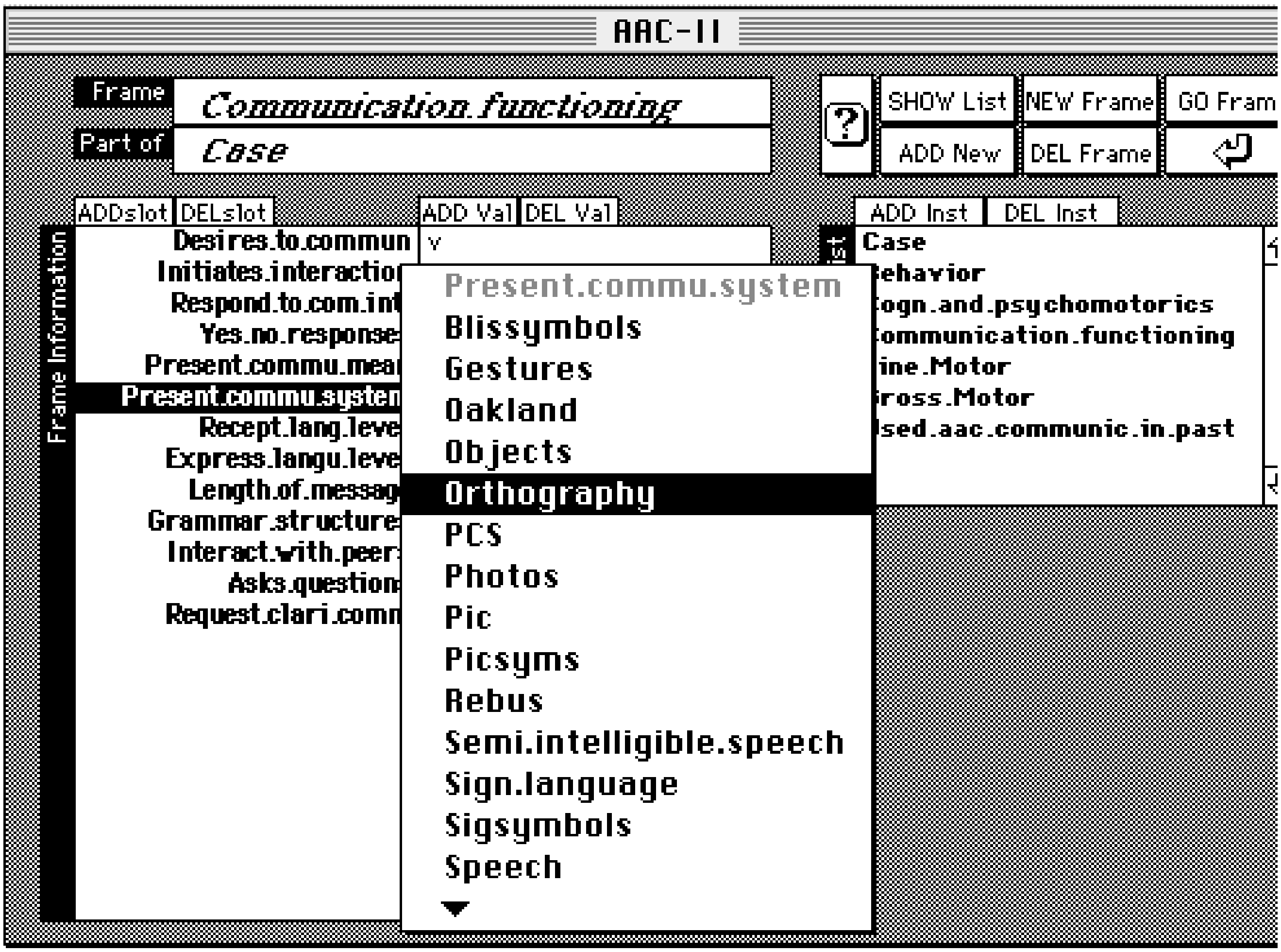

Table 1 System's recommendations of AAC systems for each case

Case	Objects	Photos	PCS	Bliss	Ortho-graphy	Gestures	Sign Language	(1st-2nd) systems
1	0	584	623	617	628	0	0	5
2	0	0	597	586	591	594	0	3
3	520	519	0	0	0	0	0	1
4	0	559	574	190	0	0	0	15
5	528	540	0	0	0	585	0	45
6	0	0	546	520	0	558	0	12
7	0	0	0	588	598	593	603	5
8	0	567	565	0	0	556	0	2
9	0	0	565	575	0	592	0	17
10	630	621	560	0	0	0	0	9
11	618	619	555	0	0	558	0	1
12	0	561	572	569	0	0	0	3
13	0	569	569	0	0	557	0	0
14	0	0	0	0	649	0	0	649
15	528	553	555	0	0	592	0	37

Table 2 Comparison of Experts' and System's recommendations of AAC systems

	Experts' recommendations	System's recommendations		Matching between Experts' and System's recommendations		
Case	**[A]** Experts' system	**[B]** 1st priority system	**[C]** 2nd priority system	**[A] = [B]**	**[A] = [C]**	**No match**
1	Orthography	Orthography	PCS	+	-	-
2	PCS	PCS	Gestures	+	-	-
3	Objects	Objects	Photos	+	-	-
4	Bliss	Bliss	PCS	+	-	-
5	Gestures	Gestures	Photos	+	-	-
6	Gestures	Gestures	PCS	+	-	-
7	Sign language	Sign language	Orthography	+	-	-
8	PCS	Photos	PCS	-	+	-
9	Gestures	Gestures	Bliss	+	-	-
10	Objects	Objects	Photos	+	-	-
11	Photos	Photos	Objects	+	-	-
12	Bliss	PCS	Bliss	-	+	-
13	PCS + Bliss	PCS + Bliss	Gestures	+	-	-
14	Orthography	Orthography	-	+	-	-
15	Gestures	Gestures	PCS	+	-	-

Table 3 Relevance-indexes by category and system for case #13

System Category	Objects	Photos	PCS	Bliss	Ortho-graphy	Gestures	Sign Language
General	76	87	108	138	0	114	0
Behavior	74	70	65	51	48	62	50
Cognition	168	168	153	0	0	164	0
Communication	0	101	100	89	83	101	87
Fine motor	40	40	40	40	40	24	0
Gross motor	80	79	79	79	79	68	0
Past AAC systems	22	24	24	22	22	24	20
Recommendation	0	569	569	0	0	557	0