Automated Data Logging in Augmentative Communication

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1. Introduction

Monitoring communication performance consists of a variety of research and clinical methods using direct observation techniques. The benefit of observing actual communication performance, compared to testing or other non-observational assessment techniques, is that the results of observation-based measures reflect the individual's actual communication performance.In an era of *evidence-based practice* [reference?], the development of valid and efficient communication performance-based techniques will be essential for demonstrating the efficacy of our technological and behavioral interventions.

1.1 Automated Data Logging in Augmentative and Alternative Communication (AAC)

With the advent of computerized AAC devices, it is possible to automatically track and analyze many aspects of user-device performance. With automated data logging, the AAC device creates a continuous log of communicator & machine activity - anywhere and at any time. The researcher or clinician can directly observe and record all aspects of communication and the data log provides valuable information on the human-computer interaction aspects of AAC device use. Also, data analysis is simplified because the logs can be stored in a permanent, machine-readable format which can be analyzed with appropriate software.

The initial development of automated data logging technologies in AAC is closely tied to the emergence of the microprocessor and its use in behavioral recording systems and augmentative communication devices. During the mid-seventies, behavioral researchers at the University of Wisconsin-Madison and University of Washington (Sackett, 1978; Coggins, 1981), developed microcomputer-based devices to record animal and human behavior. At the same time, Wesley Wilson and David Beukelman (Beukelman, 2001) at the University of Washington, and Greg Vanderheiden and David Kelso (Vanderheiden, 2001) at the University of Wisconsin applied data logging methods to the first generation of microprocessor-based augmentative communication devices being prototyped in their laboratories.

With the proliferation of microcomputers, a number of augmentative communication researchers developed research specific applications through the next two decades. These included the work of:

- Heidi Koester and Simon Levine (e.g., 1997, 1998) regularly employed computer-assisted logging and analysis to study users' performance on word prediction and AAC access.
- Romski & Sevcik experimented with automated data collection techniques for language intervention research (Romski, 2001).
- Swiffen, Arnott, Pickering, Newell (1987) used logs to track word prediction system performance.
- Higginbotham and colleagues have used computer-assisted logging and analysis to study the effect of augmentative technologies on interactive communication (Higginbotham, 1989; Scally, 1994; Higginbotham, Kim, Scally, Huang, submitted).
- Lesher, Moulton and Higginbotham's (1998ab) simulation research employed a logfile formant and automated analyses to evaluate the efficiency of a variety of augmentative selection methods.
- Katya Hill's (2001) dissertation research focused on the efficacy of using automated data logging for the collection and analysis of language samples.

The first commercially available performance monitoring system was developed for the Words+1 E Z Keys system in the mid-to-late '80s (Woltoz, 2001). It provided a number of summary measures for monitoring keystroke savings, communication rate and word use. By the early 90's, Sentient System's Dynavox2 provided on-screen usage counts of button selections. A similar measure was by Mayer Johnson3 for their Speaking Dynamically communication software.

Over the last few years, the Prentke Romich Company4 has developed a data collection system called the Language Activity Monitor (LAM) for sampling communication device output (Hill & Romich, 2000; Romich & Hill, 2000; Romich, Hill & Spaeth, 2000). Their research and development endeavor has resulted in a set of hardware and software technologies for Prentke Romich devices, data transfer and analysis software and a language analysis service.

2. Automated Data Logging Research and Development by the RERC-AAC

Over the past three years, The RERC-AAC[5] has been actively engaged in developing a comprehensive data logging system, including specifications for a universal logging format, analysis software, and device emulation software. The goal of this project is to extend automated data logging beyond the individual research laboratory and manufacturer, to make it available to the entire augmentative communication community.

2.1 A Universal Logging Format

The definition of a universal format for AAC logging is complicated by the fact that the resulting logfiles will not have a single, specific use. Researchers, clinicians,

1 http://www.words-plus.com/
2 http://www.dynavoxsys.com/
3 http://www.mayerjohnson.com/
4 http://www.prentrom.com
5 http://www.aac-rerc.com/

educators, manufacturers, and end-users will utilize logfiles for different purposes and will therefore have widely varying data logging requirements. One possible solution to this quandary is to record every parameter that could be conceivably be of interest. However, besides being extremely inefficient, such an effort is certain to fail – there are simply too many variables of interest in augmentative communication to comprehensively catalog them all.

To meet the varied demands of the AAC community, we have designed a flexible logfile format that is powerful enough to support the most common data collection requirements while also providing an extendable framework for customized logging needs. The logfile is structured such that only those parameters appropriate to a particular situation (communication paradigm, AAC device, specific user, etc.) are recorded. A file header specifies exactly what information will appear in the individual logfile entries, as well as how this information will be formatted.

A standard logfile consists of three basic parts:

- A header specifying the content and format of the individual logfile entries,
- a body consisting of an arbitrary number of newline-separated logfile entries, and
- an optional analysis section containing device-generated statistics on logged data.

In addition, comments (preceded with a #) and blank lines may be positioned anywhere within the logfile. There are no size constraints on any part of the logfile. The file is currently limited to ASCII characters, although if there is sufficient interest the format may eventually be extended to support Unicode (two-byte) characters.

The header contains a formalized description of each field that appears in the individual logfile entries. An entry may consist of an arbitrary number (and ordering) of fields. The header might specify, for example, that each entry consists of a timestamp, followed by an indication of what kind of action triggered the selection, followed by the text output associated with the selection. In the body of the logfile, these parameters would appear separated by spaces or tabs within each entry. Besides specifying the order and type of the entry fields, additional field-specific details can be defined in the header. For example, the resolution of the timestamp can be established.

Optionally, the header may be completely omitted. In this case, individual entries must consist of a timestamp followed by a text output (delimited by quotes). Since this is exactly the structure of Romich and Hill's LAM record, their format is consistent with the universal format. If a header is present in the logfile, its end is indicated by a marker sequence ($$$).

The fields that compose each logfile entry quantify unique aspects of the selection process that produced that entry. For many studies, the text output may be the only aspect of interest. For other purposes, however, information such as the selection method or the source of the output may be important. We have identified a set of fundamental parameters that can be used to quantify the communication process. A few instructive examples are provided below.

Time A timestamp with support for varying resolution (down to hundredths of a second) and varying formats (including that used by the LAM). The timestamp may be absolute (e.g., "10:15:20.54" or "5/10/99 10:15:20"), relative to the start of the logfile (e.g., "04:20:04.52" or "15604.5"), or relative to the last entry.

Output The text output (if any) associated with an entry, delimited by quotation marks.

Message The full text associated with a selection, which may differ from the output, delimited by quotation marks. For example, when selecting "thing" from a prediction list after "th" has already been typed the output would be "ing" and the message "thing".

Action The type of user action that produced the logfile entry (e.g., "keypress", "left mouse click", or "switch 2 closure"). An action field may optionally include additional information about the selection event, such as the specific key pressed or the position of the mouse at the time of a mouse button click.

Input The type of input device used in the action that produced the logfile entry. For example, "key", "touchscreen", "switch", "mouse", or "joystick".

Type An indication of the type of selection that produced the logfile entry. For example, "Letter", "Backspace", "Word list", "Page navigation command", or "Speak sentence command". The type allows for the analysis of specific classes of selections (e.g., "How often was page navigation used?" or "How many backspaces were used?").

Source The physical/logical source of the action associated with a logfile entry. For example, "key_f1" or "button (2,8)". Note that the same source may have different types – a key may have different meanings at different times.

Context The words and/or characters that immediately preceded the current entry. The context may be of a variable length (e.g., "never been th" or "th").

Page A descriptive name of the page from which the entry originated.

List The contents of the prediction list (if present) at the time of the selection.

The number of entries in the body of the logfile is limited only by the memory available to store the file. The end of the body is indicated by another marker sequence ($$$).

In addition to the "stock" logfile fields described above, the universal format supports additional free-form fields, provided that they are appropriately defined in the header. These custom fields can be used to track arbitrary parameters that may be of interested to a particular interface or study. For example, a researcher interested in knowing the state of a particular indicator light at the time of each selection might add a "Light" field that could take values of "on" or "off". During subsequent analysis, counts of custom field states can be tabulated automatically.

Following the body of the logfile, a system may optionally record some statistics on the logging session. There is no specific format for the data in this analysis section, nor is there any limitation on the type of information that can be provided. The nature of the measures recorded depends wholly upon the device manufacturer. For example, our in-house research software can be configured to record the total number of characters and words logged during a session, as well as estimates of communication rate and keystroke efficiency.

A very brief logfile example is provided in Figure 1 below. This example was recorded using a QWERTY keyboard supplemented by a 5 word prediction list accessed through the function keys (F1 through F5). Besides providing a timestamp and output information, this logfile records the source action and type of each selection, as well as information about the current context (useful for analyzing the effectiveness of word prediction).

Figure 1: Example of a simple logfile

A complete specification of the universal format can be found at www.enkidu.net/logfile.html.

2.2 The Augmentative Communication Quantitative Analysis (ACQUA) Package

Many of the measures commonly used in augmentative communication cannot be easily derived using generic statistical analysis programs. For example, keystroke savings cannot be computed without additional information about the baseline keystroke count. While it would be possible to write programs to compute most measures using commercially available statistical packages, a dedicated program for computing AAC-specific statistics greatly facilitates logfile analysis. The existence of such a program also provides additional incentive for manufacturers to adopt the logfile format. Finally, encrypted logfiles require dedicated, standard-compliant software for analysis.

We have developed a prototype statistical analysis program that provides a fast and convenient means to analyze logfile data. The Augmentative Communication Quantitative Analysis (ACQUA) package is a Windows program being made freely available to the AAC community at www.enkidu.net/acqua.html. Besides providing AAC-related statistics, ACQUA allows operators to filter and reformat logfiles for export to popular commercial analysis packages such as SPSS, Minitab, and Excel. The program also serves as a logfile viewing tool, allowing operators to browse through recorded data.

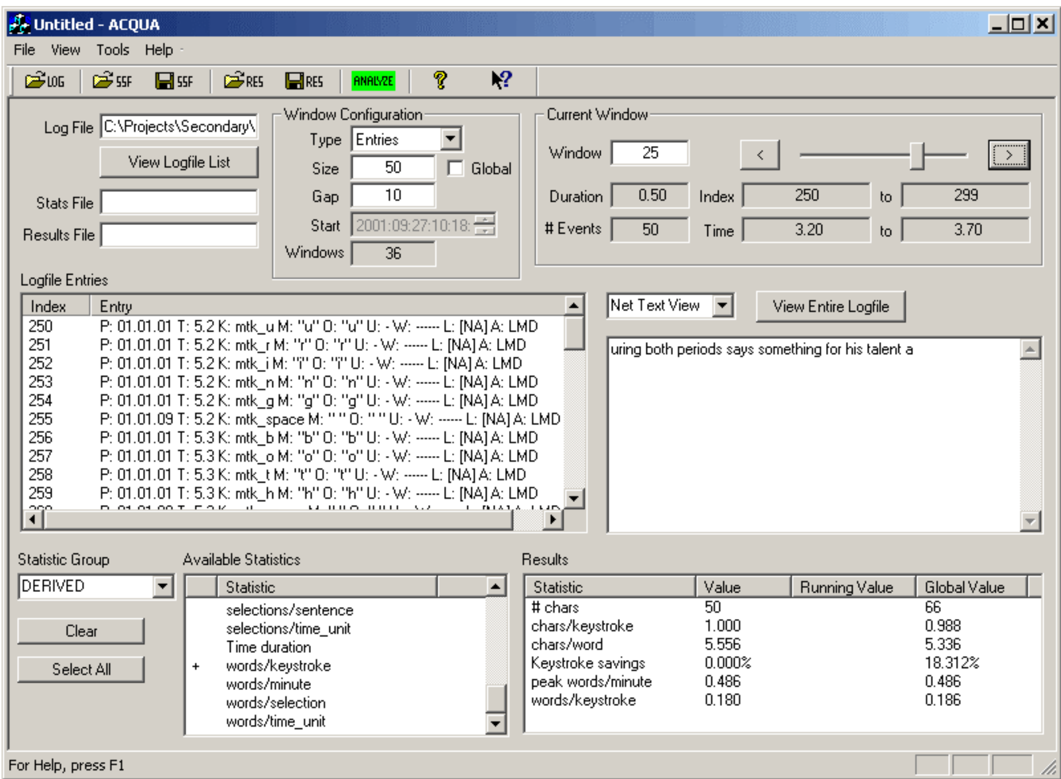

Figure 2: The ACQUA package, using windowed analysis on a standard logfile

In defining a set of statistics and performance measures to be incorporated in ACQUA, we identified a subset of those in common AAC usage. These include measures of language usage (for example, average sentence length, average word length, raw number of sentences, and vocabulary distribution), derived measures of communication efficiency (for example, keystrokes per character and communication rate), and device-specific usage measures (for example, frequency of selection for specific keys). Given the appropriate information, ACQUA can also compute keystroke savings by comparing the number of user selections needed to generate a given message (using the AAC configuration that produced the logfile) to the number of keystrokes that would be needed to produce that same message using a baseline configuration (for example, a standard QWERTY keyboard).

The operator can select an arbitrary set of statistics from a list within ACQUA. Additionally, sets of statistics can be defined, stored to files, and loaded at a later time. The statistics themselves can be written to tab-delimited files for further analysis (including plotting) by third party programs.

Usage statistics can be computed for the logfile as a whole, but can also be computed on a series of consecutive (or overlapping) subsets – or "data windows" – to provide a sliding estimate of the specified measures. Windowed statistics can provide the operator with a better sense of the exact circumstances under which a particular augmentative technique or interface is particularly effective (or ineffective). Windowing could be used, for example, to plot and analyze how communication rate changes with time. Time series analyses can provide more specific information about the effectiveness of augmentative communication than can global (non-windowed) analysis. For example, a windowed measure of communication rate might reveal specific contexts in which an interface is particularly effective (or ineffective).

The span of the data window can be based on several different fundamental units, including: elapsed time, number of selection events, number of logfile entries, number of discrete actions (selections), and number of characters, words, or sentences. The operator can configure the size of the window and the degree of overlap (if any) between consecutive windows. ACQUA's interface allows the operator to rapidly page forward and backward through the data windows to see how the usage statistics change over the course of a single logfile.

In most logfiles there will be significant blocks of time in which there are no entries – time during which the user is either not communicating or is listening to his or her communication partner. To prevent these quiet spans from corrupting rate measures (such as characters per minute), ACQUA includes a variable "pause threshold" parameter. Gaps in the logfile that are longer than the pause threshold are excluded from consideration when computing time-dependent usage statistics. Using a relatively short window can also help to compensate for quiet periods.

Because ACQUA was developed in a modular, object-oriented fashion, new statistics can be added rapidly and with only a modest programming effort. A comprehensive list of the available ACQUA statistics can be found at www.enkidu.net/acqua.html. As with the logfile format, we are actively seeking feedback from members of the AAC community regarding which statistical measurements should be included in future versions of ACQUA.

3. Current Research & Development Efforts

The RERC-AAC supports various efforts in the manufacturing and research communities to establish the logfile protocol and analysis tools. Three augmentative device manufactures (Enkidu, Inc.[6], Prentke Romich Company, Saltillo, Corp.[7]) currently make augmentative communication devices that generate logfiles complying with the universal logfile format, and at least three other manufacturers are planning to

6 http://www.enkidu.net/

7 http://www.saltillo.com/

incorporate logfiles into their development cycles. Collaborative research is ongoing with several universities and clinical sites in an effort to explore the efficacy and potential applications of automated data logging techniques. The AAC-RERC also offers free AAC emulation software to individuals interested in utilizing logfiles in their experimental or clinical research (www.aac-rerc.com/performance/). This Windows-based program is a research version of Enkidu's Impact software, with full interface configuration and logging capabilities. The emulator is also designed to automatically reproduce user-specified text files using a particular interface (including word prediction and abbreviation expansion components).

4.1 Experimental Current Research Application: Processing numerous logfiles

Researchers are often faced with the problem of analyzing a large number – sometimes hundreds – of data files. To facilitate the analysis of multiple logfiles, ACQUA includes a batch processing mode. The operator simply specifies the statistics of interest, a list of logfiles, and a destination file for the aggregate results. This feature has proven particularly useful for analysis of experimental data.

In a recent study, we examined the text prediction abilities of 60 subjects who were assigned the task of predicting the words contained in several paragraphs (Lesher, 2001). By using the multi-file analysis and text export capabilities of ACQUA, we analyzed 240 individual files and merged the results into a single tab-delimited file in a matter of a few minutes. A graphical analysis of the data is presented in Figure 3 using Minitab statistical analysis software[8].

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8 http://www.minitab.com/

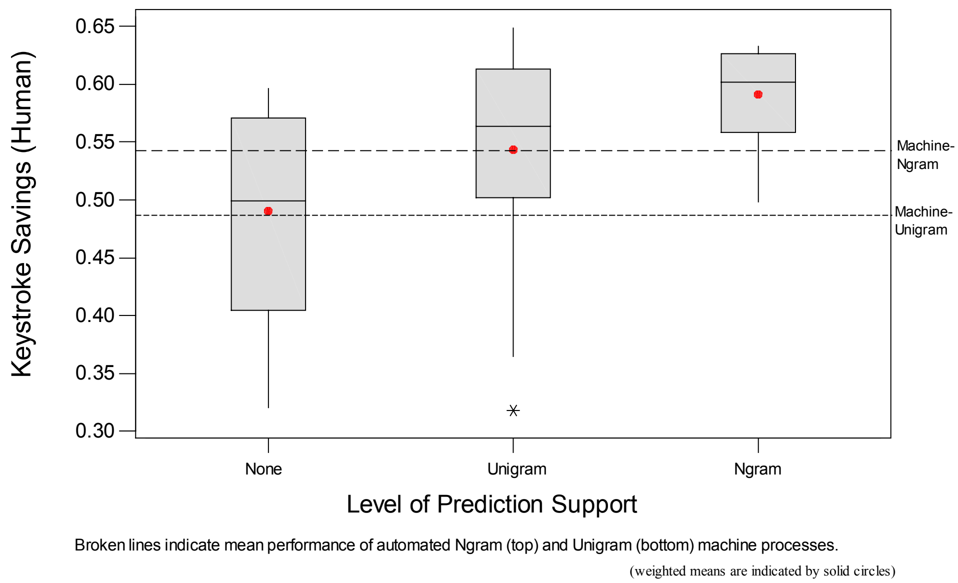


Figure 3: Three types of word prediction support.

4.2. Clinical Research Application: Time-Series Analysis

In a collaborative effort with Pamela Mathy from Arizona State University, we are studying the viability of collecting performance data in naturalistic contexts over prolonged periods of time. Using automated data collection techniques in natural settings provides a number of significant challenges. What types of data can be reliably and validly collected? How does one validly filter out periods of inactivity?

One performance measure, the number of words generated by the communication device over the course of a day, shows potential as a reliable measure obtained from automated data logging.. The time series options of the ACQUA program allowed us to collapse a week of data logging into a 24-hour activity cycle as shown in Figure 4. Here we can see that the device user primarily employed their device in the afternoon and early evening, with a smaller surge of activity occurring in the morning around 8am. Although we counted words in this analysis, any other statistic available in ACQUA could be analyzed in this fashion.

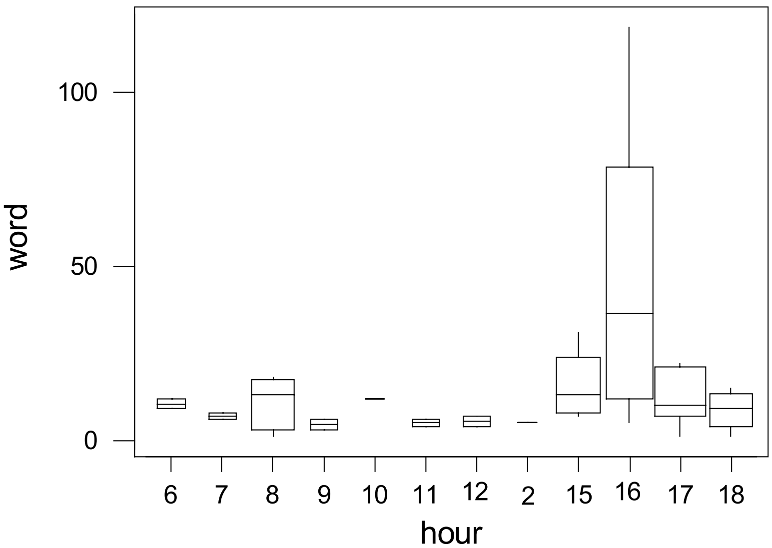
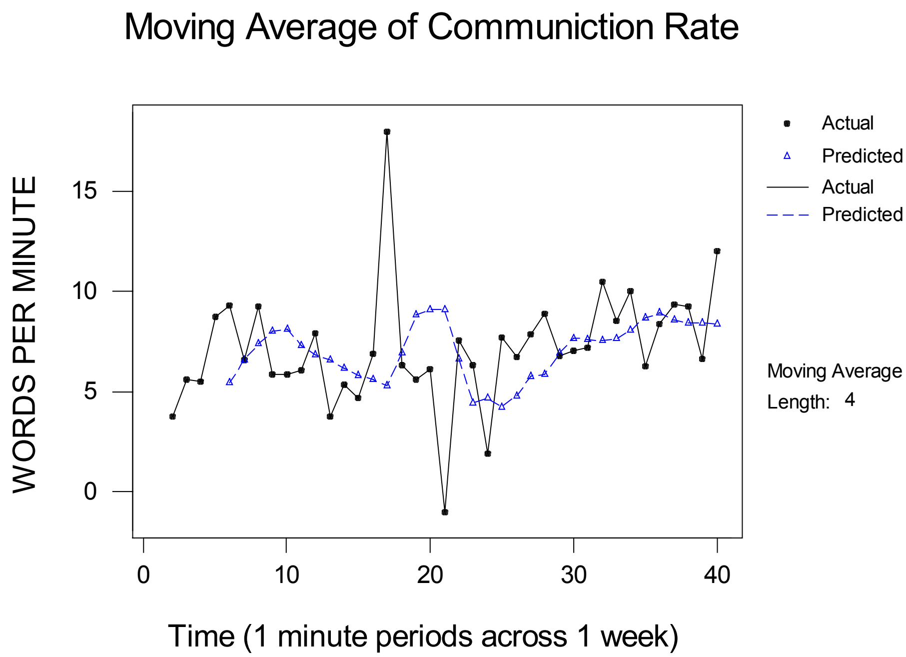


Figure 4: Time-series analysis of daily word usage using an AAC device

Communication rate can also be sampled in natural contexts. The graph below represents an analysis of communication rate, by hour (average of 1-minute samples) taken over a one-week period. In both analyses, we automatically filtered out pause times greater than 9 seconds in duration to eliminate situations in which the subjects were not actively attempting to communicate. These cases comprised less than 2% of all pauses, but significantly lowered communication rate. As before, the analysis was exported into Minitab for graphical analysis.



4.3 Measurement Limitations of Automated Data Logging

Although automated data logging shows potential for research and clinical practice, much work needs to be done to determine its validity and utility in the field. Several issues regarding measurement, ethical use of the technique and its availability across devices must be resolved before it can be used as a valid clinical tool. First and foremost, automated data logging only records information pertaining to device use. It can be used to reliably record and analyze simple and low inferential communication information pertaining to device use, such as input rates, output and error rates, word counts, and keystroke efficiency. Language use, on the other hand, is multimodal. Speech, gesture and paralanguage are employed in a coordinated fashion to signal meaning. For augmented communication, in particular, utterance meaning may depend on overt interlocutor participation and communication contextual support (Higginbotham, 2001). Data logging technologies can't record this information. Considering this, and the fact that augmentative communication devices impose communication constraints and considerable operational requirements on their users, Higginbotham (2001) argues that current automated data logging techniques may not always produce clinically valid language measures. It must be emphasized here that ease of data collection and analysis is not a substitute for validity. Premature use of unproven assessment procedures is never warranted.

4.4 Ethical Considerations

When personal communications are stored in one's device, a number of ethical concerns with respect to communication control and privacy. These issues include:

- Unauthorized viewing of logfiles. Personal communications could be unintentionally divulged to care attendants, family, friends without the permission or knowledge of the speaker.

- Unauthorized analysis of logfiles. Because of their persistent form, logfiles could be collected for one reason, then examined and analyzed at a later time, without the permission and/or knowledge of the speaker.
- Reluctance to communicate. When being logged, speakers may be reluctant to talk freely, fearing that their private communications may be inspected by a third party.
- Forgetfulness. When logging occurs over a long period of time, speakers may forget that their communications are being monitored. Even though permission to log was given, the resulting logs may contain communications unintended for a viewer.

To help address some of these privacy issues, the universal logfile format incorporates encryption as key component. Several levels of password protected encryption are available. Decryption is available only through compliant analysis programs, such as ACQUA. At the highest level of encryption, the original message is completely unrecoverable by any means, although certain statistics (such as average word and sentence lengths) can still be derived from the logfile. Unencrypted logfiles comply to the standard format, but we are encouraging manufacturers to prevent their devices from producing such logfiles. We are also looking into ways of unobtrusively reminding speakers that their communications are being logged and to provide them with the means to control the logging process.

Recently, Higginbotham (2000) recommended the that speakers be fully informed about the following privacy issues related to automated data logging:

- The kinds of information being sought
- Settings where data would be logged
- Expectations of the speaker regarding experimental or clinical procedures
- How confidentiality will be maintained
- Kinds of results generated by an analysis and how they would be used.
- Security and intended use and disposal of the data.
- How to start and stop data logging.

The American Speech and Hearing Association is also looking at the implications of logfiles as this technology relates to emerging federal policy on the storage and transmission of electronic information.

5. Conclusion

Within the next year, we are hopeful that automated data logging technologies will be made available by the majority of augmentative equipment manufacturers. As more manufactures bring this technology online, it will be possible to perform systematic, comparative assessments of AAC technologies and their usability. We should also expect the development of clinical applications to assist in the objective assessment of user performance and computer assisted customization of augmentative communication systems. Automated data logging also has application for automating device adjustment processes (e.g., adapting to fatigue). For researchers, we should expect to see more powerful and integrated analysis tools including digital video transcription systems that incorporate logging as one data stream. Ultimately, the utility of automated data logging technology will depend on the proven reliability and validity of assessment measures and the resolution of privacy-related ethical issues.

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